SEAVEG2014: Families, Farms, Food

Regional Symposium on Sustaining Small-Scale Vegetable Production and Marketing Systems for Food and Nutrition Security

25-27 February 2014
Bangkok, Thailand

AVRDC – The World Vegetable Center ● Department of Agriculture, Thailand
Food and Agriculture Organization of the United Nations
Horticultural Science Society of Thailand ● Kasetsart University
Vegetable Science International Network
ASEAN-AVRDC Regional Network on Vegetable Research and Development

AVRDC
The World Vegetable Center

AVRDC – The World Vegetable Center is an international nonprofit research institute committed to alleviating poverty and malnutrition in the developing world through the increased production and consumption of nutritious, health-promoting vegetables.

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Foreword

It is satisfying that Asia is the largest producer of vegetables in the world and China is the largest producer globally; it is also the fact that India being the second one has much less production than China; it is also observed that some Asian nations are among the lowest in production. The recent data of India has shown that India's horticultural production including vegetables has exceeded cereal production.

In the present and upcoming scenario, horticulture, with a major share of vegetables, is emerging as the second line of defense in the food domain both in developed and developing countries. This has been recognized by the International Conference on Vegetables (ICV-2002), International Conference on Horticulture (ICH-2009) and Southeast Asia Vegetable Regional Symposium (SEAVEG2012). The vegetable sub-sector is growing in importance in contributing to food security, in providing adequate nutrition to the people and in preventing noncommunicable diseases such as cancer, diabetes, blood pressure, obesity, etc. The growing knowledge on nutraceutical values of fruits and vegetables, and the breeding and improvement of vitamin- or mineral-specific fruits and vegetables brings tremendous hope for the production and consumption of these crops. In addition, studies on medicinal crops have shown great potential for health. Apart from their usefulness mentioned above, vegetables provide much more food, vitamins, minerals and fibers per unit area and per unit time compared with other crops. Processing of horticultural products has opened wide opportunities and brought big value addition to food. The FAO and the WHO have advocated the consumption of 400 grams per capita per day of fresh vegetables and fruits for good health, which demands billions of tonnes of vegetables worldwide.

The observations and experience in Asia highlights the successes and bottlenecks in vegetable sub-sector during the last few decades. The bottlenecks demand best national efforts, regional and international cooperation, and assistance to reduce the inputs required. It is important that each participating nation has knowledge of its indigenous and exotic genetic resources and has characterization, evaluation and conservation of these resources. It demands a National Genetic Resource Unit in each country followed by national or sub-regional or regional genebanks. Some Asian countries have shown tremendous progress whereas several others are short of it. Secondly, we have some excellent vegetable breeders in Asia, but a number of countries lack breeding capacity. Adequate training of vegetable breeders is essential in those countries. Thirdly, to augment GAP and related practices, extension services with expertise should be provided. This will boost crop management skills, leading to high production for food security. Fourthly, support to private vegetable seed producers has demonstrated excellent results in some countries, which other countries should be encouraged to follow. Fifthly, value addition and efficient marketing chains have promoted the availability of vegetables to consumers. Sixthly, both men and women farmers in rural and urban areas need to be educated, otherwise the lack of knowledge will hamper the adoption of advanced technologies. Seventh, people are unaware of the nutritional values of vegetables and need education about human nutrition. Awareness and education programmes are pre-requisite to mitigate nutrition insecurity. Eighthly, examples have shown significant improvement in production and availability of vegetables where effective cooperation between public and private sector exists; these partnerships need to be augmented. Ninth, arising from the above scenario, SEAVEG serves to augment national, sub-regional and regional cooperation, which should be strengthened at each level. ASEAN, international organizations such as FAO, AVRDC – The World Vegetable Center, and non-governmental international organizations such as VEGINET aim to promote technical cooperation among developing countries, and national vegetable and horticulture societies should strive to promote vegetable science and practices by strengthening their activities to ensure vegetables are available and accessible for all.

We have successfully conducted SEAVEG2012 and SEAVEG2014 and look forward to the upcoming third SEAVEG in the interest of all vegetable stakeholders in Asia and beyond.

Dr. Prem Nath
Former Asst. Director General, Food & Agriculture Organization of the United Nations
Chairperson, Vegetable Science International Network
Chairman, Dr. Prem Nath Agricultural Science Foundation

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- Kasetsart University (KU)
- ASEAN-AVRDC Regional Network for Vegetable Research and Development (AARNET)

Abbreviations

AARNET	ASEAN-AVRDC Regional Network for Vegetable Research and Development
ASEAN	Association of Southeast Asian Nations
AVA	Agri-Food & Veterinary Authority, Singapore
AVRDC	AVRDC – The World Vegetable Center
DOA	Department of Agriculture, Thailand
FAO	Food and Agriculture Organization of the United Nations
HSST	Horticultural Science Society of Thailand
KU	Kasetsart University
MARDI	Malaysian Agricultural Research and Development Institute
VEGINET	Vegetable Science International Network

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Executive Summary

Asia is the main hub of vegetable production, contributing around 70% of the global vegetable production; however, its productivity is nearly half that of some European countries. A gradual increase in vegetable production (25%) was observed during the past 10 years, but that increase was mainly due to the increased vegetable production in China alone, which accounts for nearly half of the world's vegetable production. Thus there is an ample scope to promote vegetable production in other Asian countries as well. Asia is dominated by smallholders with meager incomes who cultivate more than 80% of farmland. The vegetable market is fragmented and unorganized. Strategies pertaining to postharvest losses and food wastage, food safety and quality are lacking. The population in the region is undernourished and malnourished. About two-thirds of the global population suffering from nutrient deficiencies live in Asia. Over 70% of the world's malnourished children live in Asia. Emerging environmental challenges such as water scarcity, changing weather patterns, pests and diseases, unsustainable use of natural resources, rapid urbanization, and pressure on arable land seriously draw the attention of both policy makers and scientists.

To discuss the challenges and issues, SEAVEG2014: Families, Farm, Food, a regional symposium on sustainable small-scale vegetable production and marketing systems for food and nutrition security, was organized by the Department of Agriculture (DOA) Thailand, in collaboration with AVRDC – The World Vegetable Center, Taiwan, the ASEAN-AVRDC Regional Network (AARNET), the Vegetable Science International Network (VEGINET), Kasetsart University (KU), the Food and Agriculture Organization of the United Nations (FAO), and the Horticultural Science Society of Thailand (HSST). More than 200 participants from 25 countries attended the symposium.

After discussing the key issues, the following recommendations and policy issues were made.

Recommendations

I. Research and Development Issues

1) Vegetable research should be focused on consumers' preferences, nutritive value nutraceutical value, marketing quality and productivity. Research on spices, tuber crops, and medicinal plants, rich in phytochemicals, nutraceuticals, and antioxidants as identified by FAO/WHO needs further intensification.
2) There is a need to upgrade and scale-up technologies suitable for urban and peri-urban vegetable production close to the centers of consumption through home gardens, school gardens, rooftop gardens, organic gardens, close circuit vertical farming, hydroponics, aeroponics, sprout and microgreen production to mitigate seasonality of vegetables, dependency on off-farm resources and distant marketing. This will facilitate food and nutrition security at household and community levels.
3) Develop and promote environment sensitive management technologies through integrated pest management, integrated water and nutrient management, rain shelters, low-till farming, use of grafting and low tunnel protected cultivation, use of short duration, drought-tolerant vegetables including tubers and root crops to mitigate biotic and a biotic stresses, thus leading to sustainable vegetable production.
4) Protocols and technologies should be developed for the production of botanicals, plant products, biopesticides, and biological agents at the farm level. Rural youths

should be trained in the above-mentioned skills, helping them to run farm health clinics for self-employment.

5) Indigenous and exotic genetic resources of vegetables should be collected and conserved in national genebanks and utilized in various breeding programs. Advanced breeding lines resistant/tolerant to biotic and a biotic stresses available at AVRDC should be used in local breeding programs. Collaborative programs with AVRDC in key areas should be encouraged. Skill of vegetable breeders should be improved through specific training programs for effective output.
6) There is a need to modernize nurseries with effective quality control systems, accreditation of true to type, disease-free planting material using micropropagation and improved seedling production methods, including grafted seedlings, to counter losses due to soil-borne diseases. Use of molecular markers should be encouraged for assessing genetic purity of seed and planting material. The private seed industry should be established on a firm footing for the flow of technologies among farmers.
7) Promote nutrition sensitive horticulture through dietary diversification of vegetables, especially traditional vegetables, highlighting their nutritive values, incorporating them in demand-driven breeding programs and channeling the produce to the market mainstream.
8) Consumption of nutritious vegetables alone is not sufficient to address malnutrition. There is a need to focus on multisectorial coordination among various preventive measures like availability of clean water, proper hygiene, good sanitation, health education, early child development and family planning through women empowerment programs and by linking these activities with existing government programs pertaining to health and education at the national level.
9) Pesticide residue limits and safe waiting periods for different chemicals and vegetables should be developed and documented to overcome the non-tariff trade barriers imposed by different countries for export/import of vegetable produce.
10) Market and supply chain infrastructure should be improved to facilitate regional trade among Asian nations.
11) Awareness programmes to prevent food wastage and available low cost postharvest technologies should be popularized through extension services.
12) Multi-utility and multi-crop processing machinery/facility should be developed for year-round functioning of the processing industry.
13) Suitability of vegetable crops for organic farming should be identified based upon the validation of various organic farming practices as well as cost-benefit ratios.
14) Asian nations should develop their own quality standards and harmonize them with WTO/UNICEF standards to meet national as well as export/import requirements.
15) WTO/AFTA should review limitations/barriers/laws for transaction of trades among member countries, especially ASEAN.

II. Policy Issues

1) Special economic zones for vegetable production should be developed based upon agro climatic, biophysical and socioeconomic parameters.
2) Develop awareness programs pertaining to quality standards and phytosanitary regulations for export market, keeping in view AOA (Agreement on Agriculture) and WTO (World Trade Organization) regulations.
3) In public-private partnerships, the public sector should generate information on basic research, training and enforcement of regulatory policies; the private sector should enhance the flow of technology by putting an efficient distribution system in place.

4) An efficient supply chain management system needs to be established by linking smallholders and producers to the main market. Smallholders and exporters should receive information regularly pertaining to demand and supply of vegetables, consumers' quality preferences, and sales and return figures in domestic, national and international markets, enabling them to place their produce effectively in the vibrant market.
5) Facilities pertaining to processing industries should be extended to rural and peri-urban areas.
6) Investment should be enhanced in upgrading and scaling-up of production technologies suitable for small-scale farmers, in human skill development among rural youths, in urban and peri-urban farming, in dry land farming, in processing and storage facilities, in marketing and credit facilities, and in women empowerment programs in the areas of health, hygiene and nutrition.
7) Existing policies pertaining to food and nutrition security should be reviewed, ensuring their sustainability at ecological, economic and social levels.
8) Research-Extension-Farmer linkage should be reviewed to enhance efficiency in transfer of technologies refined for different agroclimatic conditions through participatory approaches involving the public and private sectors.
9) Strong linkages should be established within and among countries through networking of institutes, and organizations for exchange of information and technologies, seed and planting material as well as expertise for mutual benefit and development of horticulture. The FAO (Food and Agriculture Organization of the United Nations) under the umbrella of TCDC (Technical Cooperation among Developing Countries) may act as a facilitator for the formation and strengthening of such networks as VEGINET, which was established during the international conference on vegetables (ICV-2002) and other networks such as the AVRDC-ASEAN Regional Research and Development Network Steering Committee Meeting (AARNET).
10) Nutrition awareness and training programs for consumers should be intensified.

III. Follow-up Actions

The General Assembly of *SEAVEG2014: Families Farms, Food* decided:

1) To submit the proceedings and recommendations of the symposium to various government and private sector organizations of Asian countries as well as to regional and international organizations like ASEAN, AARNET, VEGINET, AVRDC, FAO, ICRISAT, ICARDA and others for their considerations and actions.
2) To hold the third SEAVEG Regional Symposium (2016?) possibly along with the next International Conference on Vegetables (2016?). The 9th and 10th AVRDC-ASEAN Regional Research and Development Network Steering Committee Meeting (AARNET) may also be held during that time.
3) To report on the actions taken on the recommendations of SEAVEG2014 during the next regional symposium to be held in (2016?).

Inaugural Presentations

WELCOME REMARKS

Prof. P.G. Chengappa
National Professor of Indian Council for Agricultural Research (ICAR)
Former Vice Chancellor of University of Agricultural Sciences, Bangalore, India

I have been requested by Dr. Prem Nath, Former Assistant Director-General, Food and Agriculture Organization of the United Nations (FAO), Chairperson, Vegetable Science International Network (VEGINET) and Chairman, SEAVEG2014 Coordination Committee to offer the Inaugural Remarks on his behalf as he is unwell and unable to attend SEAVEG2014. He is the architect of this very event and we badly miss him.

At the outset, on behalf everyone here, let us wish Dr. Prem Nath a speedy recovery.

The theme of SEAVEG2014: Families, Farms, Food—"Sustaining Small-Scale Vegetable Production and Marketing Systems for Food and Nutrition Security" is quite apt in keeping in view the changing paradigms in global food production, wherein vegetables have become an important constituent in the diet to achieve food and nutrition security. Consumption shift towards vegetables is driven mainly due to changing food consumption patterns towards nutritive and balanced food, and high income elasticity of demand. On the supply/production side, vegetables are an important component of diversified farming systems, contributing substantially to income and employment generation, and enhancing the economic viability of small farms. Demand-supply balance in vegetables is crucial, as a small change in planted area and weather aberrations can cause havoc as seen in the case of potato and onion in India.

In the world production of vegetables, China ranks first followed by India. There are an estimated half a billion smallholders cultivating less than two hectares, and these farms support 1.5 billion people and produce 80% of the food supply in developing countries. Indeed, smallholders use and manage more than 80% of farmland and similar proportions of other natural resources in Asia and Africa. Small farms are economically unviable and unsustainable; this is a real challenge we need to address. Vegetable production represents an important area for income growth and employment generation, especially for small-scale and marginal famers, as vegetable crops contribute higher net returns per unit area compared to food grains and many other crops. Vegetable production is thus seen as the key way forward to make these farms sustainable. Recognizing the important contribution that family farming and smallholder farming can play in providing food and nutrition security and eradicating poverty in the attainment of internationally agreed development goals, including the Millennium Development Goals, the United Nations declared the year 2014 as the "International Year of Family Farming."

Linking smallholder vegetable producers to markets is a great challenge. Vegetables cultivation requires higher levels of inputs, resulting in higher cost of cultivation. Vegetables are perishable and bulky, with low shelf life; these factors complicate supply chain management. Most often, the supply chain for vegetables is highly unorganized, fragmented and exploitative, and producers typically receive a low share of the consumers' price. Development of appropriate value chains and integrating producers to the value chain is thus of crucial importance. We need real value chain champions so the sector becomes competitive, benefitting both producers and consumers. Vegetable marketing in developing countries is characterized by fragmented small-scale production, leading to fragmented chains, and poor or no infrastructure at wholesale markets for packing, grading, sorting, or cold storage. There is a large amount of wastage along the chain (20-40%) and unorganized retailing. Modernizing supply chains requires huge investments for which we need to create a good environment to attract private investment. We also need good Private Public Participation (PPP) in research, development and extension so that the farmers reap the benefit of technology and markets.

Policy reforms to streamline and improve efficiency in marketing of vegetables are crucial. Superfluous middlemen make abnormal profits in vegetable marketing. The supply chain should be compressed to reduce the number of middlemen through the establishment of appropriate backward and forward market linkages. To improve the bargaining power of the farmers, collectivization through formation of farmer-driven cooperatives, associations, producer companies and self-help groups should be scaled up and replicated; these group structures have been successful in many countries.

Improved postharvest management, value addition, marketing and exports help in enhancing income and off-farm employment, stabilizing prices and evening out seasonal fluctuations, preventing wastage, and earning much-needed foreign exchange. There is vast scope for expanding the export of vegetables from Asia, but this requires controls on food safety and quality. Rationalization of import duties and export tariffs, export promotion measures in consonance with World Trade Organization (WTO) stipulations are a necessity. Food safety management systems and addressing non-tariff barriers, especially SPS issues, are major concerns in export trade of vegetables.

I appreciate the excellent support provided by all the organizers and sponsors for making this event happen and bringing us together. It is truly a collaborative effort. I am sure we will have fruitful deliberations for the next three days that will help in developing strategies and policies for enhancing the livelihood security of millions of vegetable growers and improving the welfare of consumers.

WELCOME ADDRESS

Mr. Virat Chanthrsmee
Representative of the President
Horticultural Science Society of Bangkok, Thailand

On behalf of the Horticultural Science Society of Thailand, I thank you for the honor of allowing me to deliver this welcome address on behalf of the President, Mr. Ananta Dalodom, at the opening ceremony of SEAVEG2014: Families, Farms, Food.

The Horticultural Science Society of Thailand was established 30 years ago and is an active member of the horticultural community in Thailand. The Society supports horticultural development and serves as a knowledge center for member horticulturists, business operators, farmers and the interested public at large. It also serves as a channel for research and development, both at the national and international levels. A tri-monthly publication "Pued Suan" is one of the means through which information and knowledge on diverse technical subjects is disseminated to members.

Another means of information dissemination is to hold regularly half-day meetings on many subjects of current interest. A recent addition to these meetings is lunch meetings. In fact, one was held yesterday, when a talk on "Dendrobium Cut Flowers" was given.

A recent addition to our activities was participation in Horti-Asia for the first time during 2013. This year the event will be held on May 8-10, during which participants from Asian countries will display their achievements in the field of horticulture. We will be there to publicize our activities.

Happily, we have been recognized by many international organizations such as AIPH, ISHS, as well as national horticultural organizations in China, Taiwan, S. Korea, etc. The Society was one of the organizers of the successful International Horticultural Expositions: Royal Flora Ratchaphruek 2006 and 2011, both held in Chiang Mai. We still cherish the memories of the two events, which will remain a place of pride and joy of our Society.

We are pleased to have the opportunity to be a co-organizer of SEAVEG2014. On behalf of the Horticultural Science Society of Thailand and in particular, on behalf of the

President of the Society, I would like to thank all of you for participating in this symposium. It is a good opportunity to renew existing friendships and make new ones. To you all, I extend my best wishes and a warm welcome. I also wish you a successful symposium and a most enjoyable and memorable stay in Bangkok.

INAUGURATION SPEECH

Dr. Poonpipoe Kasemsap
Vice President - International Affairs
Kasetsart University, Bangkok, Thailand

Good morning. It is my pleasure to be here. As Kasetsart University is one of the organizing institutions of this symposium, I consider SEAVEG 2014 a very important and necessary event, especially for vegetable research and development. As the representative of this fine academic institution, in the future I hope this event will greatly benefit agricultural students as well as scientists, farmers, and others involved in horticulture. With 24 countries represented by more than 200 participants, SEAVEG 2014 aims to achieve a good result for the academic sector. The meeting program covers five sectors from farm to table as well as cross-sectoral issues. I therefore feel confident that this event will generate fruitful and innovative results.

The changing climate has increased negative effects on agricultural production. Building capacity to practice sound science in vegetable research and development, especially among the young generation, will serve to combat this problem, as we begin to pay greater attention to mitigation and adaptation resilience.

Ladies and gentlemen, again I am pleased to have the opportunity to be a co-organizer of this symposium, SEAVEG 2014: Families, Farms, Food. I would like to take this opportunity to express my sincere thanks to all of you, especially to those whose continued strong support is our most valuable asset.

Thank you.

INAUGURAL ADDRESS

Dr. Jacqueline d'A Hughes
Deputy Director General – Research
AVRDC – The World Vegetable Center

This important gathering of many distinguished scientists and colleagues from Southeast Asia and around the world was made possible through the success of the first conference SEAVEG2012 held 24-26 January 2012 in Chiang Mai. The support of the vegetable community to this initiative is very much appreciated.

As we all know, vegetable consumption is important for good health through a balanced diet, and vegetable production contributes to nutritional security and income generation. There are both traditional and 'global' vegetables. Although global vegetables (for example carrots, cabbage and tomatoes) are widely known, traditional vegetables (such as kangkong [*Ipomoea aquatica*], drumstick tree [*Moringa oleifera*], Vietnamese coriander [*Polygonumodoratum*], sweet potato leaves [*Ipomoea batatas*] and Chinese boxthorn [*Lycium chinense*]) are highly valued locally and often with a high nutritional content.

At AVRDC – The World Vegetable Center we continue to focus on both traditional and global species, ensuring the availability of productive, disease and insect resistant and stress tolerant lines which have high nutrient content. We work throughout the vegetable value chain, from seed production and conservation of genetic resources, to plant breeding, production technologies, and integrated crop and pest management, and to marketing, postharvest and nutrition. This is a huge mandate and we work with both the public and private sectors to help assure nutrition security for the poor in developing countries. We target both women and men, schoolchildren and disadvantaged groups, as well as conducting training to suit all levels. Nutrition security of the whole family is critically important for future generations.

I therefore am extremely pleased to see such great interest in SEAVEG2014, the large numbers of high quality abstracts that we have received and the large number of you who have been able to join the symposium in spite of many other commitments. SEAVEG2014 is vital for sharing information, experiences and opportunities throughout the region and I look forward to quality presentations and open and productive discussions to help guide vegetable research and development to support the growing needs of Southeast Asian families over the next decades.

OPENING ADDRESS

Mr. Hiroyuki Konuma
Assistant Director-General and FAO Regional Representative for Asia and the Pacific

I am very pleased to welcome you all to SEAVEG2014: Families, Farms, Food – Regional Symposium on Sustaining Small Scale Vegetable Production and Marketing Systems for Food and Nutrition Security. I am extremely honored to be here today for this very important gathering which is organized through a joint effort of several co-organizers including VEGINET, AVRDC, DOA, KU, HSST, AARNET and FAO. This clearly demonstrates our commitment to working together to make differences in vegetable sector. I wish to congratulate and also thank them for the successful partnership and teamwork.

I would like to convey my special gratitude to the Government of Thailand for hosting this meeting in Bangkok with generous hospitality, in particular to the Director-General of the Department of Agriculture, Ministry of Agriculture and Cooperatives, Thailand, whose presence here today provides special value to this international symposium. My special gratitude goes to Dr. Prem Nath, Chairperson of VEGINET and the chief architect of this event for his leadership. Unfortunately, he is unable to participate in this gathering due to health problems and I sincerely wish his early recovery.

The world is producing more than sufficient staple food to meet the needs of everyone. Yet, there are more than 2 billion people (one in each 3.5 persons) on the planet suffering from micronutrient deficiency. Most are in developing countries and nearly two-thirds live in Asia. Micronutrients include vitamins and dietary minerals such as zinc and iodine, and they are necessary for the healthy functioning of all the body’s systems, from bone growth to brain function. If micronutrient deficiencies occur during children’s growth stages, their lifetime physical and mental growth is affected.

Vegetables are the key source of micronutrients for the human body, and hence play an important role in the daily diet. Vegetables and the micronutrients they provide promote the healthy growth of children’s bones and brains. We depend on children for our future, and for the prosperity and survival of our planet.

Yet children in so many countries in Asia suffer from micronutrient deficiencies. For example, Afghanistan, Timor-Leste, India, Laos, Bangladesh, Pakistan, Cambodia and Nepal have high children stunting rates of over 40%. Indonesia, Myanmar, Bhutan, DPR Korea and Philippines record stunting rates of around 30%.

The FAO/WHO expert consultation on diet, nutrition and the prevention of chronic diseases recommended a daily intake of 400 grams of fruits and vegetables (excluding potatoes and other starchy tubers) to prevent negative consequences of micronutrient deficiency, including stunting, heart disease, cancer, diabetes and obesity. Against this, the estimated levels of current fruit and vegetable intake is less than 100 grams per day in many developing countries, including those in Asia, which is significantly lower than the 450 grams consumed in western Europe. Indeed, a fundamental problem in the vegetable sector exists on the consumer side as well. Thus, it is essential to improve the consumption of vegetables by consumers. How?

By advocating the importance of vegetables in our diet, especially for children, through the use of media and advocacy materials; by improving the quality, safety and taste of vegetables and their products to attract consumers; by producing attractive processed vegetable products without reducing the original nutritional value; by educating women and those who cook for families about the importance of vegetables for home cooking; and by promoting access to and affordability of vegetables, especially for the poor, by producing more vegetables year-round, and reducing prices, improving market access, and reducing postharvest losses.

These are my initial thought from the consumers' point of view, while I am very much aware that the majority of participants here are producers, researchers and scientists.

My intention is to think of vegetables from a different angle and remember the fundamental goal of our endeavor: to achieve food security and nutrition. If the per capita consumption of vegetables remains so low, and if consumers are not interested in consuming more vegetables, then we can achieve very little for our efforts and good intentions. Indeed, we need innovative thinking.

Since SEAVEG2012 held two years ago in Chiang Mai, I witnessed some changes in the vegetable sector. One significant changes is the rapid expansion of hydroponic vegetable production and markets for this produce, corresponding to consumer demand for safe and ready-to-eat products. In Bangkok supermarkets, there are many suppliers of such products. Indeed, as reported recently by UNDP, the middle-income population in Asia and the Pacific is expected to triple between 2009 and 2020, with a six-fold increase between 2009 and 2030. These changes would push the consumer demand for safe and healthy products such as vacuum-packed, ready-to-eat mixed vegetables, even if the costs are little higher. Rapid urbanization is also taking place. It is anticipated that by 2050, about 63% of Asia's population will live in cities, which will necessitate the expansion of urban and peri-urban agriculture including plant factories, vertical farming, hydroponics, etc. Agricultural innovation using 3G smart phone technology for irrigation management, temperature and moisture control, etc. has already started. Another development is growing consumer interest in organic vegetables and a move among producers toward establishment of voluntary organic certification systems to reduce the cost of expensive conventional certification systems. Advancement of traceability systems and Geographical Indication (GI) are other developments to meet consumer preference, while promotion of contract farming associated with the promotion of farmer groups and skill training, and linking farmers with domestic and overseas markets, is another example of success being promoted by SWIFT Company in Bangkok as a model.

The trend of per capita vegetable production (including melon) during the last decade (2000-2010) shows an increase from 130 kg/year to 151kg/year globally, and from 150 kg/year to 195.2 kg/year in Asia (Source: FAO Statistical Yearbook 2013: World Food and Agriculture). This substantial production increase of nearly 25% in past 10 years in the supply of vegetables in Asia was mainly due to dramatic increases in production in China, which accounts for nearly half of world vegetable production. Thus, Asia's vegetable production increase was mainly contributed by China, and there is a lot of room to improve vegetable production in other countries in Asia.

Now, we look at the future. The world population, presently 7.1 billion, is expected to reach about 9.2 billion in 2050. To meet the future demand of vegetable consumption, the world needs to produce 1.13 billion tons of vegetables by 2050 from its production base of 0.78 billion tons in 2005/07, a 47% increase requiring an annual growth rate of 1.04%. This estimation does not take into account uncertainties such as negative impacts of climate change on vegetable production. Although Asian countries account for around 76% of global vegetable production, productivity of vegetables in this region is low; some crops yield only half of what can be produced in some European countries. Thus the vegetable sector in Asia has high potential to grow further as consumer demand is expected to rise, including in other regions. This is one area that warrants serious attention.

This symposium will deliberate and examine from different perspectives the opportunities and constraints related the vital issues I have raised above. Scientists, researchers and experts have come from across the world to share in this symposium the results of years of study and experience. SEAVEG2014 is a good opportunity for us to exchange views on efforts to respond to the future development of the vegetable sector in Asia and beyond, and also to explore the roles of different stakeholders in these endeavors.

I am happy to note that the response to participation in this symposium has been tremendous and about 115 scientific and research works will be presented here in next three days. This shows that the theme and the objectives are of great interest and highly relevant. I am also pleased to see that many young scientists who will hold key roles in future vegetable sector development are participating in this event.

Finally, I do hope that we will all take the advantage of this gathering of hundreds of people working in the same field to talk to and learn from each other. There are so many reasons for us to work together more closely. That is why SEAVEG2014 is a step in the right direction.

I am confident that these discussions will lead to valuable knowledge sharing and that you will be able to come up with concrete recommendations that are needed to stimulate speedy development in this sector. As a UN Agency, FAO will be happy to be associated with these endeavors, both at national and regional levels.

During the 2014 International Year of Family Farming, vegetables will play a key role in various discussions and in placing smallholder farmers at the center of issues related to food security and nutrition. It is high time to advocate the importance of vegetables for health and life.

With these few words, I wish you all productive discussions and a rewarding symposium, and welcome you once again to SEAVEG2014.

SYMPOSIUM REPORT

Mr. Chamrong Daoroung
Director of Horticulture Research Institute
Thailand Department of Agriculture

First of all, I would like to express our appreciation and gratitude to the Permanent Secretary for presiding over the opening ceremony of SEAVEG2014.

SEAVEG 2014 was jointly organized by Department of Agriculture (DOA), Kasetsart University (KU), ASEAN-AVRDC Regional Network (AARNET), Vegetable Science International Network (VEGINET), Horticultural Science Society of Thailand (HSST), AVRDC – The World Vegetable Center, and the Food and Agricultural Organization (FAO). The significant contributions of small-scale farming systems in attaining the Millennium Development Goals and other internationally agreed benchmarks to eradicate poverty, enhance food and nutrition security, and strengthen local economies will be the focus of SEAVEG 2014. This regional symposium will examine how policies and practices to sustain small-scale agriculture—and vegetable production and marketing in particular—can improve availability of and accessibility to safe and nutritious food, and contribute to better nutrition and balanced diets, thus enhancing the socioeconomic development of ASEAN member states.

This three-day symposium consists of two days of a fine blend of plenary lectures, paper presentations and poster exhibitions, and field tours on the last day. You are set to visit the East West Seed Company, Nonthaburi and Flora Park, and Nakornratchasrima.

Today we have distinguished delegates from various research organizations, the private sector and academic institutions from 21 countries including America, Australia, Bangladesh, Cambodia, Ethiopia, Germany, India, Indonesia, Japan, Lao PDR, Malaysia, Myanmar, New Zealand, Nigeria, Philippines, Singapore, Sri Lanka, Taiwan, Turkey, Vietnam and Thailand. With this critical mass of experts from various sectors and countries, we can anticipate fertile discourse and valuable outputs during this symposium.

At this point, I now invite Mr. Damrong Jirasutas, Director General, Department of Agriculture, Ministry of Agriculture and Cooperatives to deliver the opening remarks.

OPENING REMARKS

Mr. Damrong Jirasutas
Director General
Department of Agriculture, Ministry of Agriculture and Cooperatives

On behalf of the Ministry of Agriculture and Cooperatives, I am very much honored and it is indeed a great pleasure to preside over the opening ceremony of SEAVEG2014: Families, Farms, Food – Regional Symposium on Sustaining Small-Scale Vegetable Production and Marketing Systems for Food and Nutrition Security.

This workshop is organized by Department of Agriculture (DOA), Kasetsart University (KU), ASEAN-AVRDC Regional Network (AARNET), Vegetable Science International Network (VEGINET), Horticultural Science Society of Thailand (HSST), AVRDC – The World Vegetable Center, and the Food and Agricultural Organization of the United Nations (FAO).

At this occasion, I would like to express our sincere thanks to all the speakers in this workshop, who readily agreed to our request despite their busy schedules. I expect that we will hear very interesting stories of discoveries and creations as well as trials and errors, and also future perspectives for the possible directions of our objectives.

Finally, I would like to wish you all smooth and productive deliberations. I hope your stay in Bangkok will be the most pleasant and memorable. Having said this, I now declare SEAVEG2014 open.

Field Trips

SEAVEG2014 field trips were carried out at Nakhon Pathom and Supan Buri provinces on 27 February 2014. More than 100 participants visited three interesting places 1) Swift Company Kamphaeng Saen Campus, Nakhon Pathom Province; 2) Kasetsart University, Kamphaeng Saen Campus, Nakhon Pathom Province; and 3) East West Seed, Hortigenetic Research, Southeast Asia Ltd., Suphanburi Province.

Swift Company Kamphaeng Saen Campus, Nakhon Pathom Province

Swift Company is one of Southeast Asia's leading fresh produce exporters within the niche market of quality Asian and Southeast Asian organic, chemical free, and GLOBALGAP-compliant, conventionally farmed vegetables and fruits. The core product line includes asparagus, baby corn, mangoes, mangosteen, ginger, galangal and lemon grass that are processed or heat-treated and packed for sale to retail and food service markets. The company's principal export destinations include the United Kingdom, countries in the Middle East, as well as Japan and Australia.

Swift has its headquarters in Kamphaeng Saen, Thailand and more than 600 sales, production and administrative support staff oversee all produce procurement, transportation and sales efforts. It currently owns and operates three processing facilities (pack houses) in Kamphaeng Saen, Chiang Mai and Petchaboon, which were specifically designed and structured to conform to HACCP and GMP principles.

During our visit, the chairman of the company presented the company's activities and products, including the packing house and processing facilities. http://www.thaifreshproduce.com/

Kasetsart University Kamphaeng Saen Campus, Nakhon Pathom Province

Kasetsart University (KU) is the first agricultural university and the third oldest university in Thailand. It was established in 1943 with the primary aim of promoting subjects related to agricultural science. To date, Kasetsart University has revised its curricula and expanded subject areas to cover science, arts, social sciences, humanities, education, engineering, and architecture. Kasetsart University has seven campuses throughout Thailand. The main campus is at Bangkhen, Bangkok. The enrollment is over 58,000, placing it among the top largest universities in Thailand.

The Kamphaeng Saen Campus (KU-KPS) is the largest campus of Kasetsart University, and was established in 1979. It is located about 80 km west of Bangkok and covers an area of more than 1200 ha.

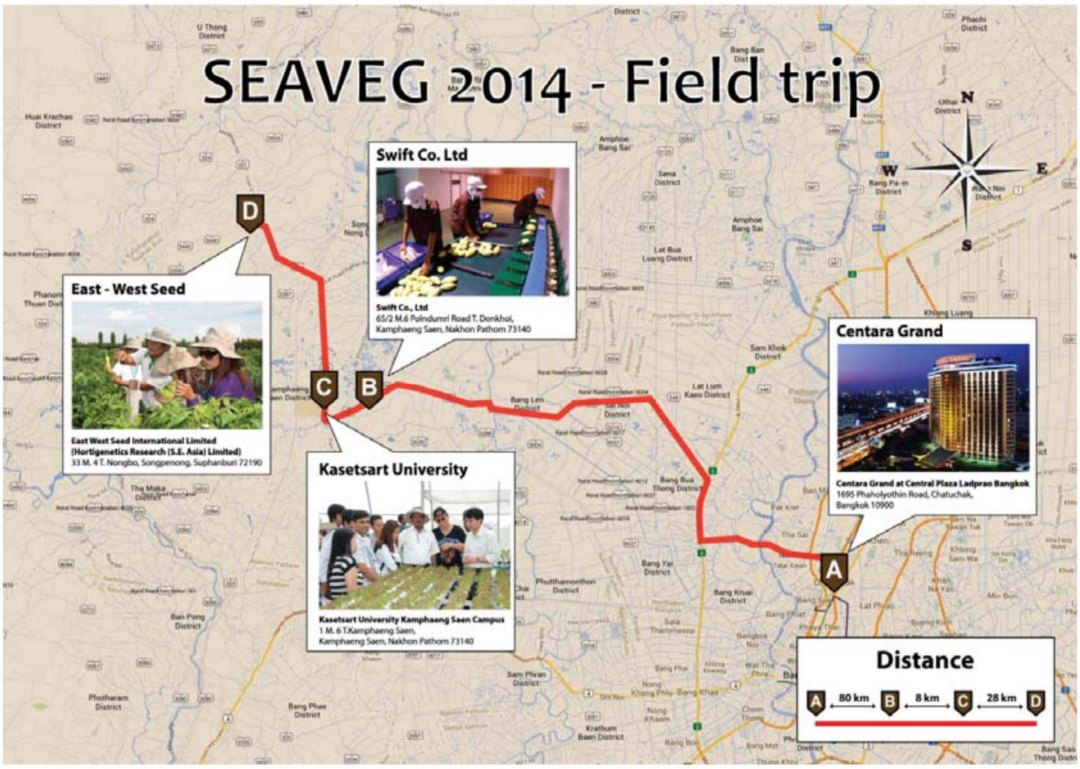
Field trip participants visited the demonstration greenhouse of KU's Agricultural Technology Complex. This complex was established in collaboration with leading agricultural companies. Participants also saw different leafy and fruit vegetables grown with fertigation and hydroponics systems under protected conditions. http://kps.ku.ac.th/eng/

East-West Seed, Hortigenetic Research, Southeast Asia Ltd., Suphanburi Province

East-West Seed is a market leader for tropical vegetable seeds in Asia. Using the most advanced technologies in vegetable plant breeding, the company has developed superior plant varieties with high productivity, better disease resistance and excellent quality. The introduction of these superb plant varieties has improved the lives of millions of resource-poor farmers in Southeast Asia and South Asia.

The company invests heavily in research and technology development utilizing cutting-edge technologies that enable its plant breeders and researchers develop new varieties at a faster rate with better efficiency and accuracy. East-West Seed is the only local vegetable breeding company that utilizes a combination of conventional breeding techniques and application of new technologies such as molecular markers and tissue culture to help its breeders achieve their goal of developing and selecting the best plants with the ideal plant characteristics. It has state-of-the-art research and development facilities across Thailand, Philippines, Vietnam, Indonesia, India and China.

The participants were welcomed by the General Manager, who introduced them to the research and development activities and led a tour to the corn, cucumber, pumpkin, luffa and wax gourd fields.
http://www.eastwestseed.com/


SEAVEG 2014 - Field trip
Swift Co. Ltd
Swift Co., Ltd
65/2 M.6 Polndumri Road T. Donkhoi,
Kamphaeng Saen, Nakhon Pathom 73140
East - West Seed
East West Seed International Limited
(Hortigenetics Research (S.E. Asia) Limited)
33 M. 4 T. Nongbo, Songpenong, Suphanburi 72190
Kasetsart University
Kasetsart University Kamphaeng Saen Campus
1 M. 6 T.Kamphaeng Saen,
Kamphaeng Saen, Nakhon Pathom 73140
Centara Grand
Centara Grand at Central Plaza Ladprao Bangkok
1695 Phaholyothin Road, Chatuchak,
Bangkok 10900
Distance
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Session Summaries

SESSION 1: SMALL-SCALE FARMING SYSTEMS

- Small-scale farming systems are highly vulnerable to pests and diseases, viruses, and other biotic and abiotic stresses, and availability of good quality seeds.

- In Asia, pesticide usage has rapidly increased, driven by strong agricultural growth and supportive government policies. Seasonality of supply also poses a threat to small-scale farming. These have created major problems in ensuring food safety and protecting the health of the farm population.

- International groups like the CGIAR and European Union are trying to address these problems by institutionalizing small-scale solutions (e.g. integrated pest management, rain shelter, grafting, home gardens) that can easily be adopted by farm households. These agricultural innovations target the entire production-consumption spectrum: increasing farm productivity, improving market linkages, and addressing the nutritional requirements of households, as well as promoting sustainable management of the natural resource base with a strong focus on gender.

- Several studies have shown the benefits of vegetable production to farm households and marginalized groups in Cambodia, Philippines, Indonesia and Bangladesh in curbing productivity and food security problems.
    - In Ifugao, Philippines, indeterminate tomato intercropping, especially using a three-row corn and two-row tomato design, can provide extra income for subsistence corn farmers with limited farm sizes.
    - The use of rain shelters can lower TMV viral disease incidence and pest attacks, increase tomato yield and profit in East Java, Indonesia.
    - Organic home gardens promoted among indigenous tribes in Ratanakiri, North-Eastern Cambodia can be a good source of income for this marginalized group. Home gardens also address the seasonality of supply and reduce the indigenous community's dependence on forest products.
    - Homeyard spaces can reduce a household's daily food expenses and provide easy access to healthier food in Bali, Indonesia.
    - Bangladesh Agricultural Research Institute (BARI) has developed several vegetable varieties that address seasonality, productivity and nutritional requirements of its population.

- Training and extension are crucial as shown by the Master Gardeners Model successfully implemented in the United States. The success of any technological dissemination and eventual adoption by farmers depends on proper training and extension activities.

- It is imperative to build partnerships between supply chain actors and facilitate market access and information.

SESSION 2a: GERMPLASM AND BREEDING

- The issue of breeding root knot nematode resistance in okra was raised. It was observed that there was scope in Thailand for new onion varieties like Fernanda, Buccaness and Colossus—all are late short day and yield better that Supparex, the popular variety. It was also mentioned that there is no evidence of association of bitterness with fruit colors in bitter gourd. More efforts from government are needed to develop the seed industry in Malaysia.

SESSION 2b: SUSTAINABLE PRODUCTION

- It was recognized that vegetables play an important role in food and nutrition security. However, vegetable cultivation is faced with several challenges that need to be addressed collectively by the public and private sectors through smart partnerships:

    - poor quality, especially during rainy season
    - poor soil quality and water management
    - lack of marketing information

- Vegetables planted in hydroponic and aeroponic systems can be implemented in areas where water availability is a problem.
- There is a need to manage pests and diseases in an environmentally friendly manner in view of injudicious use of pesticides among small-scale farmers. It is recommended that more farmers should be involved in training programs.
- Even though organic farming is considered a niche market, it has gained in importance. It was reported the demand for organic vegetables is increasing.
- Currently most organic vegetables produced in this region are exported to Europe; less are consumed locally. Government policies are recommended to tackle the problem of pricing of organic vegetables and provide incentives to organic farmers.
- Organic matter and beneficial microbes play a vital role in organic farming. Grafting to control soil-borne and virus diseases is highly recommended for use in vegetable cultivation.

SESSION 3: FROM HARVEST TO TABLE

- Postharvest
    - Engage private sectors in investing postharvest infrastructure facilities
    - Promote low cost and innovative postharvest management technologies
    - Build knowledge based on postharvest issues and management practices/technologies
- Nutrition
    - Identification of data gaps (research areas) to provide an evidence platform to further develop appropriate programs addressing malnutrition
    - An interagency, multi-sectoral (multi-stakeholders) dialogue to discuss issues on nutrition and develop strategies
    - Diversification of vegetables, especially traditional vegetables, on the table to increase intake of micronutrients
    - Increase investment in research and development
    - Enhance partnerships and involvement of private sectors
    - Institutionalize school garden programs and provide supporting policy frameworks
- Seeds/Germplasm
    - Increase availability of quality seeds
    - Preservation/conservation of germplasm material of indigenous vegetables
- Marketing
    - Maximize the use of information technology for farmers to improve marketing systems

SESSION 4: CROSS-SECTORAL ISSUES

Presentation 1: "Lessons learned from implementing nutrition-sensitive agriculture as a platform to improve nutrition and household food security" presented by Nancy J. Haselow, Vice President, Asia Pacific Helen Keller International. Nancy briefed the audience on nutritional problems and causes commonly existing in vulnerable groups, such as women and young children. Evidence-based strategies inform the program implemented by Hellen Keller International (HKI). The interventions deal with the direct causes of malnutrition, and cover promotion of appropriate infant and young child feeding practices; micronutrient supplementation; management of acute malnutrition; and balanced energy and protein supplements for women. Integrating nutrition-sensitive issues that contribute to the underlying causes of malnutrition is important. These include agriculture and food security; women empowerment; and health services, such as early child development and health protection, family planning, hygiene and sanitation.

HKI's Enhanced Homestead Food Production (EHFD) program model aims to improve food security and nutritional status of women with children less than 2 years of age. This model includes food production and health care components, implemented through local networking and resource mobilization. The program, implemented in five countries including Bangladesh, Nepal, Philippines, Indonesia and Cambodia, has covered more than a million households.

The program evaluation resulted in satisfactory findings. The EHFD improved food security, and reduced the prevalence of anemia and underweight among women. Impact on the children was observed in the reduction of anemia. Yet improvement in children's growth was not significant, which may be due to the short-term implementation of program.

Nancy ended her talk with four lessons learned: First, women must be empowered for household food security and to maximize positive nutritional impact. Second, an evidence-based and participatory program design was efficient to identify food, care and health determinants. Third, the implementation was effective as it linked with existing systems including agriculture, health and markets. Finally, effective monitoring and evaluation were important mechanisms of learning.

Presentation 2: "Strengthening Market Integration of Smallholder Famers: A Demand-Driven Approach to Technology Transfer in Myanmar" by Stuart Morris of East-West Seed International Company Ltd. About 70% of Myanmar's population is engaged in agriculture. Myanmar has good water resources with relatively low population pressure compared to neighboring countries. The people have access to land in suitable agro-climatic zones.

Vegetables have been overshadowed by a focus on field crops. Smallholders are the main vegetable suppliers. One advantage in Myanmar is that there is no competition from imports.

Stuart mentioned the challenges of market integration due to limited access to technical knowledge and market information, weak linkages in the value chain, fragmented flow of information and low levels of trust, a supply-driven approach, poor access to quality agro-inputs, and reliance on farmer saved seed.

In the view of East-West Seed International Company, Myanmar's vegetable sector should emphasize higher quality. Meanwhile, the competitive position of smallholders must be maintained. There is considerable opportunity to upgrade domestic markets as well as develop the potential for exports. Improved varieties alongside better farm practices will define the future position of smallholders in Myanmar's transforming market.

East-West Seed Company is aware that knowledge transfer is a precondition for developing higher farm incomes. Improve farming techniques (e.g., using better quality seeds) will enable small farmers to get full benefits. The company promotes good practices with key farmers, who host peer-managed demonstrations.

Presentation 3: "Plant Factories" by Mike Nichols. Producing greenhouses crops close to centers of consumption is not always possible due to land or climatic constraints. The plant factory or vertical farm may be a solution. Vegetables can be grown successfully in containers using various types of light sources: fluorescent tubes, high pressure sodium lamps, and light emitting diodes (LEDs).

Plant factories provide various advantages. They can be used for high quality seeding production. Vegetable production can be enhanced by using CO_2 levels of up to 6 times of normal because the plant factory is airtight, so CO_2 losses to the outside atmosphere are minimal. The productivity per square meter of ground area in a plant factory can be 50 times that of a standard greenhouse. Plant factories consume cheap sources of energy (solar radiation, wind). Growing mediums must be sterile. Airtight plant factories ensure produce will be pesticide-free with low microorganisms. Plant factories should result in high yield of vegetables and can produce crops at any time of the year in any quality and quantity. Currently, plant factories are used to produce leafy vegetables such as lettuce and herbs in Japan.

Presentation 4: "Research and development on vegetables and mushrooms project of Thailand Department of Agriculture" by Grisana Linwattana, Horticulture Research Institute, Thailand. Dr. Grisana updated audiences on the project to enhance Thailand's vegetable industry for food security as well as to promote Good Agricultural Practices (GAP). He described on-farm experiments with chili, okra, mushroom, asparagus, ginger, potato and other potential crops (pakia, sweet potato) undertaken during 2008-2011 carried out in 10 northern and northeastern provinces (Chiang Rai, Chiang Mai, Pichit, Petchabun, Kanchanaburi, Sisaket, Khon Kaen, Ubon Ratchathani, Nan and Sukhothai). The research resulted in 7 new varieties of chili and 20 varieties of mushroom, and produced new knowledge and technologies for crop care, protection and seed production of chili, ginger, asparagus, potato and okra. Some knowledge and technologies gained from this research have been transferred to farmers, especially chili and mushroom. The research findings have been disseminated via http://www.doa.go.th.

SESSION 5: ENABLING POLICIES

- Food safety strategies for ASEAN members should be addressed (e.g. ASEAN GAP)
- Urban and peri-urban agriculture focusing on home gardens, school gardens, rooftop gardens for food security.

Roundtable Colloquium

Moderator

Robert Holmer, *Regional Director East and Southeast Asia, AVRDC – The World Vegetable Center*

Participants

Joost Pekelharing (JP), *President, East-West Seed Group, East-West Seed International Ltd.*

Jacqueline d'Arros Hughes (JH), *Deputy Director General – Research, AVRDC – The World Vegetable Center*

Subash Dasgupta (SD), *Senior Plant Protection Officer, FAO Regional Office for Asia and the Pacific*

Nancy J. Haselow (NH), *Vice President Asia Pacific, Helen Keller International*

Grisana Linwattana (GL), *Horticulture Research Institute, Department of Agriculture, Thailand*

P**.G. Chengappa** (PGC), *National Professor, Indian Council of Agricultural Research, Institute for Social and Economic Change*

Gary Jahn (GH), *Agricultural Development Officer, United States Agency for International Development (USAID), Bureau for Food Security*

N.K. Krishna Kumar (KK), *Deputy Director General (Horticulture), Indian Council of Agricultural Research*

Detlef Virchow (DV), *Executive Secretary, Global Horticultural Initiative*

Q1: Alignment of breeding objectives to the demands of the market? What are the challenges? How to improve availability of quality seeds?

- ***JP:*** East-West Seed Company has passion to provide affordable seeds, in fact 40% of our seeds are open pollinated varieties already. Before it was sold in cans, which is expensive for farmers, but we are distributing seed in pouches, which is cheaper for farmers. Millions of pouches of seeds were distributed globally. We produce open pollinated seeds because it is very important to farmers.

- ***JP:*** The need to collaborate with government agencies to improve and increase availability of quality seeds to the farmers.
- ***JH:*** As for AVRDC, we have a huge genebank where vegetable germplasm is stored. We can give advance lines as public goods to seed companies, and they can develop varieties from these advance lines. Public and private sectors must work together to improve the availability of seeds.

Q2: Scaling up of technologies and strengthening of extension and research

- ***GJ:*** I think there is a need to distinguish between project based and non-project based research. It is important that there is a pathway to scale up. Scaling up as a nation might be difficult. It is important to look at the value chain and identify areas to scale up.
- ***PGC:*** We need private institutions to manage the supply chain. Their role is very important.
- ***SD:*** In Asian countries, the challenge is how can we transfer the informal seed sector into the formal business sector, because there are many informal seed sectors in Asia.
- ***JP:*** Look at China, government, make the distribution systems available across the country. The easy way to solve problem in the market is to put a distribution system in place.

Q3: Improving public and private sector engagement and increasing participation of farmers.

- ***DV:*** Depends on the political system; depends on the kind of innovation. If, for example, we are talking about marketing, who are the beneficiaries (women groups, etc.?) Programs to be more specific and should involve multi-stakeholders in different stages.

Q4: Addressing malnutrition…

- ***NH:*** Eating vegetables alone can't solve malnutrition. There are other determinants—such as access to food (quality of food in terms of nutrition) and preventive measures including proper hygiene, access to clean water, and good sanitation practices—that are very important aspects of addressing malnutrition. Multi-sectoral coordination is very important to address malnutrition.

Q5: What are some strategies of Thai DOA to make farmers/climate resilient?

- ***GL:*** We have a regional strategy based on technology and we conduct capacity building for farmers. We also do co-benefit partnerships, like working with agencies with a clear understanding of the benefits from the partnership.

Q5: Harnessing the importance of traditional vegetables.

- ***NH:*** A lot of indigenous vegetables are utilized as animal feed. Position these vegetables differently, preserve them, they are good not just for animals. Pregnant women need the important nutrients these indigenous plants contain.
- ***GJ:*** There is a reason why people consume hybrids. Incorporate traditional vegetables into breeding programa and include them in the market mainstream. They have to be demand-driven.
- ***JH:*** Make seed available. The challenge is, make seed companies take up indigenous vegetables. For example, in Africa, marketing is not there.
- ***DV:*** Demand can be created. In Kenya, for instance, showing that it is a cultural heritage of the people to eat such indigenous vegetables; incorporating them in meals or through diets; making people aware of the good taste.
- ***SD:*** Indigenous vegetable preservation is a problem. In Asia, indigenous vegetables are already in decline and we need a discussion about this.
- ***KK:*** Highlight the value of indigenous vegetables.

Messages from the participants:

- ***NH:*** Bring sectors together to address nutrition security. Defining nutrition indicators is important.
- ***KK:*** Three points: 1) where do micronutrients come from: the soil—to have sustainable production, soil is important; 2) there is a need to invest in research; 3) conservation of genetic resources is very critical.
- ***JP:*** The need for good extension and market accessibility is very important. The role of the public sector is also very important.
- ***JH:*** Minimizing food wastage is a taking a small step to address some issues on food availability. Governments should have a renewed focus to improve vegetable productivity. Ensure supply chain.
- ***GJ:*** The importance of changing attitudes through education, policies and systems to be in place, as well as improved research and innovation.
- ***DV:*** Vegetable sector is a "gold mine"! To improve it, we need to fine-tune the enabling environment, target women through awareness raising and research. People working in health and agriculture need to think of ways to incorporate nutrition in our work.
- ***PGC:*** It is important to involve all sectors across various disciplines**.**

Southeast Asian vegetable production – a vision for the future

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ABSTRACT

Global production of common and traditional vegetables is steadily increasing, and traditional vegetables in particular are attracting the attention of farmers, researchers, policy makers and the public. Nonetheless, many factors constrain vegetable production, including climate change and extreme climatic events, increased urbanization and pressure on arable land, ever-present pests and diseases, an aging farming population, and adverse policies toward horticulture. Families must have year-round access to affordable and nutritious food for a balanced, healthy diet, which must include vegetables as a source of many micronutrients. Southeast Asia must maximize crop productivity while minimizing losses, wastage and the overall impact on the environment. Solutions to improve productivity, profitability, and human nutrition include expansion and mechanization of protected agriculture, better production and environmentally sensitive management technologies, investment in research to support traditional vegetables, improving all elements along the vegetable value chain, better engagement of the private sector (including postharvest value addition, food preservation technologies, and more efficient marketing performance), better information flow and management, and improved business skills, particularly for small-scale growers, distributors and marketers. Future initiatives to increase production must also emphasize consumer education to raise awareness about the value of vegetables for a well-balanced, healthy diet for all family members.

Keywords

Healthy diets, production, post-harvest, wastage, future perspective

FUTURE CONSTRAINTS TO PRODUCTION

Production of common (global) and traditional vegetables worldwide is steadily increasing, and traditional vegetables in particular are attracting enhanced attention from farmers, researchers, policy makers and consumers. However, it is unfortunate that national governments and international donors are not yet showing sufficient investment in research and development for horticulture—a field which significantly contributes to several dimensions of the post-2015 global development agenda (Keatinge et al. 2011a; Sustainable Development Solutions Network 2013). Families must have year-round access to affordable and nutritious food for a balanced, healthy diet, which must include vegetables as a source of many micronutrients, vitamins and dietary fiber (Hughes and Keatinge 2013). However, present levels of vegetable production in Southeast Asia are not sufficient to achieve this goal. Production levels in the 10 member states of the Association of Southeast Asian Nations (ASEAN) plus Timor-Leste reached 34.2 million tons in 2012, out of which 1.3 million tons were exported and an estimated 2.7 million tons were lost during postharvest and marketing processes (FAOSTAT 2014). A further 2.4 million tons were imported into the region resulting in 32.6 million tons of vegetables available for consumption by a total of 582 million people, which corresponds to an annual average regional per capita intake of 56 kg versus the recommended minimum intake of 146 kg of vegetables and fruits per capita and year by the World Health Organization and Food and Agriculture Organization of the United Nations (WHO & FAO 2005). Annual vegetable per capita intakes, however, vary considerably among countries, from 154.7 kg in Lao PDR to 33.7 kg in Cambodia and 24.5 kg in Timor-Leste, respectively (FAOSTAT 2014).

With the advent of the ASEAN Economic Community in 2015, the region now must seek to maximize crop productivity and profitability to ensure sufficient supply of health-promoting vegetables for its populace while minimizing losses, wastage and the overall impact of horticultural activities that may impinge upon the sustainability and resilience of the environment (Holmer 2011).

Many factors currently constrain vegetable production, including climate change and extreme climatic events, increased urbanization and pressure on arable land, pests and diseases, an aging farming population, and adverse policies toward horticulture. Abiotic stresses may have an increasingly potent effect on vegetable production as horticultural crops are often vulnerable to extreme events of wind and rain, and global vegetables such as tomato (*Solanum lycopersicum*) and sweet pepper (*Capsicum* spp.) are sensitive to heat damage, waterlogging, drought and increasing salinity through their individual or combined effects on flowering and fruit set (Keatinge et al. 2011b). Rising trends in abiotic stresses imposed on horticultural crops may be inferred to be increasing rapidly in East Asia (Keatinge et al. 2012a), which will have significant effects on crop production. Biotic stresses are also expected to respond to these predicted changes in air temperature, precipitation regime and within-canopy relative humidity, perhaps more rapidly than the general public and policy makers would expect. For example, the incidence and severity of bacterial and fungal pathogens responsible for major epidemic diseases in vegetables such as late blight (*Phytophthora infestans*), bacterial and Fusarium wilts (*Ralstonia solanacearum* and *Fusarium oxysporum*) are likely to change, probably becoming more severe, as temperature and rainfall levels increase (Keatinge et al. 2012a).

The incidence and severity of diseases caused by plant viruses is likely to increase as their vectors become more numerous and more mobile as a result of increased temperatures. Changing temperatures may also expand the distribution of viruses, and new viruses may become important in crops in warming areas. For example, begomoviruses, which infect and cause severe damage to a wide range of horticultural crops, are likely to become an even more serious constraint to vegetable production as the number of generations per year of whiteflies (their principal vector, *Bemisia tabaci*) increases with warmer temperatures (Hanson et al. 2011). Additional generations of other highly damaging insect species such as the pod, fruit and shoot borers (e.g. *Leucinoides* spp., *Maruca* spp., and *Helicoverpa* spp.) may also potentially mean greater crop losses or additional misuse of insecticides—already a severe challenge to the safety of vegetables sold in the markets of Southeast Asia that should not be further exacerbated (Weinberger and Srinivasan 2009; Srinivasan 2012; Schreinemachers et al. 2012). In addition to the damaging effects of pests and diseases, the effects of a changing climate on pest natural enemies (e.g. Wolbachia and Buchnera endosymbionts, two of the major groups of parasitoids or hosts endosymbionts) and on pollinators are also likely to be severe (Gutierrez et al. 2008; Hance et al. 2006).

As Asian populations are scheduled to increase markedly in the next 25-50 years and the Asian farming population seems to be starting to follow the Americas and Europe with a decreasing trend in the size of the agriculturally active population, and with a higher and higher proportion of the overall population living in urban areas, horticultural activities, particularly those in the peri-urban fringes, will need to cope with much greater pressures on land availability, the need for much higher, better quality and consistent supply of vegetables to markets in the face of an inexorably aging rural farming population and rapidly increasing land prices (Midmore and Jansen 2003; Alexandratos and Bruinsma 2012). The predicted decrease in rural populations, increasing pressure on urban land and the potential misuse of resources and inputs are constraints that must be overcome, but this will be a continuing challenge given the continuing and new pressures being placed on the horticultural industry (Schreinemachers et al. 2012).

ACHIEVING AN EFFECTIVE HORTICULTURAL FUTURE

1. It will be necessary to seek measures to increase vegetable quality/nutrient density, productivity and cropping intensity per unit of land and labor. Davis and Riordan (2004) have reported falling nutrient quality in a wide range of temperate vegetables bred and produced in the USA since 1950. Seed companies have been breeding for more rewarding characteristics such as appearance and long shelf life, often at the expense of nutritional content and taste. This trend must be reversed, and consumers must be knowledgeable and willing to demand produce with better nutritional content and good taste, rather than unblemished, uniformly shaped and highly colored vegetables if world malnutrition issues are to be addressed through better balanced diets. A greater use of traditional green leafy vegetables and legume/pulse-type vegetables in the future would be sensible as many of these are highly nutrient-dense (Hughes and Keatinge 2013; Yang et al. 2007). The need for greater intensity of use of land and a reduction in the use of toxic inputs such as pesticides, or risk of contaminating groundwater with fertilizer runoff suggests a further rapid expansion of rain shelter, screenhouse and glass/plastic house production, with a need for both more skilled labor and greater mechanization in the production of vegetable crops (Jat et al. 2011).

The current relatively restricted use of grafting for solanaceous and cucurbitaceous crops will need a substantive novel research effort if the large potential benefits to be derived from avoidance of soil-borne diseases, excessive salinity and waterlogging is to be gained. The range of rootstocks conferring resistance to bacterial wilt and root-knot nematodes must be expanded to ensure the resistance is not overcome by pests and pathogens. It may also be possible to exploit grafting multiple scions onto a single rootstock or graft annual plants onto perennial rootstocks; adaptive research is required but proof of concept is already available. Likewise, supergrafting, in which two crops such as tomato and potato can be produced simultaneously, are novelties whose commercial exploitation is feasible, as are multiple apple or citrus scion grafts onto one apple or citrus rootstock (Fruit Salad Tree 2012). Opportunities to exploit these possibilities with vegetable crops must still be explored. AVRDC holds the world’s largest collection of tropical solananceous plants, and a wide range of Cucurbitaceae in its genebank which will be explored as an opportunity for grafting research, as the potential for enhanced productivity is substantial (Ebert 2011).

2. It will require a substantive reduction in crop losses in both the pre- and postharvest elements of the vegetable market chain. This will require the adoption of careful, appropriate harvesting practices and procedures, with produce sorting and collection at the farm gate. Harvesting at cooler times of the day and rapid cooling of many vegetable crops is the key to effective postharvest handling and quality maintenance (Kader 2013) to minimize the crop losses of 17-42% reported by Bautista (2001) from Thailand, Indonesia, Malaysia, Vietnam and the Philippines. This cooling needs to be maintained along the complete market chain. In all cases sanitary measures should be mandatory to ensure wholesome produce at the market and food safety. Proper marketing and care of the products while on sale and ensuring that the product is attractive and safe for the consumer to buy and eat is required. Better understanding of the need for a clear link between vegetable production and industrial processing and the adoption of simple or suitable postharvest technologies such as solar drying, freeze drying, freezing, canning, bottling, waxing, and modified atmosphere packaging is required (Kitinoja et al. 2011; Saran et al. 2012).

3. It will require the human population to seek effective ways of reducing presently excessive levels of food wastage, of understanding the need for a balanced diet to obtain and maintain good health and to adopt ways of vegetable processing and cooking that maximizes the bioavailability of the essential vitamins and minerals present in vegetable crops (Keatinge et al. 2012b, Teng and Trethewie 2012). Food wastage remains an unsolved issue today with wastage occurring at the producer/farmer, at market, in the supermarkets, in restaurants and hotels, and in the home.

One technological solution to reduce waste and increase shelf/refrigerator life is through irradiation. Gamma irradiation can be used to eliminate harmful bacteria, potentially retard unwanted product maturation, extends shelf life and reduces spoilage. This technology is employed on 500,000 t of global food products annually and is accepted in around 50 countries (Farkas et al. 2011; Kume et al. 2009). As vegetable shelf life can be increased 3-5 times by gamma irradiation, this technology needs to be considered and introduced more widely in Southeast Asia. Brazil is currently a leader in this technology, some South Asian countries also accept some irradiated products and thus there should be no major impediment to its introduction into Southeast Asian countries other than the need for better consumer education and understanding.

4. More information, better business skills and job creation will be needed. While production of vegetables is a widely promoted activity, production of quality vegetables is a knowledge-intensive occupation. Information is required to ensure farmers use the most adapted varieties of vegetables, that they are aware of the most appropriate production technologies (e.g. rain shelters, glasshouses, integrated pest management) and the optimum methods to ensure their produce reaches the market in good condition. Business skills for vegetable production increases profitability and minimizes losses and wastage. Better information for farmers results in increased bargaining skills to get produce from the farm to the market at the right time for increased profitability. The increased marketing information flow will also reduce the opportunities for cheating or excessive profiteering by middlemen. It can also minimize risk for farmers by enabling them to locate forwards sales contract opportunities.

Further consumer education measures need to be actively pursued amongst householders, particularly women who need to be further empowered with knowledge so that they understand the need for good nutrition for all members of their family from the very young to the very old, as well as other vulnerable members of the community. Likewise, they need to know how to grow and cook vegetables appropriately and in what combinations (Oluoch et al. 2012) so that they can maximize nutrient bioavailability and directly help abolish malnutrition amongst their family, friends and relatives (Keatinge 2013).

5. Vegetables and their products must be of better quality. The use of Good Agricultural Practices (GAP) such as those published by the Secretariat of the Association of Southeast Asian Nations (ASEAN 2006) in the field or greenhouse, with careful harvesting, sanitary preparation for the market, proper marketing and care of the produce will result in safe, high quality, and attractive products for the consumer. There are many different consumer target groups: the household, the rural wet market, urban wet markets, and supermarkets. Within these consumer groups there are opportunities for niche markets of traditional vegetables, provided seed of preferred varieties are available to farmers and that the produce can reach the market efficiently and effectively. Many traditional vegetables are leafy, green vegetables – these are a challenge for transport to market as they are particularly prone to wilting and loss of quality and also due to the concurrent loss in weight, bring in less profit. Vegetables can also be sold as pre-packed washed and prepared vegetables which meet the needs of busy urban households. Vegetables can also be grown organically, often with a premium price tag as organic produce, but similarly village or community quality labels can be used to convey the focus on food safety. There are also many opportunities for processing and adding value, ensuring that vegetables (and their nutritional content) remain available throughout the year.

6. Solutions to improve productivity, profitability, food safety and human nutrition are required. This may include intensive production, with potentially considerable expansion and mechanization of protected agriculture. Traditional technologies of rain shelters, greenhouses and net housing (at the likely expense of open field-style production) must be expanded, but should also include ways in which energy, nutrients, and water-use efficiency can be achieved. For example, with the next generation of more efficient, and probably cheaper, solar cells could be built into greenhouse design to cope with local power needs for mechanized heating, cooling and controlled fertigation (Jat et al. 2011). Also, the wide availability of robust, but with very fine grade mesh, net-housing capable of excluding all undesirable insects including whiteflies and thrips, as well as pod, fruit and shoot borers. This protected cultivation will greatly increase the quantity of marketable vegetables and increase their wholesomeness by largely eliminating pesticide residues (Sidhu et al. 2013). A parallel reduction in soil-based plant delivery systems in controlled environments for artificial or sterilized peat/compost based alternatives will help reduce risks to the sustainability of production systems from the build-up of severe soil-borne diseases and pests.

Furthermore, consideration of the need for expansion of productivity away from distant rural farms towards urban and peri-urban environments in order to retain product postharvest quality by reducing delivery times and transport costs to market will automatically raise the issue of competition for land and thus the inevitability of increased land values. Opportunities thus will exist for much more intensive use of space through better use of the vertical dimension of greenhouses and other vertically designed and stacked plant growth structures. Examples of such approaches are being tested currently in locations such as Singapore where land prices are prohibitive but there is yet a need for local vegetable production (Doucleff 2012; Bee Ling Poh 2013 personal communication). Module farming (and plant factories) are opportunities for production of vegetables where the environment can be well controlled. There is a requirement for a reliable power supply for lighting and for use of a conveyor-based system, and also a ready market for the produce which can be grown year-round. Examples of such module are indoor vertical farms Farmed Here® in Illinois and Green Farms A&M in Indiana, USA. Other examples of this futuristic type include fully hydroponic and artificially lit systems designed for use in public areas or the home (e.g. AeroGarden® hydroponic, Omega Garden® system); if prices of installation become reasonable these could be widely adopted in urban environments. Another opportunity is to utilize gamma irradiation as a mechanism to ensure the quality of fresh vegetables is retained over a longer period after harvest; it is comparable to pasteurizing milk, in that the product is left fresh, but is much safer. Gamma irradiation destroys harmful bacteria, extends shelf life, retards maturation of vegetables, reduces spoilage by organisms that can grow under refrigeration and can also be used in place of fumigants and other quarantine procedures. Gamma irradiation of food is currently permitted by over 50 countries and over 500,000 tons of food is treated annually worldwide (Farkas et al. 2011; Kume et al. 2009). Although the cost of developing a Cobalt 60 irradiation facility can be high, the final costs of irradiating foods would eventually be low (low dose applications such as disinfestation of fruit range between US$0.02 and US$0.18 per kilo, higher dose applications can cost as much as US$0.44 per kilo (Corrigan 1993) and the increase in food safety significant.

7. Biotechnology will need to become a useful tool. Biotechnology will ensure that the range of molecular tools which can be used to increase the rate of production of improved, adapted vegetable varieties are available as well as the similar tools to test for and identify pests and pathogens. A range of molecular markers are currently available and speed up the development of disease resistant crops. This includes for tomato, for example, the range of *Ty* gene markers for chromosome loci that convey resistance to *Tomato yellow leaf curl virus* (Verlaan et al. 2013). This means that the appropriate combination of *Ty* genes can be combined in one variety to confer resistance to the current strains of the virus. Molecular markers for other genes such as those conferring resistance to late blight (*Ph* genes) or against root knot nematodes (*Mi* genes) already exist (Foolad 2007), or for pungency (e.g. in chili, the *Pun1* genes, Steward et al. 2007) but new markers are needed for these and an increasingly wide range of characteristics, pests and diseases.

Conventional breeding of vegetables has developed many new varieties. The use of biotechnology to enhance the breeding process is particularly useful where genes for a particular trait are in a different species and where crossing is not feasible. Several genetically-modified vegetables crops are currently available (courgettes and sweet pepper with virus resistance, eggplant with insect resistance and tomato with delayed ripening/fruit softening/senescence and insect resistance) and tomato FLAVR SAVR™ is commercially approved in Canada, Mexico and USA, while chicory Seed Link™ is commercially approved in USA. In many countries, genetically-modified vegetables cannot be grown and the products cannot be approved for release to the public until the necessary country regulations have been approved. (Gupta et al. 2013)

8. Public-private partners must work towards common goals. It is unlikely that in the near future public sector investment in horticultural research and development will be sufficient to provide all the seed and technological answers to some of the questions posed. This must then require a much closer engagement with the private sector (including postharvest value addition, food preservation technologies, and more efficient marketing performance), better information flow and management, and improved business skills, particularly for small-scale growers, distributors and marketers. It is also essential for the private sector seed industry to wean itself off its present "free-rider" dependence on trait specific germplasm and long term breeding investments provided by the public sector without effective compensatory re-investment. Many of the private sector seed companies produce only hybrid vegetables and within this group, a very restricted set of global vegetables, often with a focus on shelf life, and consistent color and size rather than nutritional content, will be available in the future to the human population. Many developing country farmers prefer to use open-pollinated varieties which may allow them to save their own seed. This is often not considered a good market strategy for the private sector seed industry. In direct contrast, the need for adequate system resilience and the requirement for balanced human diets demand that the public-private sector accord must ensure a continued availability of a wide range of vegetables species with improved, trait specific, nutrient dense germplasm (Keatinge et al. 2010a; Keatinge et al. 2010b, Kahane et al. 2013). Crop input suppliers must also recognize the need for producer and consumer health and minimize the risk to farmers and families when consuming vegetables that have been treated with chemical inputs; an opportunity exists to build on integrated pest management products rather than on synthetic pesticides. In the case of fertilizers, both the public and private sectors must ensure information is available so that appropriate fertilizers are used and minimizing the effect on the environment.

Additionally, it is also concomitant on the public sector to ensure that they adequately address the needs for enhanced consumer education to raise awareness about the value of vegetables for a well-balanced, healthy diet for all family members (Hughes and Keatinge 2013). The present prohibitive, ever-rising, cost of the global health sector, resulting from unwise or uniformed food choices in both developed and developing countries must soon force governments to recognize the urgent need for adequate investment in consumer education. It will surely be much cheaper and a more effective policy in the long run to reduce, and where possible avoid, non-communicable diseases which are the result of resource-driven or ignorance-driven malnourishment resulting in unbalanced diets and poor human health.

FUTURE PERSPECTIVE

The perspective of the next 40 years of vegetable production can be viewed optimistically as the opportunity to render many of the previously intransigent constraints to on-farm production such as insects and soil-borne diseases can be considerably diminished if protected horticulture becomes the norm. In addition, nature has been generous to humankind; copious numbers of digestible nutrient-dense vegetable species can be valuable in the kitchen if further research can bring them into the production mainstream.

Influencing populations becomes even more vital, not only influencing what we eat, but also making sure that different parts of the community interact, that policy-makers in education, health and agriculture interact to make sure that vegetables are grown well, that quality produce is available and that the population is aware that a balanced and diverse diet leads to good health. We also need both a new generation of agricultural scientists and a new generation of farmers to feed a growing population. We also need to influence policy makers so that these needs become a reality.

And yet, while we are aware of many of the issues, we are still challenged by inadequate consumer understanding of the need for effective diets, and the difficulty in changing mindsets to enhance vegetable and fruit consumption among adults. Disciplinary silos between agriculture, health and education professionals will need to be overcome if the public are generally to accept the need for better diets and of what these might consist. If we can link agriculture, health, education and government policy together effectively and encourage a new generation of scientists and producers to take up horticulture...then AVRDC believes we have every chance of bringing "Prosperity to the Poor and Health for All" in the next 40 years in the Southeast Asian region.

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The role of private seed companies in the development of small-scale vegetable farming systems

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ABSTRACT

There have been many improvements in vegetable farming and technology in recent times that have vastly contributed to increasing farmers' incomes. Among these are improved vegetable seed varieties that have considerably increased the productivity of labor and land (Eaton and Wiersinga 2009). There are, however, major barriers to adopting quality seed: rural poverty, lack of knowledge on inputs, poor cultivation techniques, and weak functioning of value chains.

High quality seed alone does not ensure higher income and productivity. In an environment where a majority of farmers have little or no access to information, agricultural extension has been identified as a precondition for opening and sustaining markets.

The private sector is in a position to play a key role in developing small-scale farming systems. (Sjauw-Koen-Fa 2012) Apart from investing in R&D to develop better products, many seed companies are active in extending knowledge to farmers.

The contribution of private seed companies to the industry is two-fold: 1) to support the continuous improvement of vegetable varieties by investing heavily in R&D and innovation, and 2) to improve the profitability of vegetable production for small-scale farmers by promoting improved market-focused production techniques. Together, these create opportunities for wealth creation among small-scale vegetable farmers, and transform them into dynamic actors in the value chain.

The experience of East-West Seed, a private vegetable seed company focused on developing better tropical vegetable varieties, demonstrates that incorporating extension/advisory services is a fundamental long-term business strategy.

East-West Seed was one of the first private companies to introduce hybrid vegetable seeds in tropical Asia. Since the 1980s, it has focused on variety development, seed production and the distribution channel. In addition to developing good genetics, it also focuses on equipping farmers with technical and managerial capability for vegetable farming under a tropical climate. Over the last three decades, East-West Seed's advisory services have improved the profitability of vegetable production for farmers by promoting access to technical know-how, developing embedded services and improving the availability and choice of inputs.

By developing improved varieties and promoting knowledge and better farming practices, private seed companies can contribute significantly to developing small-scale farming and a sustainable food strategy.

Keywords

Private sector, smallholder farmers, seeds, hybrid, R&D, innovation, technology transfer, extension services

SMALLHOLDER FARMERS IN THE FOOD SYSTEM

Smallholder farmers drive the rural economy and are the main food producers in developing countries. Of the approximately 500 million small farmers in the world, the majority are located in Asia. This region is home to the largest number of farmers in the world, with an average farm size of only 1.1 ha. They belong to the dominant group (85%) of small-scale farmers in the world farm structure, and are therefore crucial to food security.

Current global agriculture production must increase by 70% by 2050, according to the FAO, in order to meet the increased demand for food of a growing world. (FAO 2009) The big question on everyone's mind now is: how can smallholder farmers produce the additional food needed to feed the world?

Extensive studies on the topic have concluded that integrating smallholder farmers in the value chain is the key to food security and sustainable food production for the needs of today's world. We cannot begin to solve the problem of imbalances in food supply without factoring in the contribution and potential of small-scale farms in developing countries.

For purposes of the SEAVEG symposium, this paper limits the discussion to small-scale vegetable farmers. Fruits and vegetables are the most sustainable and affordable sources of micronutrients in diets (ISHS 2012), therefore vegetable farmers have a unique role of not only supplying food but providing essential nutrition and a balanced diet to the population.

Addressing the challenges of smallholder vegetable farmers

Vegetable farmers must make decisions and manage risks in an ever-changing environment. Small farmers tend to be risk-averse, so the challenge is to cut their risks while improving their income.

Simple and effective mechanization tools, irrigation, crop nutrition and specialized knowledge have made vegetable farmers more efficient and productive. In addition, improved communication tools like SMS and the internet also provide opportunities for them to make the better decisions and lower their risk.

Perhaps the one thing that has made the most profound impact on vegetable farming is modern plant breeding. Plant breeding has paved the way for better-performing varieties with good genetics, more adaptive to stress conditions, more efficient in terms of energy and fertilizer, and more resistant to pest and diseases, which cuts the need for chemicals, has higher yield, and allows the farmer to harvest early. These advances in the plant sciences have created opportunities for farmers to further improve their income. Studies support this.

Improved seed varieties have considerably increased the labor and land productivity in vegetable production, especially those varieties that are developed for country-specific climatic conditions and pest and disease profiles. (Eaton and Wiersinga 2009) High quality seed is a key factor in cutting the risks of farmers, reducing uncertainty, and improving their livelihood.

Nonetheless, breaking the low-income trap for farmers is not without challenges. There are major barriers to the adoption of high quality seed. These include rural poverty, lack of knowledge on inputs, poor cultivation techniques, and weak functioning of value chains.

The provision of new technology and proper cultivation techniques are necessary steps to ensure that farmers are able to take advantage and unleash the potential of these improved seed varieties.

THE PRIVATE SECTOR IN A KEY POSITION

Because agriculture and food production creates a "public good," it was traditionally assumed that the responsibility to invest in agricultural research and extension fell solely on the public sector and aid agencies. The reality is far from it, though. The private sector is an active partner in generating knowledge and technology for improved farming, as well as extension services. In fact, the production and marketing technologies for the fastest growing products, such as fresh fruits and vegetables, have been introduced mostly by the private sector (IFPRI 2005).

Innovation is a key concept in this role. The motivation for private companies to embrace innovation is its ability to help them attain their growth objectives. Private companies recognize that achieving business goals requires putting innovation at the core of their activities.

Innovations take the form of products and services. Speaking from our experience in the seed sector, our efforts on innovation are focused on breeding hybrids that have higher yields, improved resistance to diseases and pests, and better fruit quality. Research and development (R&D) is the main engine of growth in the seed business. We invest heavily in R&D, not just in terms of infrastructure and technology, but also in talent/human resources and linkages with research institutions.

We do know, however, that in order for better seeds to make a difference in farmers' income and productivity, there has to be—first and foremost—adoption. There has to be a fundamental shift within agricultural systems towards improved technologies, better inputs and more effective cultivation practices. This is a challenge amid a landscape of rural poverty, limited capital, and lack of knowledge. In an environment where a majority of farmers have little or no access to information, both public and private sector-led agricultural extension have been identified as a precondition for opening and sustaining markets.

The private sector is in a position to play a leading role in linking food demand and supply in an integrated fashion. (Sjauw-Koen-Fa 2012) Apart from investing in R&D to develop better products, many seed companies are active in extending knowledge to farmers. The objective of this is to improve the profitability of vegetable production for poor small-scale farmers by promoting improved market-focused production techniques.

The contribution of private seed companies to the industry can thus be seen as two-fold: 1) to support the continuous improvement of vegetable varieties by investing heavily in R&D and innovation, and 2) to improve the profitability of vegetable production for small-scale farmers by promoting improved market-focused production techniques. Together, these create opportunities for wealth creation among small-scale vegetable farmers, and transform them into dynamic actors in the value chain.

The value chain

The private sector can contribute greatly towards unleashing the potential of small-scale vegetable farming systems, particularly by integrating them to into the value chain through a market-based approach.

A market-oriented system is necessary to build an environment that makes wealth creation possible. (Prahalad 2007) Shifting towards a market-driven approach is a key element to promote sustainable growth in the vegetable sector. In a dynamic and functioning value chain, the provision of inputs and the promotion of production techniques respond to the specific quality demands of the market.

The value chain is crucial for small farmers. Vegetable farmers get higher returns if they are market-oriented, meaning they produce the products that vegetable consumers demand. When good market linkages are in place, primary producers stand to earn more.

A study led by Wageningen University Netherlands on the impact of improved vegetable farming technology on farmers' livelihoods in tropical Asia supports this. In terms of institutional and market factors, market demand for fresh produce was mentioned as the most important factor for a farmer to select that variety for planting. Consumer and market demand for the produce from hybrid varieties is reflected by the traders' requests for certain varieties according to their characteristics. (Eaton and Wiersinga 2009)

Improved varieties increase farmers' income

East-West Seed was one of the first private companies to introduce hybrid vegetable seeds in tropical Asia. Since the 1980s, it has focused on variety development, seed production and the distribution channel. It stepped into a vacuum and started market-oriented plant breeding, first in the Philippines and Thailand, and later in India, Indonesia and Vietnam.

It focused on systematic classical selection for improvement of the main regional open-pollinated crops, like looseleaf Chinese brassicas, yard-long bean and kangkong. It also focused on hybrid variety development for the main tropical cucurbits and solanaceous crops. Spectacular increases in yield and fruit quality stabilization were achieved within 5-10 years in the main Southeast Asia cucurbit crops, including cucumber, bitter gourd, pumpkin, and luffa.

This experience has underscored that plant breeding creates added value to crops and increases the income of resource-poor farmers in Southeast Asia. To make this more explicit, EWS developed the *Quality Seed Multiplier* concept, which measures additional farmers' income for every dollar spent on quality seed.

$$\frac{\text{(Gross revenue of new variety)} - \text{(Gross revenue of old variety)}}{\text{(Seed cost of new variety)} - \text{(Seed cost of old variety)}} = \text{Quality Seed Multiplier}$$

For instance, the QSM for an improved variety of bitter gourd in Vietnam can be shown in Table 1. For every additional VND spent on hybrid bitter gourd seeds, the farmer earns an additional VND 11 revenue compared to using the old variety.

Case 1: Developing the corn market

Developing the waxy corn market in Thailand and the sweet corn market in Indonesia are key contributions of East-West Seed in growing markets, generating value for the farmers, and making better produce available for consumers.

About 85% of waxy corn sold in Thailand is an East-West Seed variety. Since entering the waxy corn market in 2003, EWS has launched more than eight varieties. It started selling 0.5 metric tons (MT) of seeds of its first variety, 'Big White 852.' The company then introduced Sweet White and Sweet Violet, which are "sweet waxy corn" innovations of EWS. The market soon learned to love the varieties, which combine the sweetness of sweet corn and the chewiness of waxy corn. Today, sales volume has grown to 300 MT of seeds which can produce 360,000 MT of fresh corn and generates value to farmers of more than 2.5 billion baht (USD 76.1 million) a year.

In Indonesia, the development of a sweet corn variety has shifted the market preference from low grade corn to high quality sweet corn. Traditionally, Indonesian consumers were accustomed to eating low grade corn, which is being fed to livestock in the West. Since the introduction of the variety 'Bonanza' ten years ago, sweet corn has grown immensely popular among Indonesian consumers and can be commonly found in roadside stalls selling the ears as boiled or grilled corn. 'Bonanza' is also Indonesia's first sweet corn variety that is resistant to the high disease pressure of the tropics. In sum, the production and trade of sweet corn today adds at least USD 300 million to the Indonesian GDP while the total sweet corn acreage in Indonesia is estimated at 75,000 hectares.

Case 2: Gemini virus resistant tomato

In the past five years, Gemini virus outbreaks have been occurring in a number of vegetable production centers in Indonesia, including tomato farms. The damage can reach as much as 100%, resulting in failure to harvest and huge losses for farmers. In 2011 in East Java, for instance, of about 500 hectares of land planted with tomatoes, 70% or 300 hectares were damaged by this disease. As a result, the production of tomatoes fell significantly and consumer prices rose to 300%.

East-West Seed in Indonesia has successfully developed tomato varieties resistant to Gemini virus. The tomato variety, called 'Tymoti F1' is a hybrid that is resistant to Gemini virus and bacterial wilt, and is tolerant to the hot climate. 'Tymoti' is also an early type and a prolific variety, giving farmers better yield. Jajang Mubarok, a farmer in Tasikmalaya, West Java, uses 3 kg of 'Tymoti' seeds to plant 1.5 hectares. The first fruits can be harvested after two months, earlier than any other variety. Jajang said he can produce 60 tons of tomato fruits per ha, 25% higher compared to previous varieties.

Extension services and technology transfer

The dissemination of technical and marketing information demonstrating the benefits of improved seed varieties is critical to adoption. Often private seed companies together with government agencies organize this effort. Although regional differences in cultures and development stages have resulted in some variations, the basic approach to extension is similar: assess current farming practices, come up with practical recommendations, and disseminate them through demo-fields, trainings and farmer field visits. The objective of these interventions is to improve the profitability of vegetable production for poor small-scale farmers by promoting improved market-focused production techniques.

East-West Seed focuses on equipping farmers with technical and managerial capability for vegetable farming under a tropical climate. Over the last three decades, advisory services and technology transfer have improved the profitability of vegetable production for farmers by promoting access to technical know-how, developing embedded services, and improving the availability and choice of inputs.

Philippines

East-West Seed extension activities started with the establishment of the technology transfer department in the Philippines in 2000, which initially focused on training smallholder farmers (one hectare or less) in off-season vegetable production. Demonstration farms were set up where a six-month Farmers Field School on off-season vegetable production was conducted. On-field training and technical advice on soil fertility management, vegetable entomology, and crop nutrition was given to farmers and government extension workers. Intermediaries such as national government agencies, local government units, NGOs and international development organizations shared the cost. East-West Seed's effort was soon widely recognized and drawn on by government agencies and development organizations.

Cambodia

In 2009, technology transfer activities started in Cambodia, where a local team was empowered to support farmers with improved vegetable production techniques. A public-private partnership was established with the Regional Economic Development Programme, a Cambodian development programme co-financed by the German Federal Ministry for Economic Cooperation and Development and implemented with technical assistance support by Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ). As part of the RED programme, the Department of Agriculture is the main partner working directly with East-West Seed.

Myanmar

East-West Seed has a public-private partnership with Swisscontact (The Swiss Foundation for Technical Cooperation) to implement technology transfer activities in Southern Shan and the Nay Pyi Taw area. It also collaborates with academia through joint research with Yezin University and the establishment of a small demonstration farm for students in the Hlegu campus.

Indonesia

The company plays an active role in the 'Veg Impact' program by the Dutch-Indonesian governments, aimed at improving vegetable production and marketing for small farmers in Indonesia through market linkages and knowledge sharing. It trains a select group of farmers in the five largest vegetable production areas of Indonesia, who then disseminate good agricultural practices to their communities.

CONCLUSION

- Plant breeding has come a long way in producing better-performing seed varieties that have higher yields, better disease resistance, and preferred consumer traits. The private sector supports the continuous improvement of vegetable varieties by investing heavily in R&D and innovation.

- Further, the private sector is instrumental in linking food demand and supply, by integrating vegetable farming systems into the value chain through a market-based approach.

- Extension activities are a strong driving force for opening and sustaining new markets. They improve the profitability of vegetable production for small-scale farmers. By taking advantage of new market opportunities, farmers realise better yields and gain higher income.

- Drawing from the experience of smallholder vegetable farmers in the Philippines, Cambodia, Myanmar and Indonesia, the adoption of hybrid seed varieties alongside better farm practices has vastly improved the livelihood of farmers. In the overall picture, this promotes the attainment of rural development and food security goals.

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Table 1. Quality Seed Multiplier: Comparison of profitability between local and hybrid bitter gourd in Vietnam (first introduction year 2001)

Variable	Before introduction	After introduction
Seed Cost (VND/ha)	VND 1,000,000	VND 4,480,000
Marketable Yield (kg/ha)	18,000kg	40,000kg
Farm gate price (VND/kg)	1,200	1,500
Total Gross Revenue	21,600,000	60,000,000

Quality Seed Multiplier = 11

For every additional VND spent on hybrid bitter gourd seeds, the farmer earns an additional VND 11 revenue compared to using the old variety.

Vegetable production in Asia: Innovation, involvement, income and impact

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ABSTRACT

Vegetables are an important non-staple food and provide unique nutritious elements in our diets. The FAO projections of food demand indicate that demand for pulses, potatoes, oilseeds, and fruit and vegetables is projected to grow more rapidly than demand for cereals, and FAO land use projections rely on greatly accelerated yield growth for many of these secondary crops. The sector is constrained by widespread fragmentation in the supply chain, low productivity levels, and large postharvest losses arising out of inadequate storage, cold chain and transport infrastructure, logistics and supply chain management. Asia should demonstrate that it can produce clean, safe and nutritious food from a clean environment. It is also the region that holds the greatest prospects for this. Achieving high quality levels is essential for continued growth of domestic vegetable consumption and gaining a competitive advantage in export markets. Vegetable production systems can be broadly categorized into five groups: a) wild collection and homestead vegetable production system; b) vegetable production systems in the crop field adjacent to homestead areas; c) vegetable production systems in rice growing fields; d) peri-urban vegetable production system; and e) urban vegetable production systems. Simultaneous efforts both in terms of policy direction and technology development and adoption are required for all five production systems to ensure vibrant and sustainable development in this sector. Sustainable crop production intensification by adopting “Save and Grow” approach could be a viable option to grow safe and quality vegetables under all five production systems. Innovation, involvement, income and impact will determine future contribution of vegetables in achieving food and nutrition security of the millions of people of this region.

Keywords

Production system, policy harmonization, research, value chain approach, environment

INTRODUCTION

The Food and Agriculture Organization of the United Nations (FAO) attaches top priority to nutrition security of people as malnutrition and undernourishment persist at very high levels, despite substantial resources invested in the past to ameliorate these conditions. This brought to the fore a renewed focus on fighting malnutrition and undernourishment in a more concerted manner to bring down the prevalence of these scourges in a shorter time frame. In its recently concluded 32nd APRC meeting (March 2014), FAO has warned that governments in Asia and the Pacific should take some major, fundamental decisions to increase their food production and address undernourishment. While the Asia-Pacific region has achieved laudable progress in reducing undernutrition, it still holds more hungry people than all other regions of the world combined – more than 550 million. The FAO projections of food demand indicate that the demand for pulses, potatoes, oilseeds, and fruit and vegetables is set to grow faster than the demand for cereals, and FAO land use projections rely on greatly accelerated yield growth for many of these secondary crops.

The emphasis on consumption of more vegetables and thus making the diets healthy and balanced has drawn renewed focus across the globe. Although it is a common knowledge since ancestral times, a number of factors hindered increasing consumption of vegetables to the desired level, in some countries growth in vegetable production recorded a downward trend. FAO/WHO recommended 200 g of vegetable consumption per day per capita (excluding potatoes). Current growth rates of domestic production of vegetables fall far too short of meeting the minimum requirements of vegetables. As a result, concentration of undernourished people, particularly women and children in these countries is extremely high. Increasing the availability of vegetables and promoting the access of low-income and vulnerable people to consumption of vegetables at enhanced levels are critical to bringing changes in the predominantly carbohydrate-based diets causing undernourishment and malnutrition in rural areas.

This profoundly impacts food security, a perennial struggle in which many poor households in Asia and the Pacific region find themselves locked in. In spite of concerted efforts since the late 1960s to boost domestic supplies of food, latest available figures indicate that there are still gaps and achieving the target of MDG-1 by 2015 will require more focused and concerted efforts and investment of resources. As the 2015 timeline is drawing closer, the reality is dawning on policy makers both in the international community and national governments that the issue of food security in the post-2015 agenda will have to be addressed with innovative approaches and in a broader context.

The future food production scenario should focus more on the production of nutritious foods rather than staples. The shift in emphasis, as we know, is driven by the need to urgently redress persistence of malnutrition and undernourishment caused by a singularly focused attention on staple production over the last 50 years. The Asia-Pacific region holds the highest concentration of malnourished and undernourished people.

One of the options to improve the situation is to diversify food basket of these people, which has to come mainly through crop diversification by diversifying their farming systems. The challenge is how to include nutritious foods in their cropping and production systems. Among the nutritious foods vegetables come first. Apart from their nutrition value, they offer the advantages of rapid growth and short production cycle, suitability for cultivation in the homestead areas or adjacent to homestead areas, and scaling up women’s involvement in production and management to lower the cost of production as well as improve family nutrition. This approach holds the bright potential for increasing productivity and production of vegetables as well as raise family incomes with equity. The new technologies are improved seeds and innovative low-cost management practices, particularly those that allow off-season cultivation of winter vegetables to maximize profits by avoiding market gluts and depressed prices in the winter season.

Past and even current efforts to place excessive emphasis on production with poor technological base in isolation of considering other factors such as storage, marketing facilities, and consumers’ choices led to poor performance of this sector in the rural areas. It is widely believed that the value chain approach, where the entire issue is examined from plough to plate, could bring substantial changes in engaging rural women in vegetable sector development.

Among the factors that rank top in constraining expansion of vegetable production are low quantity of production, perishable nature, poor marketing facilities and lack of information on consumers' choice. To address those concerns, producer and consumer groups and forums can be formed. Creation of such groups in production areas will enhance farmers' knowledge as also their bargaining power and voices that will contribute to increasing not only production and productivity of vegetables but also their incomes.

The main limitation of the past approaches was the unilateral dimension of the conceptual framework to address the issue of food security. It is evident in steady increases in production of staple food crops to the extent that majority of countries in the region feel comfortable with the levels of domestic production attained to meet consumer demand for staple food. Undoubtedly, it has significantly contributed to enhancing the food security status in this region. However, in the course of attaining this objective the importance of nutrition security was grossly ignored. Now time has come to revisit the framework of food security in its multilateral dimension.

It means diversification of diets by expanding the food basket with other nutritious foods that can be produced locally and creating awareness among people about the need to consume more of these foods. There will also be a consumer-driven demand for diet diversity as most countries in the Asia-Pacific region are in the midst of expansion of their economies, rapid growth of per capita GDP, frenzied pace of urbanization, and more people joining the rank of middle class who look for food beyond coarse grains, roots, and tubers. One of the easiest, cost-effective, and affordable approaches for diet diversification is inclusion of a variety of nutritionally-rich vegetables in the food basket and the region is home to a wide variety of vegetables that can be grown year-round in all types of agro-ecological environments.

This sets the stage for more focused and concerted efforts and approaches to rapidly increase production of vegetables. Given the pressure on arable lands to sustain production of staple food crops at current and anticipated rates, it is worth examining other options for growing vegetables in addition to existing cropping patterns in sequence with staple crops. The strategy of promoting balanced diets must envisage advocacy for planting various types of vegetables to bring nutritional balance in food systems. Production of different types of vegetables also reduces the risk of crop losses. Due to their short growing season, they can escape from adverse impacts of natural calamities and thus can be used to adapt crop cultivation to changing climate. The value chain (from plough to plate) mechanism will be adopted by following the sustainable crop production intensification (SCPI) approach. It means the system will be based on environmental sound footings to bring less damage to the environment.

METHODS

This paper draws on data and findings of several FAO implemented projects related to promotion of vegetables in different countries in Asia (Philippines, Mongolia, Bangladesh, Pakistan, Democratic Republic of Korea, Myanmar and Cambodia). Current production scenario and future needs are explained by using data retrieved from the FAOSTAT database.

RESULTS

Table 1 shows the share of selected countries in global production of vegetables. The largest vegetable producer in the world is China. In 2010-11 the country produced

47% of world vegetables followed by India with 14%. The increase is attributed to its technological progress in vegetable cultivation and processing.

Table 1. Share of different countries in global vegetable production 2010-2011

Sl. no.	Country	Share (%)
1.	China	47
2.	India	14
3.	USA	4
4.	Turkey	3
5.	Egypt	2
6.	Iran	2
7.	Italy	1
8.	Russia	1
9.	Spain	1
10.	Mexico	1
11.	Others	24
	Total	100

China has made substantial progress in vegetable cultivation techniques, involving species resources collecting and research, seed cultivation through genetic engineering, and diseases and pests prevention. With China's grain production no longer under heavy government protection, many Chinese farmers are switching over to production of more profitable high- value commodities, such as vegetables. China has adopted policies that emphasize quality and safety issues, which may facilitate increase in import of vegetables from this country and hence increase in its production capacity. India, in contrast, faces the challenge of substantially increasing production of vegetables to meet the demand. Having almost similar size of population, China's vegetables production is three times higher than that of India. This requires a significant policy-level thrust to boost India's vegetable sector development in order to reduce the number of undernourished and malnourished people in the country.

Each region/country has its own opportunities and limitations in increasing production of vegetables.

Table 2. Vegetable production share by region (1992-2012)

Region	Total production (million tons)	%age
Asia	567	71.71
Europe	93	11.72
Americas	74	9.41
Africa	53	6.75
Oceana	3	0.42

Source: FAOSTAT 2014

As evident from Table 2, Asia is still the major hub of vegetable production in the world contributing around 72% of global production. This is explained by wide diversity in terms of production and productivity of vegetables that exists within the countries of the region. The diversity of climate ranging from tropical, sub-tropical to temperate makes it possible to grow year-round a wide variety of vegetable crops in Asia. On average (1992-2012), Asia alone produced 72% of global vegetables, whereas Europe contributed only 12% of the global share. This highlights the critical role Asia will continue to play in supplying vegetables not only to meet domestic demand but also for exports. It is also important that all regions of the world give equal priority to increasing the production and productivity of vegetables so that the global demand for vegetables can be fully met in 2050.

Table 3. Largest vegetable producing countries

Vegetable	Largest producer	Second largest producers
Cabbage	China	India
Potato	China	India
Brinjal	China	India
Onion and garlic	China	India
Cauliflowers and Broccoli	China	India
Tomato	China	USA
Spinach	China	USA
Carrot	China	Russia
Cucumber	China	Iran

Asian countries rank top in production of a number of widely consumed popular vegetables. China leads the world in production of tomato, potato, brinjal, cabbage, onion and garlic, cauliflower and broccoli, spinach, carrot and cucumber. India is the second largest producer of many of these vegetable crops (Table 3).

Of all the regions of the world, Asia experienced faster growth in annual per capita supply of vegetables between 1979 and 2011. Asia's annual supply of vegetables rose from 56.6 kg/capita in 1979, ranking next to Europe, North and Central America, and Oceania, to 195.2 kg/capita in 2011, the highest in the world (Table 4). Much of this success was due to impressive growth of vegetable production achieved in China.

Table 4. Supply of vegetables per capita, by region (kg/capita/year)

Region	1979	2000	2011
World	68.1	101.9	132.0
Africa	45.4	52.1	68.6
North and Central America	88.7	98.3	87.5
South America	43.2	47.8	64.0
Asia	**56.6**	**116.2**	**195.2**
Europe	110.9	112.5	125.4
Oceana	71.8	98.7	90.4

But the picture becomes less rosy for Asia when the focus shifts from per capita supply to actual consumption of vegetables. Taking into account the loss and waste of food in the supply chain (Table 5), per capita consumption of vegetables falls below the half of production considering 44% loss for fruits and vegetables.

Table 5. Loss and waste of foods by KCAL and weight

Commodity	Loss and waste of KCAL(%)	Loss and waste by weight (%)
Cereals	53	19
Roots and tubers	14	20
Fruits and vegetables	13	44
Oilseeds and pulses	8	3
Meat	7	4
Milk	4	8
Fish and seafood	1	2
Total	100	100

It means per capita consumption is still around 100 g/day as against 200 g/day recommended by FAO/WHO for vegetables. Therefore, despite contributing 72% to global production of vegetables, Asia's vegetable production needs to be doubled to meet the FAO/WHO-recommended levels, provided access is ensured. It is a big challenge for Asian countries.

In this context, it is important to look at the future demand for vegetables. FAO estimates show that the total demand of vegetables will be around 1.13 billion tons in 2050. It is 47% higher than 2005/07 base year. It also indicates that vegetables production in Asia should increase at 1.04% annually against the current growth rate of 0.78% (Table 6). It is worth mentioning that FAO estimates did not take into account possible impacts of climate changes on production of vegetables. Asian countries widely differ in their record of increasing the production of vegetables matching the growing demand.

Table 6. World demand of foods by 2050

Crops	Production in 2005/07	Demand in 2050	Annual growth rate (%)
Cereals (billion tons)	2.2	3.2	45 (1%)
Meats (tons)	257 894 736	453 895 737	76 (1.69%)
Roots and Tubers (billion tons)	1.11	1.83	64 (1.42%)
Soybeans (tons)	217 721 519	389 721 519	79 (1.76%)
Fruits (tons)	630 882 353	1 159 882 353	68 (1.45%)
Vegetables (tons)	776 595 745	1 131 595 745	47 (1.04%)

Source: FAO

Total annual production of vegetables in countries, member of ASEAN, increased from 30.18 to 33.80 million tons over the period 2003-2012 (Table 7). Obviously, it cannot be considered as significant growth over a decade. Most of this growth came mainly from two countries, i.e. Indonesia and Viet Nam followed by Myanmar and the Philippines. Production stagnated in Thailand. Growth in production of vegetables in Cambodia and Lao PDR was among the slowest among ASEAN countries.

Table 7. Vegetable production in ASEAN countries in last decade (million tons)

Country	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	Average production (2003-12)
Brunei	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Cambodia	0.47	0.50	0.48	0.48	0.49	0.46	0.54	0.53	0.62	0.63	0.52
Indonesia	7.78	8.17	8.26	8.57	8.48	8.89	9.62	9.78	10.52	10.51	9.06
Laos PDR	0.78	0.75	0.83	0.75	0.84	0.64	0.85	0.90	0.95	1.04	0.83
Malaysia	0.55	0.60	0.64	0.66	0.67	0.72	0.87	1.20	1.23	1.22	0.84
Myanmar	3.84	4.14	3.94	4.29	4.28	4.46	4.52	4.71	4.86	5.35	4.44
Philippines	5.44	5.14	5.16	5.21	5.97	5.90	5.81	6.30	6.20	6.32	5.74
Singapore	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Thailand	3.68	4.07	3.87	3.83	4.11	3.90	3.82	3.83	3.78	3.82	3.87
Viet Nam	7.60	7.80	8.01	7.82	8.04	7.72	9.04	8.98	9.01	9.44	8.35
Total	**30.18**										**33.80**

Source: FAOSTAT 2014

Average productivity of vegetable growing in ASEAN countries rose from 9.36 t/ha in 2003 to 10.67 t/ha in 2012 (Table 8). Malaysia registered highest growth in productivity followed by Singapore, Myanmar and Viet Nam. But higher productivity of Malaysia and Singapore did not have much impact on total production of vegetables in the region due to insignificant land areas where vegetables are produced. Average productivity in ASEAN countries is only half of the average of Asia. This suggests there is significant scope that can be exploited to increase aggregate production of vegetables in these countries.

Table 8. Vegetable productivity in ASEAN countries in last decade (t/ha)

Country	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	Average productivity (2003-12)
Brunei	1.19	1.13	1.23	1.59	1.68	1.71	1.73	1.63	1.74	1.83	1.55
Cambodia	6.02	6.31	6.25	6.11	6.24	5.92	6.08	5.74	6.49	6.54	6.17
Indonesia	8.63	8.58	8.80	8.67	8.67	9.07	9.18	9.04	10.02	9.91	9.06
Laos PDR	5.94	6.23	8.34	7.78	8.62	6.57	6.50	6.37	6.47	7.50	7.03
Malaysia	15.75	16.92	19.40	18.45	18.57	19.33	17.83	20.57	21.08	20.42	18.83
Myanmar	12.81	13.83	12.86	13.15	13.06	13.14	13.31	13.43	13.52	14.04	13.32
Philippines	8.85	8.85	8.90	8.43	8.78	8.74	8.66	8.77	8.69	8.70	8.74
Singapore	16.79	16.88	16.80	17.80	16.75	16.84	17.29	19.53	19.77	17.80	17.63
Thailand	5.88	6.92	7.49	7.61	7.70	7.55	7.53	7.42	7.39	7.37	7.29
Viet Nam	11.72	11.79	11.58	11.62	11.80	11.88	11.93	12.41	11.79	12.55	11.10
	9.36									**10.67**	**10.07**

Source: FAOSTAT 2014

In contrast to ASEAN countries, South Asian countries, members of SAARC, recorded more impressive growth in vegetable production. Between 2003 and 2012 aggregate production of vegetables in these countries increased from 88.77 to 101.15 million tons with an annual growth of 1.3 million tons.

Table 9. Vegetable production in SAARC countries in last decade (million tons)

Country	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	Average production (2003-12)
Afghanistan	0.90	0.72	1.04	1.12	1.18	1.15	1.36	1.26	0.93	0.99	1.07
Bhutan	0.01	0.01	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.03	0.02
Bangladesh	1.83	2.10	2.57	2.91	3.20	3.47	3.42	3.69	3.97	4.15	3.13
India	79.04	65.56	71.45	81.88	87.98	91.73	90.63	100.40	107.38	109.14	88.52
Maldives	0.03	0.03	0.03	0.03	0.02	0.03	0.03	0.03	0.03	0.03	0.03
Nepal	1.84	1.93	2.11	2.24	2.38	2.61	2.82	3.08	3.28	3.38	2.57
Pakistan	4.57	4.74	5.01	5.43	5.17	5.48	5.27	5.06	5.33	5.09	5.12
Sri Lanka	0.53	0.56	0.64	0.67	0.72	0.72	0.73	0.73	0.76	0.82	0.69
Total	**88.75**										**101.15**

Source: FAOSTAT 2014

This growth, though remarkable, was still inadequate to increase per caput consumption of vegetables given the total size of the population in these countries. But it also illustrates the commendable efforts these countries invested in ramping up vegetable production given little scope of area expansion. Bangladesh's record is particularly impressive – the country more than doubled the production of vegetables during this period and also sustained significant growth in rice production, its staple food, from almost the same net cropped area. While ASEAN countries still have considerable opportunity to increase production through area expansion, the SAARC countries confront the challenge of achieving it primarily through productivity gains.

As evident from Table 10, gains in productivity of vegetables in South Asian countries were slower than they were in ASEAN countries. Average productivity in SAARC countries rose from 8.42 t/ha in 2003 to 9.53 t/ha in 2012.

Table 10. Vegetable productivity in SAARC countries in last decade (t/ha)

Country	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	Average productivity (2003-12)
Afghanistan	8.61	11.44	9.44	9.88	10.42	10.14	10.25	9.72	9.24	9.36	9.85
Bhutan	2.84	3.73	4.19	4.19	3.71	3.22	3.45	3.08	2.75	2.84	3.40
Bangladesh	5.87	6.09	6.59	6.88	7.06	7.28	7.38	7.55	7.86	8.01	7.06
India	11.02	12.14	12.23	12.93	13.41	13.49	13.43	13.83	14.23	14.54	13.13
Nepal	10.59	10.72	11.16	11.27	11.43	11.35	11.91	12.45	12.78	13.08	11.67
Pakistan	13.00	12.93	13.06	12.90	12.74	12.61	12.70	12.64	12.58	12.50	12.77
Sri Lanka	7.00	8.03	7.95	8.30	9.15	9.22	9.51	9.66	9.71	10.00	8.85
	8.42										**9.53**

Source: FAOSTAT 2014

India, Nepal and Pakistan registered yields higher than 10 t/ha and in all other countries yields fluctuated below 10 t/ha level which is significantly low given the size of the population of these countries. However, growth rate in productivity is higher in South Asian countries than in Southeast Asian countries, indicating that it can be increased further provided that appropriate policies and other supports are in place and functional.

The potential of Asia's vegetable production and productivity is best illustrated by phenomenal successes achieved in China, Japan, and the Republic of Korea.

Table 11. Per capita vegetable production in China

Year	Population (x 1000)	Vegetable production (tons)	Vegetable production (kg/caput/year)
2001	1 271 850	383 860 655	301.8
2002	1 280 400	413 421 107	322.9
2003	1 288 400	419 710 690	325.8
2004	1 296 075	427 799 333	330.1
2005	1 303 720	443 829 146	340.4
2006	1 311 020	462 066 856	352.4
2007	1 317 885	487 077 193	369.6
2008	1 324 655	512 025 390	386.5
2009	1 331 260	522 679 815	392.6
2010	1 337 705	545 437 622	407.7
2011	1 344 130	565 397 572	420.6

Per capita vegetable production in China increased from 301.8 kg/day in 2003 to 420.6 kg/day in 2012 (Table 11). This had profound impact on the entire scenario of vegetable production at global level. In China more emphasis is being placed on quality and safety aspects in order to increase the volume of vegetable export. In all other developing countries of Asia, concerns for increasing vegetable production still override those for quality and safety.

Table 12. Vegetable production in China, Republic of Korea and Japan, 2003-2012 (million tons)

Country	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	Average Production (2003-12)
China	417	425	441	459	485	509	520	543	560	574	493.3
Japan	12.10	11.56	11.75	11.72	11.84	11.85	11.67	11.08	11.18	11.35	11.61
Republic of Korea	11.10	11.84	10.97	11.31	10.72	11.27	11.27	9.87	11.18	9.93	10.95

Source: FAOSTAT 2014

China increased production of vegetables from 417 million tons in 2003 to 574 million tons in 2012 with an average of 493 million tons over 2003-2012 (Table 12). In contrast, there was a conspicuous trend toward reduction of vegetable production in Japan and the Republic of Korea. While China recorded a consistent growth in vegetable productivity over 2003-2012, productivity in Japan, albeit higher than in China, stagnated during the same period. In Korea, productivity increased from 30.43 t/ha in 2003 to 36.18 t/ha in 2012, despite a sharp decline in aggregate production, suggesting decrease in area under vegetables (Table 13). As a result, there is increasing likelihood that these countries will be more reliant on import, unless necessary steps are taken to reverse it.

Table 13. Vegetable productivity in China, Republic of Korea and Japan, 2003-2012 (t/ha)

Country	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	Average productivity (2003-12)
China	20.67	20.45	20.61	21.14	21.88	23.05	23.02	23.12	23.12	23.37	22.04
Japan	27.99	27.60	27.68	28.86	29.40	29.47	28.75	27.45	27.98	27.94	28.31
Republic of Korea	30.43	31.86	33.32	34.45	35.07	36.73	38.76	35.83	38.16	36.18	35.08

Source: FAOSTAT 2014

Structural Changes in Vegetable Production Systems in Asia

Vegetable production systems in developing countries are undergoing structural changes. A number of factors are driving this process. This includes, among others, availability of new technologies including hybrid seeds and short duration varieties and the emergence of private sector (both national and international) in seed business. Short duration varieties and hybrid seeds of vegetables contribute to making existing cropping patterns more productive and profitable. These innovations also helped in creating space for vegetable crops to be included as components of cereal-based cropping patterns/rotation. This process led to identification of five very clearly distinguishable vegetable production systems in developing countries of Asia including China.

1. Wild collection and homestead vegetable production system: This age-old and most primitive form of production system encompasses both collection in the wild and production on and around homesteads. Wild collection is still in practice in different parts of this region, although the frequency of harvesting is dwindling with the passage of time. This system helped domesticate many vegetables in the world. But it is widely documented that some wild vegetable species disappeared due to pressure to convert fallow land into arable lands during the Green Revolution. Efforts need to be undertaken to preserve and conserve the available wild vegetables for current and future uses. These are precious genetic resources because they carry many important genes that may have great value for contemporary vegetable breeding programs and also for enhancing food and nutrition security of rural people through consumption. But in the era of convenience and fast foods, these vegetables do not appeal to a large section of young consumers owing to bitter taste and traditional method of cooking. Recent addition to indigenous vegetables is vegetables available in the sea.

Sea vegetables offer one of the broadest ranges of minerals in any food, containing virtually all the minerals found in the ocean. Western cultures are only recently beginning to enjoy the taste and nutritional value of sea vegetables, often referred as seaweeds, which has been a staple of the Japanese diets for centuries. Sea vegetables can be found growing both in the marine salt waters as well as in fresh water lakes and seas. They commonly grow on coral reefs or in rocky landscapes and can grow at great depths. There are thousands of types of sea vegetables, which are classified into categories by color, known either as brown, red or green sea vegetables. Although not all sea vegetables that exist are presently consumed, a wide range of sea vegetables are currently enjoyed as foods. While in developed countries their use is high, it is almost negligible in the developing countries. Around 49 edible sea vegetables have been identified that can contribute to food and nutrition security of poor people and particularly those who are living in the coastal belt of the country. This production system is poised to play a greater role in future as a source of nutritious food. With supportive government policies in place, these can be an enormous source food for any country.

2. Vegetable production systems in crop fields adjacent to homestead areas: This production system expanded during the Green Revolution that saw progressive converting of main cropland into rice fields and production of vegetables from traditional homestead areas failing to meet the growing demand for vegetables for household consumption. Land scarcity also facilitated the promotion of multiple cropping in areas adjacent to homesteads. In this system, the choice of crops to be planted and the area to be covered under particular crops depend on family needs, preference and availability of seeds at household levels and availability of other inputs required to grow vegetables. Lately, farmers plant also seeds of high yielding varieties knowing that their productivity is much higher than the local ones. This is the area where we can see most judicious use of lands with diversified crops and women's intelligence in farming. All family members work together in the field during afternoon time until sunset down. They irrigate fields using pond water either mechanically or through motorized machines. Male members of the family help during irrigation. Negligible use of inorganic fertilizers and non-use of any harmful chemicals to control pest and diseases are the remarkable features of this production system. Farmers generally solve their production-related problems in discussion with neighboring farmers and they also share tools and techniques for increasing production and productivity. It is widely believed that the concept of Farmers Field Schools originated from here. Their interactions increased gradually since the adoption of seeds of high yielding varieties focusing on issues related with pest and diseases. This production field is the life market of vegetables of the farmers. They harvest vegetables almost every day and due to proximity it is easy for them. They first harvest if any plant they found is attacked by either diseases or pests. In this way they always keep field free from pest and diseases. Space intensity is very high in such production systems. They share and exchange their harvested produces with neighbors and among the members of kinship. Sometimes, they also share their cooked foods with others. This production system is sustainable and reasonably productive without inflicting any major harm to environment.

3. Vegetable production systems in crop fields: This production system is a driving force in increasing vegetable production in any country. It is more dynamic and vibrant production system compared with others. Farmers always have intention to include more crops in cropping patterns/rotation and also to include more productive variety of crops in order to increase productivity of cropping pattern/rotations. In selecting crops they give more emphasis on per day productivity than productivity of any individual crop or cropping pattern. The advent of hybrid seeds of most vegetable crops, their short duration and also renewal of varieties at regular interval and availability of seeds of new varieties through private seed companies played key role in promoting vegetable production in Asian countries. This was facilitated by development of short duration varieties of cereal crops that allowed adjustment in developing very dynamic cropping pattern/rotation.

In order for this system to expand further, efforts need to be focused on providing farmers with market information at regular intervals. This will help them make right selection of crops taking in view the market demand. Besides adoption of modern varieties, farmers are also keen on adopting associated management technologies to maximize their productivity. The emergence of private seed sector is facilitating promotion of improved technologies in farmers' fields. From the farmers' point of view, the key constraints to sustainability and profitability of this production system are high input costs, production instability due to natural hazards, investment crisis, low market prices and involvement of middlemen in the marketing chain. Environmental sustainability doesn't feature prominently in the list of farmer's concerns. They are more interested in short-run financial returns rather than in managing long-term damages that intensive cropping patterns cause to the environment by removing significant amount of nutrients from the soil that are not adequately replenished. The challenge lies in educating farmers to use balanced doses of fertilizers and scheduling their application according to plant growth needs.

4. Peri-urban vegetable production system: This is a relatively new phenomenon in developing countries. It began since the early 1990s when most developing countries initiated structural reform of their economies by opening up to market forces and privatizing the agricultural input supply chain. This production system is more advanced encompassing adoption of modern technologies, mechanization, labor-intensive practices and value addition to the produces. It mainly relies on market (urban, rural and export). Quickly perishable vegetables also can be grown in this system because of market proximity. More recently, the system is playing significant role in supplying fresh vegetables to urban populations which are growing at considerably high rates than even expected. Labor involvement here is also high because of short cycle of crop life and value addition. Temporalities are the main concern for sustaining this production system as land scarcity in peri-urban areas is increasing because of expansion of urban settings. The flipside of this production system is that it triggers environmental pollution caused by excessive use of chemicals making the produces less safe and of poor quality. Available technologies are more suited to growing vegetables in the winter season. This system has the potential to produce more dividends if it can be expanded in summer and monsoon periods.

5. Urban vegetable production system: Vegetables are becoming increasingly important in diets of Asia's urban populations and the demand for vegetables in these countries is soaring. The pertinent question is how farmers can take advantage of this trend and increase their income. It is based on highly sophisticated technologies and originated from developed countries. The main purpose is not bulk production but production and uses of fresh vegetable products, mainly leafy vegetables and tomato. It is gaining popularity in developed countries and there are attempts to adopt this technology in developing countries. However, its expansion in developing countries is slow. Thanks to invention of new technologies that require less space, such as vertical farming, soilless cultivation, hydro-phonics and other multiple technologies, this production system can be widely practiced in developing countries if governments provide conducive policies and other supports for their quick adoption. Inputs and energy costs are very high here and it may create problems for the producers of developing countries. It is relatively less polluting production systems with quick return and ensured market. A major advantage is the use maximum use of family labor. A comparison of the five vegetable production systems is listed in Table 14.

Table 14. Vegetable production systems in Asia

Production System	Main distinguishing characteristics	Major advantage	Limitations
1. Wild collection and homestead vegetable production system	-rely on indigenous technologies -adapted to local conditions -use of farm inputs - women and family labor -stable production system -knowledge on production systems is reasonably good -less disturbance to ecosystems -stability in production	-maximize crop biodiversity -depositor of local germplasm -production diversity	-low productivity - could not meet family demand -no value addition -part time jobs of family members
2. Vegetable production system in the crop field adjacent to homestead	-use of seeds of both local and improved varieties -surface water irrigation -use of mainly organic fertilizers and other natural resources as production inputs - family farming approach in terms of labor use -production knowledge is reasonably good -less production risks and environmental consequences	-wide range of diversity in selection of seeds and crop mixing -production expansion to meet family demand - widely practiced inter-cropping/multiple cropping	-no value addition -part time jobs of family
3. Vegetables production system in crop fields	-adoption of seeds modern varieties and management technologies - external input based production systems - use of mainly hired labor -productivity is reasonably good and at the level of national average -support from extension services (both public & private) in adoption of modern technologies -production is not stable -use of chemicals to control disease and pests -production risk and environmental consequences are high	-select crops with low perishable products -bulk of the vegetables come from this system -marketing of surplus production -vegetable production is a component of cropping patterns -vegetable crop selection varies from year to year	-marketing risk is high -little value addition -timely availability of inputs mainly inorganic fertilizers
4. Peri-urban vegetable production system	-semi-intensive vegetable production systems -modern technology -selection of crops depends largely on market -high external inputs and energy costs - production risk and environmental consequences are considerably high	-produce only for market -productivity is high -higher value addition -partial mechanization of production system	-small-scale farmers in peri-urban areas try to maximize outputs from small plots of land by overuse of harmful chemicals - temporalities -market vulnerability
5. Urban vegetable production system	-use of highly sophisticated technologies -production of crops dominated by leafy vegetables -use of mainly family labors and hired technicians -high input and energy costs -less exposure to severity of natural disasters and climate changes	-quick return from investment -better marketing facilities -very high value addition	-heavy investment -less volume of production

AGENDA BEYOND 2015

Innovation

Like all other sectors of economy, innovation, creativity and knowledge management will be the deciding factors in the development of the vegetable sector in future. Development of varieties suitable for specific agro-climatic conditions, their adoption and replacement at regular intervals offer the most promising option for increasing productivity and production. This would require robust national vegetable breeding programs funded by governments with support from international organizations. Such programs should include vibrant pre-breeding programs with application of advanced tools and technologies such as DNA sequencing, functional genomics, bioinformatics, and data management. Breeding programs should focus on developing varieties that will be not only highly productive but also should consume less external inputs. The national research system should engage in development of climate smart and climate resilient green technologies to cope with the impacts of climate change in agriculture. Policy and strategy harmonization in the agriculture sector will also require development of rice-based cropping pattern/rotations with vegetable crops as component.

Involvement

In the world of more than 500 million smallholder farmers, 86% of total farming households in Asia belong to smallholders, running 1 to 2 ha of lands. These farmers are only responsible for their production, but they do not have any control over marketing and pricing of their produces. On an average, farmers receive only 35 to 45% of the retail price. The challenge is how to tilt this ratio in favor of smallholder farmers. This can be addressed by expanding the involvement of the whole family beyond production into the entire value chain encompassing input supply systems, access and knowledge on new technology, production, marketing, processing and utilization. It is time to critically review the failure of the concept on "linking production with marketing" first floated in the 1990s. On the other hand, the rise in involvement of middlemen in the marketing chain is further lessening farmers' income. Development of small-scale entrepreneurship is central for promoting involvement in the value chain.

The absence of strong local governments with adequate capacity for good governance, lack of market transparency and information are the major contributing factors to existing weaknesses in the value chain. The involvement of small-scale farmers in the value chain can be facilitated if the existing constraints on these two factors are alleviated. Additionally, farmers need to be involved not only with the market but also with local input supply systems and access to technology in response to market demand and transform their production systems into market-oriented ones. They have to choose variety and associated technologies having market demand. This process will play substantial roles in increasing their involvement in value chain and supply systems.

Income

Vegetable production base of small farmers should be linked with their sustainable income. Producers produce vegetables not only for consumption but also for earning incoming by selling their surplus production. However, on an average, poor producers get maximum 35 to 40% of the retail price for their produces. Besides, low farm gate price and perishability of extra production keep farmers' profitability at low level and in most cases, they incur loss for vegetable production. Adoption of modern technologies at regular intervals can reduce the cost of production. New opportunities arise thanks to advent of hybrid seeds and short duration varieties of different vegetable crops. It has also opened up windows for introducing vegetable crops in the cereal based cropping patterns that are dominant in this region. Here lies the main opportunity to raise income through vegetable production. To realize the income opportunity created through introduction of short duration variety, hybrid seeds and increasing harvest frequency, a key prerequisite will be enhancing farmers' knowledge base and resource availability. The first gap in the vegetable value chain starts just after production. This is the main gap in whole chain. Success of value chain approach will largely depend on how to minimize this gap. Farmers or producers should not be involved only in production but also in marketing and other activities of value chain. In addition to direct involvement they have to invest too. Their involvement in this process will help in increasing quality and safety of their produces. This would also help farmers increase their share of the retail price up to 50%.

Impact

The anticipated impact of increased vegetable production should be analyzed from two viewpoints. The first is an indication of positive impact on reducing the number of malnourished and undernourished people in this region. However, this process is very slow to produce expected results because it depends on increasing consumption of vegetables, where existing national efforts in this direction lag far behind those aimed at increasing production and productivity. In the production front, the expansion of cultivation of high value and quick-growing vegetables by the small and marginal farmers is silently transforming the rural economy. It is also expanding in urban and peri-urban areas. This has resulted in increase of consumption of vegetables both at household and national levels.

In order to continue this trend, further growth in vegetable production is necessary. This is vital because per capita consumption of vegetables in this region is still lower than the recommended one. Despite considerable successes achieved in vegetable production, the number of malnourished and undernourished people living in this part of the world is unacceptably high. This is exacerbated by poor buying capacity of rural poor people, seasonality in vegetable production and consumption of poor quality and less safe vegetables by them. To see the substantial impact of vegetable production on nutritional status and health outcomes, it has to be produced throughout the year in the crop fields. But impact is already visible on development of rural entrepreneurs with capacity to intervene in market functioning. Although, as research indicates, rich entrepreneurs mostly reap benefits from vegetable production owing to their greater capacity to exert control over market and local political powers. The challenge now lies in developing mechanisms and structures that allow enhanced involvement of individual farmers and groups of small farmers in the market mechanisms to make their vegetable production systems productive, sustainable and profitable.

The second point relates to environmental sustainability. High production and productivity are generally associated with higher uses of external inputs and also natural resources. For example, 35% of total fertilizers consumed in China go to vegetable cultivation. The amount of chemical fertilizers and pesticides consumed in China is steadily increasing. This highlights the need to steer efforts to increase production and productivity of vegetables in a direction that is more environmentally friendly.

CONCLUSIONS

1. Policy decisions to harmonize staple production and vegetable production polices so as to promote both groups of crops simultaneously will play a crucial role in attaining food and nutrition security. In the absence of such policy, the scourge of malnutrition and undernutrition will continue to persist in this region. Innovative policies and strategies are also urgently needed to implement science-based nutrient management practices to attain sustainable vegetable production while protecting natural and environmental resources.

2. Major emphasis should be given to redesigning vegetable pre-breeding and breeding systems to make them market-oriented and demand driven. Future research programs should be targeted based on production systems as mentioned above. Any general program on vegetable production in any country will be less effective.

3. In order to make the best use of the region's vast diversity in vegetable crop germplasm and its agroclimatic conditions congenial for year-round production of vegetables, efforts need to be focused on harnessing women's skills in safe production, promotion and utilization of indigenous vegetables and collection of sea vegetables in coastal zones.

4. Given the great prospects of Asia, it should take the lead in producing clean, safe, and nutritious vegetables to support continued growth of domestic vegetable consumption and gaining a competitive advantage in export markets.

5. Concerted efforts need to be undertaken to overcome widespread fragmentation in the supply chain, low productivity levels, and large postharvest losses arising out of inadequate storage, cold chain and transport infrastructure, logistics and supply chain management. This should be done in recognition that only organized and traditional retailing will ultimately drive the growth of the vegetable sector in the region.

6. Suitable approaches and institutional mechanisms must be in place to adequately address the contemporary challenge of producing more with less damage to the nature. FAO recently has come up with one such approach called "Save and Grow" that can be realized through implementation of Sustainable Crop Production Intensification (SCPI) programs at national levels. One of the easiest ways to adopt this approach is to establish Farmers Field Schools and encourage producers and consumers to attend class regularly to enhance their knowledge on SCPI and on other technologies.

7. A potential pathway to sustainable development is the development of permanent vegetable production systems with producers cooperating in producers' organizations, enabling them to work on a larger scale, produce larger volumes, introduce harvest date planning and quality control, and aim for the integration of production with marketing in a vegetable value chain. To make this happen,

taking into view consumers' food safety concerns and environmental sustainability, countries should take concerted steps to introduce and popularize Good Agricultural Practices in vegetable production.

8. In most countries of Asia, the private sector has emerged as one of the key drivers of change in the horticulture industry. Its involvement spans the entire value chain of vegetables making it more profitable for farmers, including smallholders, to invest in vegetable production. Private seed companies have broadened farmers' access to a wide range of high-yielding varieties of vegetables, including hybrids, that allowed rapid expansion of high-value vegetable and fruits across Asia. It has also allowed fitting vegetable crops in cropping patterns as well as in homestead areas, creating opportunity for women to be engaged in vegetable production with a positive impact on household nutrition. Governments should provide a favorable policy environment including financial incentives to promote private-sector led growth and expansion of the horticulture industry in Asia.

9. Government support should be at the core of interventions aimed at fostering sustainable growth in production and productivity of vegetables and eliminating loopholes leading to production vulnerability and instability in production. Government support must also be directed to creating an enabling environment that promotes public-private producer partnerships through a value chain approach.

10. In view of demographic changes occurring in rural areas due to migration of men to urban areas and abroad in search of more lucrative jobs, priority should be given to capacity development of women farmers to ensure their increased involvement in food production and marketing of mainly high value crops, which, among others, include vegetables. In addition to their own requirements, women have to produce more nutritious foods to meet the demand of rapidly increasing urban populations, but on more marginal lands using family labor.

New opportunities for integrated agricultural systems research in the Central Mekong region: Humidtropics - a CGIAR Research Program

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ABSTRACT

With 2.9 billion people on about 3 billion hectares of land, the tropical and subtropical areas of the world are critical to global food supplies and central to the maintenance of global biodiversity. Intensification of agricultural systems in these areas offers the potential for improving the incomes and nutrition of poor people, especially women and other vulnerable groups. Yet these areas are prone to rapid resource degradation such as soil degradation, depletion of water sources and loss of biodiversity.

To address the challenges to sustainable agricultural intensification in the humid tropics, the CGIAR (formerly the Consultative Group on International Agricultural Research) has initiated Humidtropics, a large international research program. It is one of 15 CGIAR Research Programs designed to address major global agricultural development challenges. But it is only one of three such programs adopting a systems perspective to focus on challenges typically facing resource-poor households. Humidtropics is a global initiative, working in tropical Africa, Asia and the Americas. Its vision is to develop agricultural innovations that integrate increased productivity, improved institutions and market performance, and sustainable management of the natural resource base. The program is led by the International Institute of Tropical Agriculture (IITA) and implemented in collaboration with 11 primary partner international agricultural and advanced research institutions including AVRDC – The World Vegetable Center and hundreds of other local partner organizations at various 'Action Areas' cross the globe.

In Asia, Humidtropics focuses on the Central Mekong region, including parts of Cambodia, Laos, Myanmar, Thailand, Vietnam and Yunnan province (China). This is a very dynamic and diverse region, with marked contrasts in topography, farming systems, markets, people and institutions. Although the region is currently experiencing rapid economic growth and has lifted millions of people out of poverty, there is much uncertainty associated with the complex interplay of the major drivers of change, all of which have impacts on agriculture, land use, and natural ecosystems, particularly in upland areas.

The program has taken a bottom-up approach to identify priorities for research and development. It has a strong focus on gender, as women generally play a key role in the smallholder production systems that characterize the humid tropics, but generally exert too little control over resources. It also has a strong focus on innovation processes and aims to be inclusive in all its research and development activities. This inclusiveness offers plenty of opportunities for various research organizations to link their research with Humidtropics and to form effective partnerships with international research centers and beyond. Together with other partners and stakeholders, AVRDC is committed to contributing to the specific

integrated research thrust on sustainable intensified food, multi-crop and horticultural systems. Emphasis is being placed on research that allows farm families to feed themselves, earn an income, and ensure that land remains productive for future generations.

Introduction to the new CGIAR Research Programs

The status of agricultural research as an international public good has been widely accepted since the Green Revolution of the 1960s and 1970s. The Consultative Group on International Agricultural Research (CGIAR), the world's largest partnership for agricultural research, evolved during that time;it has been described as a 'prime example of the promise, performance and perils of an international approach to providing international public goods' (Pingali and Kelly, 2007; Brooks, 2011). Established in 1971, the CGIAR grew out of widespread concern about famine in developing countries during the 1960s. By the early 1970s, the CGIAR had developed into a partnership of 64 members representing countries, international and regional organizations, and private foundations that support the work of 15 international research centers. The CGIAR research contributions in crop genetic improvement, pest management, natural resources management, and policy research have, in the aggregate, yielded strongly positive impacts relative to investment, and appear likely to continue doing so (see for example, Renkow and Byerlee 2010; Walker et al. 2010).

However, fragmented funding and declining financial support in the early to late 2000s challenged the CGIAR in delivering its mandate objectives. A meta-evaluation of the CGIAR at 31 years found that the CGIAR's productivity-enhancing research had sizeable impacts on reducing poverty by increasing employment, raising incomes, lowering food prices, and releasing land from cropping (Lele 2004). The author noted that the CGIAR was at that time less focused on enhancing agricultural productivity than it used to be, and concluded that the CGIAR's mix of activities reflected neither its comparative advantage nor its core competence. Although the CGIAR claimed to foster 'partnership' and 'consensus', new forms of exclusion and restriction were emerging within everyday practice, reproducing North-South inequalities and undermining the ability of the programs to respond to the needs of projected beneficiaries (Brooks, 2011). Lele (2004) also notes that the CGIAR had not responded sufficiently at the system level to the biotechnology revolution, the increasing importance of intellectual property rights, and the growth of private sector research, and proffered several recommendations to enhance the group's role in agricultural research into the future. The complex issues facing agricultural research for development require innovative approaches to research (Raitzer and Kelly 2008). No single research institution working alone can address the critically important issues of global climate change, agriculture, food security and rural poverty.

Not surprisingly, members of the CGIAR had for more than a decade recognized the challenges, and the proposed changes spurred it to redesign its institutional structure. The CGIAR endorsed a set of far-reaching reforms on 8 December 2009 that aimed to enhance the organization's ability to mobilize science for overcoming poverty and hunger and achieving ecosystem resilience in developing countries. The CGIAR brought together its 15 centers into a consortium to work on a series of research programs—financed from a central donor fund—to address agricultural issues in a more holistic fashion. The new reforms emphasize building strong relationships with key CGIAR stakeholders and partners, establishing effective oversight of the consortium's management, and cementing reforms with a performance management system to evaluate progress and verify results.

The agreed reforms should help boost funding for priority research areas, simplify organizational structures, reduce transaction costs, avoid duplication of efforts by competing centers, and give greater emphasis to jointly contributed development results through the new CGIAR Fund. The fund centralizes and harmonizes donor contributions to improve the quality and quantity of funding available, engenders greater financial stability, and reverses the trend toward restricted funding. It focuses research investment on priority areas and seeks to harmonize reporting requirements.

According to the CGIAR consortium, the reforms have transformed loose coalition of like-minded but separate research and donor organizations into a coherent, business-like whole that is greater than the sum of its parts (http://www.cgiar.org/who-we-are/). CGIAR operations are currently implemented through 15 CGIAR Research Programs led by members of the CGIAR Consortium and conducted in close collaboration with hundreds of partner organizations, including national and regional research institutes, civil society organizations, academia, and the private sector. This structure serves to better coordinate Research for Development efforts, enhance efficiencies, and encourage cooperation and collaboration with a focus on effective partnerships to achieve more development-oriented impact.

The new ambitious CGIAR Research Programs have been designed to tackle cross-cutting issues in agricultural development across the globe. These programs engage a cluster of several centers and other partners in tackling a myriad of issues to reduce rural poverty, increase food security, improve human health and nutrition, and ensure more sustainable management of natural resources.

Three of the new Research Programs aim to improve the productivity, profitability, sustainability, and resilience of entire farming systems. “Integrated Agricultural Systems for the Humid Tropics” (Humidtropics for short) is one of these. Humidtropics is a partnership to improve people’s lives in the humid and sub-humid tropics while enhancing the ecological integrity of natural resources. Funding for this 15-year program was approved in 2012.

The reformed CGIAR has created greater and more open linkages between consortium members and other national and international agricultural and advanced research institutes such as AVRDC – The World Vegetable Center. This has strengthened the CGIAR’s ability to share the knowledge it creates with farming communities around the world.

Overview, objectives and scope of Humidtropics

With 2.9 billion people on about 3 billion hectares of land, the tropical humid areas of the world are critical to global food supplies and central to the maintenance of global biodiversity. The region has a great wealth of untapped resources and potential. Within the agriculture sector, this potential is driven by rich agroecological resources of water, soils, flora, and fauna, etc., and by a population for whom agriculture is often a way of life and part of the culture. Agricultural systems span the humid and sub-humid tropics from integrated tree crop systems in West Africa and banana-based systems in East and Central Africa to densely populated systems in the Greater Mekong and vulnerable integrated crop-livestock systems in Central America and the Caribbean. Intensification of the major agricultural systems in these areas has the potential to improve the incomes and nutrition of poor people, especially women and other vulnerable groups. The humid and sub-humid tropics are critical to global supplies of basic foodstuffs and meeting future world food demand in the coming decades, and central to the maintenance of global biodiversity and the mitigation of greenhouse gases.

However, the agroecological stability of the humid tropics region is fragile, and carries a high risk of degradation such as loss of soil fertility and accelerated erosion; depletion of water sources; deforestation and loss of forest biodiversity; difficulty of adapted wetland plants to thrive under heat and drought conditions; and high incidence of pests and diseases in both production and postharvest situations. Social and economic limitations, such as poor access to markets and inputs, weak governance, and lack of information about efficient exploitation of the resource base via alternative production technologies tends to limit farmers' options. Past efforts to address these constraints by focusing on individual components and commodities either have not been very successful or are now facing a declining rate of impact, indicating a need for new integrated and diversified approaches to research for development in humid tropics systems. Managing risk and enhancing productivity through diversification and sustainable intensification is critical to securing and improving rural livelihoods.

The humid tropics thus have the biggest gap between the potential of ecological resources, productivity and livelihoods, and what actually exists today. The multifaceted constraints facing humid tropics agricultural systems call for broad-based, integrated approaches addressing the full range of household socioeconomic and biophysical constraints that farmers, traders and other actors in food value chains typically face. This requires innovative approaches that bring together all participants in the impact pathway, from primary producers to policymakers, to develop technologies, resource management strategies and institutional arrangements that strive to maintain species biodiversity; efficiently use water under rainfed production systems; reduce demand for water per crop area and livestock unit; improve water capture and storage; increase productivity per unit of land at farm and landscape scales; enhance the capacity of communities and the most marginalized actors within them; strengthen institutional arrangements to build resilience of livelihoods; and increase system productivity through diversification and sustainable intensification. Such approaches aim to identify, quantify and address the driving forces and interactions that shape and constrain farming systems and the management of natural resources (Lockeretz and Boehncke 2000; Roetter et al. 2000).

To realize tangible synergies between centers and partners, Humidtropics opts for a common approach towards research for development in well-defined Action Areas across tropical Africa, America, and Asia. This will allow comparison and learning, resulting not only in international public goods, but also in local and specific solutions. The choice of Action Areas within the Humidtropics is a crucial component of its future success, since these areas will determine the range of opportunities and interventions the program will invest in, and thus the applicability of the international public goods generated. Humidtropics also seeks large-scale impact and therefore requires synergies and strong partnerships in the Action Areas.

The overall goal for Humidtropics is to strengthen research and stimulate institutional innovation that increases economic and social returns among rural households adopting enhanced and sustained agricultural production and marketing strategies, while improving the biological and ecological integrity of their natural resource base (IITA and Partners 2012). To meet this goal, a program has been organized based onfour specific objectives: (i) to develop an integrated research program on sustainable intensification of rainfed smallholder farming systems in the humid and sub-humid tropics that leads to place-based Research for Development; (ii) to develop a network of Action Areas systematically comprising the variability of ecologies, agricultural potential, levels of market and other institutional development, population pressure and exposure to climate change that maximizes learning and raises potential for scaling-up and out; (iii) to undertake research on system-level interventions and scaling up to achieve impact on the four critical CGIAR system-level outcomes; (iv) to establish a platform for international public goods and global change research in response to agricultural challenges and associated impacts on tropical ecosystems and resources; and (v) to build capacity in scientific research, technical skills, and dissemination approaches related to systems integration and linking improvements to system-level outcomes.

Well-managed partnerships are critical for targeting research and delivering large-scale impacts in integrated agroecosystems through a systems-oriented program such as Humidtropics. Communication among partners and stakeholders plays a key role in new modes of working together—most importantly when farming communities become involved with setting goals for mainstreaming target gender and vulnerable groups, and when they interact with national research and extension systems, policy makers, international and regional organizations, advanced research institutes, civil society and non-governmental organizations, the private sector, and development agencies. The program proposes iterative and participatory design and implementation through the use of innovation platforms to ensure program priorities match those of stakeholders, and encourages support from policy makers. By offering opportunities for several organizations to be brought on board, the Humidtropics program expects to develop strong local and national support for sustainable activities and to achieve high impact on livelihoods and the environment in the identified global Action Areas with the initial three-year funding of approximately US$145 million.

Current primary partners and Action Areas of Humidtropics

Humidtropics is led by the International Institute of Tropical Agriculture (IITA). There are ten primary partner institutions—six CGIAR consortium members (i.e., International Livestock Research Institute (ILRI), International Water Management Institute (IWMI), International Potato Center (CIP), World Agroforestry Center (ICRAF), International Center for Tropical Agriculture (CIAT), and Bioversity International) and four advanced research institutes (AVRDC – The World Vegetable Center, *icipe* – African Insect Science for Food and Health, Forum for Agricultural Research in Africa (FARA), and Wageningen University and Research Center)—implementing the program.

Programmatically, Humidtropics is to be implemented in a three-phase work plan in three tiers of Action Areas over its 15-year duration. Tier 1 Action Areas are where the first program actions will occur. They typically contain ongoing research for development activities focusing on various components within specific farming systems and through cooperation between various centers and national research systems, backstopped by advanced research institutes. Tier 1 areas currently include: (i) West Africa Humid Lowlands, (ii) East and Central Africa Highlands, (iii) Central America and Caribbean, and (iv) Central Mekong (Fig. 1). Tier 2 Action Area stypically have ongoing research for development activities focused on one or a few system components promoted by a single center: West Africa Moist Savanna, Southern Africa Moist Savanna, Northern Andes Transect in tropical America, and Indonesia Humid Lowlands. Market linkages and value chain investments are usually minimal and dissemination partners commonly promote single-component technologies developed by that center. Activities in these Action Areas are scheduled for implementation from 2018 – 2023. Activities in Tier 3 (Central Africa Humid Lowlands, Southern Africa Humid Lowlands, and South Asian Sub-humid Lowlands) are planned for implementation from 2023–2027 as they presently have a very limited range of activities focused on specific, often isolated technologies without clear linkage to markets and with weak and disorganized dissemination channels.

Humidtropics is driven by the major global development challenges and the CGIAR system-level outcomes of (i) reducing rural poverty, (ii) increasing food security, (iii) improving nutrition and health, and (iv) sustainable management of natural resources. The intermediate development outcomes (IDOs) of Humidtropics are derived directly from the overall goal and the strategic objectives (SOs) of the program, defined as: SO 1 - Livelihoods improvement; SO 2 - Sustainable intensification; SO 3 - Gender empowerment; and SO 4 - systems innovation (IITA & Partners, 2013). Activities are currently being implemented in the Tier 1 Action Areas based on identified entry points and interventions that are specific to, and evaluated at, different levels: household, community, field site, action sites. The program logic is presented in Figure 1, where the strategic objectives are realized together in an interactive and integrated fashion. Each strategic objective relates directly to one or two intermediate development outcomes over the program's 15-year cycle. The realization of these intermediate development outcomes is then accomplished through a number of so-called Flagship Projects, which are seen as the main vehicles through which the research of Humidtropics partners is carried out to ensure impacts of the program (Fig. 1).

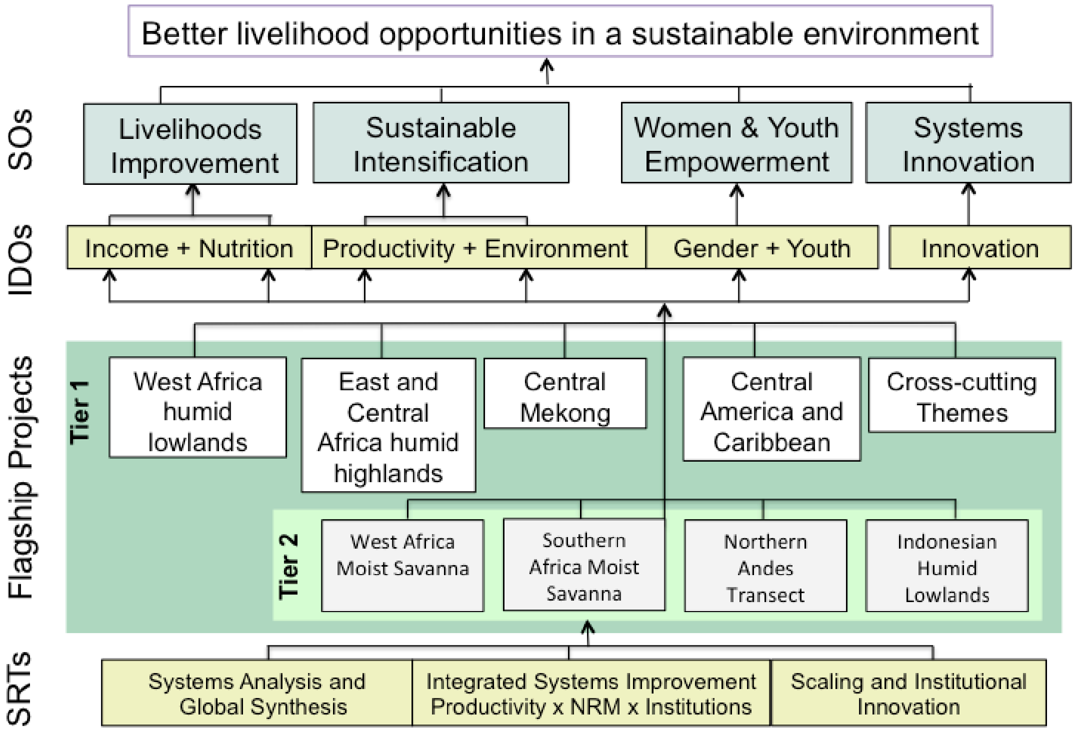

Figure1. Humidtropics programmatic framework
Source: IITA and Partners (2012)

Humidtropics research has three main integrated strategic research themes (SRTs) that work together as illustrated in Figure 2 (IITA and Partners, 2012). SRT1 focuses on system analysis and global synthesis, which involves a capacity to undertake characterization of Action Areas and their component Action Sites; identification of entry points; coordination of the development of tools, such as surveys to monitor agricultural system change; and providing analytical support in research synthesis. SRT2 research is organized around systems interventions and the trade-offs that exist with integrated system productivity, institutions and markets, and natural resources management. SRT3 studies and develops capacity for institutional innovation and scaling of social and technical solutions that impact on rural poverty and gender equity. The research framework is a matrix of location-based research in the Action Areas, and draws on critical capacities in thematic research groups arrayed across CGIAR centers and partner organizations. All the SRTs interact and come together at the Action Areas and Action Sites.

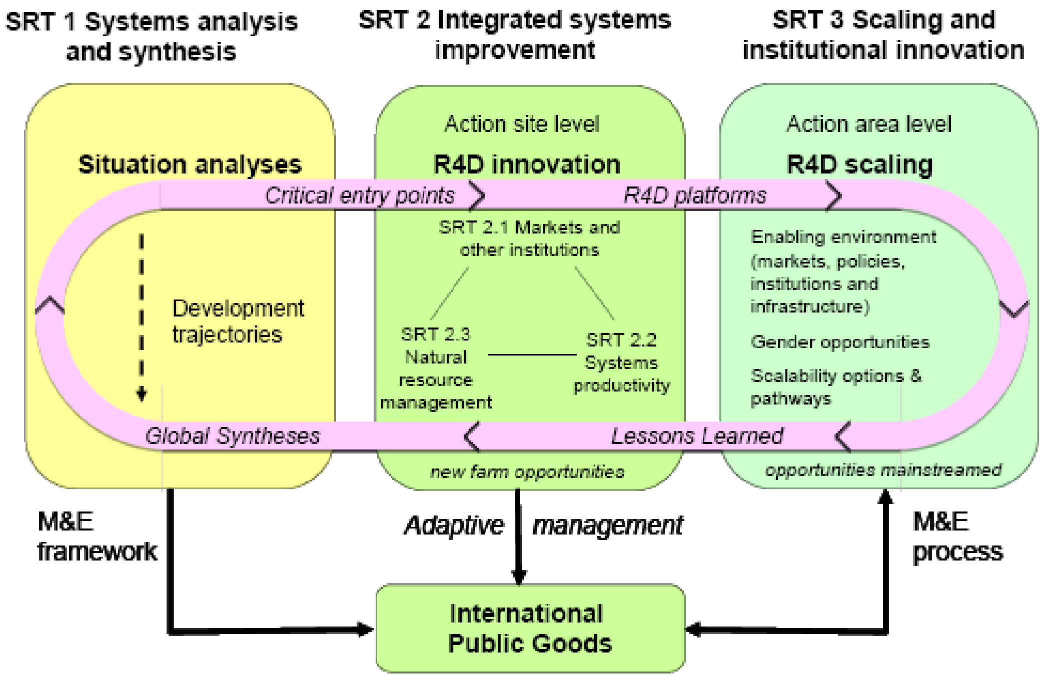

Figure 2. Humidtropics program research framework
Source: IITA and Partners (2012)

Overview of the Mekong Action Area

The Mekong Action Area includes parts of Cambodia, Laos, Myanmar, Thailand, and Vietnam plus the two southwest provinces of China (Yunnan and Guangxi). Countries in this region, which includes more than 300 million people, have experienced rapid economic growth, resulting in significant reductions in poverty rates. Yet the benefits of economic development have not been equally distributed and poverty levels remain high, particularly in the upland and highland areas. Agricultural intensification offers one pathway out of poverty but needs to strike a careful balance between the use and conservation of natural resources. Land use intensification on erosion-prone hills can lead to irreversible soil loss as is widely experienced across the region (Schreinemachers et al. 2013). Maize monocropping on sloping lands is widely practiced in Vietnam, Thailand and Laos and is driven by a rapidly expanding livestock sector. This type of land use causes rapid degradation of upland agricultural systems. Land use intensification also goes together with a more intensive use of agrochemicals (fertilizers and pesticides) and this also has large-scale consequences as residues are translocated to larger lowland areas and deltas through the hydrological system and can have a detrimental effect on water quality and human health. The challenges for the Central Mekong Action Area are to improve the livelihoods of poor smallholder farm households through more intensive agricultural production systems while maintaining the natural resource base, including soil fertility, water resources, forests and biodiversity.

Humidtropics does not work in all parts of the abovementioned countries. The program has strategically selected smaller areas within these countries, based on a relatively high rate of rural poverty and a high risk of land degradation, but with a high potential for agricultural intensification. Using these variables, the Action Area was divided into three parts, with each part covering portions of three to four countries: (1) northern Thailand (Nan, Phayao, Chiang Rai), northeastern Myanmar (Shan), northwestern Laos (Bokeo, Xayaboury, Luang Namtha) and Xishuangbanna prefecture in China; (2) northern Laos (Phongsali), northwestern Vietnam (Son La, Dien Bien, Lai Chau, Lao Cai) and Honghe prefecture in China; and (3) southern Laos (Saravane, Sekong, Attapu, Champasak), central Vietnam (Kon Tum, Gia Lai, Dak Lak, Dac Nong, and Lam Dong), and northeastern Cambodia (Stueng Treng, Ratanak Kiri, Mondul Kiri).

Progress and opportunities for intensification through horticulture in the Central Mekong Action Area

The selected project areas within the Central Mekong Action Area are mostly border provinces characterized by upland and highland conditions. Horticulture currently plays a limited role in most of these areas because of the perishable character of most vegetables and fruits, which makes it more profitable to produce them nearer to major cities. Upland areas are dominated by maize, rainfed and irrigated rice, cassava, and more recently by rubber. Tea and arabica coffee are the only horticultural crops of local significance as these cannot be grown in the lowlands. There are exceptions, such as Lam Dong province in central Vietnam and Lao Cai in northern Vietnam, which have successfully adopted vegetable farming at a significant scale. For instance, tomatoes from Lam Dong province are transported to markets all over Vietnam. Still, horticulture could have an important role in other areas as well, particularly considering the rapid growth in demand for fresh fruits and vegetables stimulated by population growth, urbanization and rising incomes, but also improvements in infrastructure that connect previously remote areas to the major urban centers. For instance, Son La province in northwestern Vietnam was previously too remote to produce vegetables for the Hanoi market, but after a major improvement of road infrastructure vegetables farming has started to develop.

The potential for upland areas to produce fruits and vegetables is especially high during the wet season from May to September. During this period, vegetable production in the river deltas such as the Red River Delta, the Mekong Delta and the Chao Phraya Delta is constrained by poor drainage and flooding. Relatively cooler temperatures also give a competitive advantage to farmers in upland areas for growing cool-climate vegetables such cabbages, carrots, tomatoes and sweet peppers.

A scoping study in northwestern Vietnam (Son La and Dien Bien provinces) by AVRDC and the Fruits and Vegetables Research Institute (FAVRI) showed that there is much potential for expanding vegetable production in parts of Son La province to supply the Hanoi market (Loc et al. 2013a). The most promising crops included tomatoes, cabbages, fresh beans, local mustard, celery cabbage, Chinese cabbage chayote, and lettuce. The study also showed that those areas of Son La that had successfully adopted commercial vegetable growing had received extensive outside support from government and research organizations and had a strong community organization. A survey among traders and consumers in Hanoi was part of the study. It showed that urban consumers currently consume a negligible quantity of vegetables originating from the northwestern region. Consumers associate the region with traditional vegetables such as local ("Hmong") mustard, celery, cabbage and taro, but not with standard vegetables such as tomatoes, fresh beans, or lettuce.

The Hanoi vegetable market currently has its own challenges. Consumers are concerned about food safety and have a low level of trust that the vegetables they buy from the market are safe to eat. They are particularly concerned with vegetables and fruits imported from China, which they associate with a high risk of pesticide residues. Vegetables coming from the northwestern region, on the other hand, are associated with relatively low levels of risk, as consumers assume poor upland farmers use few pesticides. These findings thus suggest there is potential for the development of vegetable farming in the northwestern region of Vietnam, but care must be taken to comply with good agricultural practices to produce safer vegetables that have recommended pesticide residue limits.

Having confirmed the potential of vegetables in northwestern Vietnam, Humidtropics will initiate a local innovation platform on vegetable production. This will be a network of local stakeholders in horticultural production, including farmers, government offices including extension, and input suppliers including seed producers, traders and researchers. The innovation platform will be encouraged to define a common objective and develop a strategy for the sustainable intensification of agricultural systems. Technical constraints identified by the platform will be turned into research questions for Humidtropics to address. The use of innovation platforms ensures that research will support the development process by addressing the needs of local stakeholders.

AVRDC researchers and local stakeholders are discussing and pre-testing best-fit options for ecological intensification of vegetable production in Son La and Dien Bien. Quality seed is the most critical input for vegetable production. The vegetable seed supply system in Dien Bien, a remote highland area, was explored to better understand and learn from the existing situation. Local seed retailers located in main towns only sell a few kinds of vegetable seed. The provincial agriculture seed station mostly produces and sells staple crop seeds, although it has the capacity to produce vegetable seeds. Rural households usually produce their own seeds. Possible mechanisms to improve the efficiency of the local seed system will be discussed in the local innovation platform. The platform will be used to interact with farmers, input suppliers, market agents, and other local stakeholders to select the best-fit options for ecological intensification. Possible options include new crops with market potential, improved varieties, integrated pest and crop management practices, and soil fertility management practices. Researcher-led and farmer-led trials will be conducted. Adoption of good agriculture practices will be emphasized for branding the vegetables from northwest Vietnam as safe and nutritious produce, targeting main markets like Hanoi or niche markets for tourists.

Nutrition-sensitive agriculture in the Central Mekong Action Area

The targeted areas in the Central Mekong Action Area are predominantly in the uplands and highlands. Most people living in these areas are ethnic minorities such as Hmong and Karen in northern Thailand, and Hmong and ethnic Thai in northwestern Vietnam. Malnutrition remains a problem in these areas and is driven primarily by relatively high rates of poverty, poor diets, a lack of sanitation, and poor reach by government agencies in health and education. In Vietnam, although the average level of vegetable consumption is high in the total population, the level of vegetable consumption among certain ethnic minorities is low.

AVRDC and FAVRI conducted a scoping study to assess the nutritional situation of Thai and Hmong ethnic minorities in Son La and Dien Bien provinces in Vietnam and to assess the potential of improved home gardens to improve nutrition (Loc et al. 2013b). The study found that the dietary diversity of ethnic Hmong households was poorer than that of ethnic Thai households. This could be related to economic and cultural factors but also because Hmong households live under much poorer environmental conditions. For both Thai and Hmong households, access to markets to buy fresh fruits and vegetables is a problem, particularly during the rainy season when roads are inaccessible. Own food production from gardens and fields or the collection of food from the forest is therefore a more important source of food. Only 15-20% of the vegetables consumed within the household are purchased. If money is spent on food, then it is mostly for animal products, rice, snacks and beverages. The study showed that few people knew about the role of vegetables in providing vitamins and minerals, or that vegetables are good for health. Among women of Thai ethnic origin, about half knew about vitamins and that vegetables have high vitamin contents, but none of the women of Hmong origin knew this. Local health care workers do not train women in nutrition; they focus only on treating diseases and conducting health examinations. The prevalence of child malnutrition appeared to be significant, with 22-30% of children under five being underweight in one commune studied.

From the study it appeared that an intervention of improved home garden methods combined with nutritional education for women could make a significant contribution to improved household nutrition. Nearly all households cultivated a relatively large garden (about132 m^2 per household on average), but productivity was relatively low. The main constraints were incidence and severity of pests and diseases and lack of quality seed. Hmong households grew only three different species of vegetables on average (compared to seven for Thai households). Tomato, cabbage, cauliflower and kohlrabi were the most popular crops for Thai and Hmong households, but these crops are not as nutritious as leafy vegetables. The use of raised seedbeds or irrigation was uncommon. Most households used animal manure, kitchen waste and ash to fertilize the home garden.

Having confirmed the potential of home gardens in northwestern Vietnam, Humidtropics will establish demonstration home gardens in several communities and initiate an innovation platform on the topic to work with stakeholders to make an optimal design. This will consider crop selection and seed sources, crop management methods, cooking methods and nutritional information. Gender aspects will be carefully considered in the implementation of home gardens as it is mostly women who decide about household food consumption and home garden work, although garden implementation and maintenance should ideally be a joint activity among women and men resulting from a collective household decision.

CONCLUSION

This paper provided background information about Humidtropics, the CGIAR Research Program on Integrated Agricultural Systems for the Humid Tropics. This is a large-scale global research program with a strong focus on research for development. For the Central Mekong region the program has selected research sites that are mostly in upland and highland areas populated by ethnic minorities. These areas are not traditional areas for commercial vegetable production, but nevertheless have much potential both for commercial and home-based vegetable production. Humidtropics will work carefully with local stakeholders to develop, test and adapt innovations for sustainable intensification of agricultural systems. Vegetable production will have an important role to play and there are potential synergies with livestock and fruit trees.

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Healthier families, wealthier farmers: Vegetable growing benefits to indigenous peoples in North-Eastern Cambodia

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ABSTRACT
Small-scale farmers in Ratanakiri have recently started to grow vegetable in organic home gardens in the framework of Annâdya, a development project funded by the European Union[1] to improve indigenous peoples' food security. This study intends to identify benefits of vegetable growing for this marginalized population, which remains highly dependent on forest resources that are dramatically declining. Among participating farmers, about 90% of the families were able consume the vegetables they grew on a daily basis for 3 months in the dry season. Thereby, farmers increased the family weekly intake of fresh vegetables during the lean season nearly up to the level of the rainy season, when wild vegetables are plentiful in forests. But benefits extend further beyond the producer's circle. Indeed, nearly all the participating farmers tend to offer vegetables they produce to family members and other neighbors. Finally, more than 40% of them were also able, out of their own initiative, to produce a surplus they could sell to neighbors and local markets. This activity was profitable despite its rather modest scale and allowed some families to earn more than the monthly average income of rural households. Last but not the least, vegetable growing has been identified as an empowerment tool for women to increase their decision-making power; generate income; reduce their workload; increase their participation to the community and improve gender parity.

Keywords
Northeastern Cambodia, Small-scale farmers, Vegetables, Indigenous Peoples

CONTEXT
Ratanakiri province stands at the northeastern edge of Cambodia and shares borders with Laos to the north and Vietnam to the east. Up to early 2000, the region was particularly isolated, still largely covered by dense forests—some of which are evergreen—and inhabited by a majority of indigenous peoples. Aside from Khmer and several ethnic minorities (Lao, Cham, Vietnamese and Chinese), twelve indigenous groups, recognized as *Chunchit Daeum* or "original inhabitants," were settled in the province (Bann 1997). Among those, Tampuan, Kreung and Jarai were representing altogether 81% (Helmers and Wallgren 2002; White 1996). With a little less than 95,000 inhabitants (National Census 1998) sharing its 11,673 km^2, Ratanakiri was one of the country's least densely populated areas.

[1] The content of this article does not reflect the official opinion of the European Union. Responsibility for the information and views expressed therein lies entirely with the author.

Indigenous people were living in small, scattered villages and were utterly dependent on a mixed subsistence system made of swidden agriculture[2] and hunting-gathering. Their livelihood and culture was deeply rooted in the forest from which they were dependent for food, medicine, housing material, fuel wood, and a source of rattan for crafting baskets. The forest also constituted a key place to perform traditional rites (especially burial rites) that are important in reinforcing indigenous identity. From an economic standpoint, indigenous peoples were only starting to join in a monetized economy (Hamade 2003). Land rights were mainly community-based and families were granted use rights from traditional village authorities (Bann 1997). Thanks to the low population density, and up to the eruption of large economic land concessions, arable land was plentiful and the agricultural system of slash-and-burn was not having the large negative impact for which it is often blamed (Dufumier 2006).

This portrait should not give the impression that this rather self-sufficient period was a state of heaven since then lost by indigenous peoples. Health indicators were quite alarming, as reports by some non-governmental organizations have shown. Chronic malnutrition was particularly high, with 70% of children found stunted (and 36% severely); 90% of children and most women were iron-deficient; and the lack of vitamin A was resulting in 2 % of children and 6.8% of pregnant women having night blindness (Hamade 2003).

The rapid development process in which the province and its indigenous population are being swallowed over the last decade has contributed much but has failed to improve an already precarious situation. In 1999, a regional inclusion plan also known as the “Development Triangle” was initiated between the three former Indochina governments[3]. Through cooperation in the fields of transportation, trade and electricity the region suddenly has become hugely attractive for powerful investors. With road construction to Vietnam completed in 2010 and to Kratie in 2011, transportation of agricultural goods and timber has largely facilitated an export-oriented production scheme centered on rubber plantations owned by foreign and national elite investors. In the process, indigenous peoples have been facing massive land-grabbing or disadvantageous deals that are now seriously affecting their food security, not to mention damage to their cultural identity in an increasing and already large number of villages (Global Witness 2013). Non-timber forest products (NTFP), that constituted previously a much-needed free amount of animal proteins and vegetables to consume and trade or barter are now vanishing due to massive logging. Losses to economic land concessions (ELC) increases pressure on the remaining land, reducing fallow times and forcing indigenous farmers to clear new areas, which further speeds up deforestation and soil fertility degradation, affecting even more food security (Ironside 2008).

In this context, and in its global plan to foster food security and nutrition for vulnerable population, the European Union has funded a three-year project named Annâdya. The project started in February 2012 and operates in 64 villages among 5 of the 9 districts in Ratanakiri. Following a food-based strategy, Annâdya combines efforts to increase households’ food production diversity and quantity while building up capacities in simple processing methods and raising households’ awareness of nutrition. The project aims to go beyond the consumption self-sufficiency threshold and support farmers to engage in trade individually and collectively.

[2] Also known as shifting agriculture, swidden agriculture is “often used by tropical-forest root-crop farmers in various parts of the world and by dry-rice cultivators of the forested hill country of South-East Asia” (Encyclopedia Britannica 2008)

[3] http://clv-triangle.vn/portal/page/portal/clv_en/817327

Annâdya adopted an integrated approach, relying on organic production techniques that have been found to be a good vehicle for food security and poverty reduction in developing countries (Beban 2009). The project methodology is articulated around training and in-the-field continuous technical support provided by extension staff and a network of farmer promoters. Concretely, the project supports farmers to produce more food by setting up vegetable home gardens during the dry season; promotes the system of rice intensification (SRI) both for lowland paddy and upland rice production; and encourages farmers to improve their chicken-raising practices and to engage in edible-insect or fish farming. In parallel, Annâdya introduces farmers to simple food processing techniques and encourages community-based organizations such as community fruit tree nurseries and saving and selling groups.

The potential for agricultural interventions to improve the nutritional status of vulnerable populations has been debated for at least three decades (Lunven 1982). If some compelling evidence has been put forward, particularly for home gardening (Berti et al. 2004; Olney et al. 2009), a difficulty in assessing the extent of this effectiveness remains, arguably due to the lack of statistical power of the studies and the need for agreed quality standards for measuring impacts (Masset et al. 2012). Nevertheless, dietary diversity has been found associated with nutritional status independently from socio-economic factors in many developing countries including Cambodia (Arimond et al. 2006). Even if the latest trend is to favor supplementation or a fortified food approach that relies on the private sector involvement (de Pee 2009), in Cambodia the latter is still at the intervention-design phase (Theary et al. 2013) and the former is financially unaffordable to poor households. Diversifying food production, especially in a remote context such as Ratanakiri province, thus remains the most relevant and sustainable approach to date (Keatinge et al. 2011). In this scheme, and based on the highly significant association between vegetable availability per person and the mortality rate of children under-five (Keatinge et al. 2011), relevance of promoting home gardening to vulnerable populations that experience severe seasonal shortage, in combination to efforts to increase animal-protein intake, cannot be denied.

The Annâdya home gardening activity was initiated at the end of the rainy season in November 2012 and ran up to the beginning of the monsoon in June 2013. Interested farmers were given training instructing them on the initial steps such as suitable location and size for a garden, land preparation, vegetable types, water-saving techniques and fencing benefits. Farmers who demonstrated commitment by preparing a suitable garden were given the initial inputs (seeds and, if needed, watering cans) to start production. Twenty-nine varieties of vegetable seeds were provided. On average, farmers received 6 seed varieties, among which the most commonly requested were cucumber *(Cucumis sativus* L.); yard-long bean *(Vigna unguiculata* subsp. *sesquipedalis* (L.) Verdc.); morning glory *(Ipomoea aquatica* Forssk.); mustard green *(Brassica juncea* (L.) Czern.); white cabbage *(Brassica oleracea* L. var. *capitata* L. f. *alba* DC.); and swatow mustard (*Brassica oleracea* var. *alboglabra* (L.H.Bailey) Musil).

After planting time, project extension staff provided ongoing support to farmers to monitor plants growth and health, and to measure the outputs.

Similar to all the other production activities, registrations show significant gender disparity, with only 198 women registered compared with 395 men. But these figures are misleading, firstly because it is common for female decision-makers to register under their husband's (family head) name (qualitative study showed that 28%

of women decision-makers were registered under their husband’s names); and secondly, because even when men are registered, women still usually take a major part in the activity.

Garden size was on average 160 m^2, but the distribution analysis shows a median size of 100 m^2 as a few households initiated larger-size plots for commercial purposes (Table 1).

METHOD

The findings were obtained through a combination of qualitative and quantitative methods.

Quantitative data were collected through the Annâdya monitoring system of the activity inputs/outputs for the total amount of households participating in vegetable growing during the dry season (593 households). All these families were asked how they had been using the vegetables produced (consumption within the households; offerings to relatives and neighbors and/or sales made). Households who reported sales were asked the total amount of gross income they could generate from it. This survey was done on a monthly basis by the project extension staff, and – apart from a few literate farmers who recorded their sales in a book—was based on a recall period of maximum one month. Land size and vegetables grown were recorded for all participating farmers as well, at the inception of the activity. The quantitative survey was conducted between January and mid-June 2013, while production started during November 2012.

To complement this first set of data, a set of qualitative semi-directive interviews was conducted with a sampled number of participating households grouped in two significant sub-groups: *Very Poor* households belonging to the highest-poverty end and *Poor* households, characterized by a comparatively better ratio of economically active members to total amount of members; more assets and better housing conditions than the very poor. Although a household poverty measurement tool, called the *ID Poor*[4] exists in Cambodia, project staff observation and experience resulting from long-term collaboration with these families appeared to be more reliable. It was simply not available for all farmers interviewed to begin with, and in addition, as *ID Poor* identification was conducted in 2011, it was outdated for the others. Respondents for the qualitative study were selected to match the socio-economic segmentation of participating farmers (1/3 very poor households; 2/3 poor households). Semi-directive interviews were conducted until reaching the data saturation point[5]. In total, 12 very poor and 27 poor households have been interviewed.

In order to access information from female respondents, qualitative surveys were done separately with women and men in nearly half of the households that we interviewed (18 couples with husband and wife interviewed and 21 couples with either husband or wife interviewed—57 individuals, 28 females and 29 males). Indeed, even when targeted specifically, indigenous women tend to be denied *de facto* the possibility to respond. Males and elders especially tend to impose themselves first as interview translators and ultimately respond instead of women. Interviewing men and women separately and simultaneously through two (respectively a male and a female interviewer) offered the advantage to keep men busy in order to collect information from women. It also opened up the possibility to cross check information

[4] led by the Ministry of Planning (MOP) with funding support from several donors

[5] Point beyond which information collected through a qualitative research method becomes redundant

and analyze gender-specific issues and views, particularly in the matter of decision-making: workload, benefits and constraints.

Measuring precisely the additional food resulting from the activity is known to be difficult to monitor (Pomerleau et al. 2004). Proper scaling with the target group was technically impossible and in addition would have introduced a bias since it would have required some basic education of the sample group. It would have therefore favored the better-off and the men, while in fact it is the women (usually non-educated) who mostly in charge of this activity. Hence, we had to rely on farmers' statements, using a recall period of a maximum of one month for the ongoing quantitative survey; record consumption in terms of average amount of daily meals; and sales and gifts in terms of occurrence during qualitative surveys. Weights provided must therefore be taken as estimation. Sales have been quantified in terms of income rather than weight or volume.

Relying on a recall method is not optimal, for it is prone to errors and likely to induce under- and over-estimation, at times in a voluntary manner respectively for sales (out of fear not to be considered 'poor enough' to be entitled to further support) and gifts (out of social pressure to be considered as a good community member), or as part as a general unconscious tendency to skew intakes towards higher values (Willett 1998). Nevertheless, proper participatory observation, which also has its bias, provides a general idea of how households use vegetables and perceive the activity to be compared with other experiences. Moreover, some bias mitigation measures can be put forward, as within our sampled respondents: The systematic interviews of men and women within the same households gave us a cross-check tool; sales/gifts have been further assessed through qualitative surveys; and some of the before/after comparison, such as between vegetable garden and forest consumption, are both based on a recall-period.

As the exercise required various levels of translation, working in English with native Khmer-speaking supervisors and interviewing farmers from five different ethnic groups speaking each its own language (Tampouan, Kreung, Jarai, Preuv, Lao), we conducted an analysis workshop with the project extension staff to summarize findings and cross-check interpretation issues.

EMPIRICAL FINDINGS

Positive effects of the action were found in food security, nutrition and household economics; as well as on social capital at community-level and women empowerment.

Food security

Impacts from Annâdya home gardening activity at households level have been looked at in the four commonly accepted pillars[6] of food security: availability; access; utilization and stability.

At the household level, food security refers to the ability "to secure, either from its own production or through purchases, adequate food for meeting the dietary needs of its members". But this actually fails to capture how food security was articulated locally, at least up to very recently. Indeed, indigenous peoples in Ratanakiri were sourcing traditional vegetables from forests surrounding their villages. From qualitative survey and observations, it appeared that vegetable gardening was practiced, but this was limited to the wet season (June-Oct) and to a few varieties of Cucurbitaceae (pumpkin; bottle gourds) in *chamkar* (upland rice

[6] Adopted at the World Food Summit in 2009 that also stated that "the nutritional dimension is integral to the concept"

fields)[7]. Wild vegetables were abundant which made home gardening unnecessary during more than half of the year. On the other hand, water scarcity during the lean season, lack of experience with other types of vegetables (such as the ones promoted by the project); and seed unavailability impeded the activity development during the dry season. This explains why previous to Annâdya project, the few families who practiced non-traditional vegetable gardening from January to June had for most been introduced to it by previous actions from NGOs or the Provincial Agriculture Department[8].

As food preservation was -and still is- often limited to some pickled bamboo shoots, availability was highly dependent on the seasons. But dramatic deforestation has resulted in vegetable scarcity even outside the usual lean time. This explains that food security is becoming an increasing matter of concern for the population, especially for the poorest one. If ten years ago vegetable availability (from the forest and in traditional *chamcar*) was reported to be plentiful from July up to December (Hamade 2003), such a situation is not found anymore. And even if 82.5% of the families have reported they collect non-timber forest products (NTFP) at the Annâdya Mid-Term Evaluation in September 2013, all of them lamented at the same occasion the fact that "wild food" is vanishing.

The need for an alternative free or cheap food source is certainly the strongest driving force behind farmers' proportionally massive involvement into home gardening promoted by the Annâdya project. As a matter of comparison, there were 593 families involved in the activity in 2012, for only 191 in the system of rice intensification activity, though more than 90% of the population is locally farming rice and suffering from extremely low average yield (0.44 t/ha measured through Annâdya baseline external survey, 2012). Participants in dry-season gardens also represent more than 4 times the amount of participating households in chicken-farming activity for which a high-valued input of 5 adult chickens was provided, while the project only gave some watering cans and seeds for gardening and only a hoe for those engaging in the system of rice intensification.

The daily amount of vegetables supplied from the forest to feed each individual member of the households previous to large-scale wood logging is unknown. But from our enquiry, it appears that quantities were bigger throughout the year than that which is found nowadays, and that current amounts are seen as too scarce even in the rainy season, with a need to "starve oneself". As one of our elders and poorest respondents puts it: "*It is much harder for us to find food now then during Pol Pot's regime: there is no more forest where to get it from.*" However, we could estimate from interviews a current average daily amount of vegetables at the shift between rainy and dry season (second half of November 2013; which is neither the most plentiful nor the scarcest period) is about 120 g, with variations between villages that reflects the access to and degradation state of the forest, and among families that reflects their economic status. We also know that on average at the end of the season when vegetables are most plentiful (end of September), households were consuming vegetables 5.4 days per week which would equal to about 2.6 meals containing vegetables if converted to a daily-basis.

[7] which has previously been observed by other NGOs such as Hellen Keller that ran a large Homestead Food Programme in Cambodia or Health Unlimited
[8] One of the respondents mentioned doing it since "before Pol Pot regime" but we could not determine with confidence that he referred to non-traditional varieties.

Collecting vegetables was—and still is—mainly done by women who currently spend half to full days doing this chore one to three times a week depending on forest remoteness, month and family size. They usually go out gathering indigenous leafy vegetables[9] near streams and watersheds. Duration varies between villages, but it seems that it is shaped by the quantities that must be collected: half or one *Kapa* (indigenous traditional basket people carry on their back) of 2 to 3 kg.

During the hottest dry months (mid-March to mid-May), vegetables are almost nowhere to be found until the monsoon starts and provides again mushrooms, bamboo shoots and leaves for collection. In that meantime, households who can afford it will occasionally purchase vegetables from "motoshops"[10] supplying villages daily or more rarely from markets that are usually remote. Small shops are found in almost all villages, but they usually rather sell long shelf-life basic products. Purchasing vegetables is a coping strategy when vegetables cannot be found in the forest, and the low economic power of the households implies that quantities remain small. Indeed, the average selling price surveyed in the villages ranges from 2000 to 5000 KHR (0.50 to 1.25 USD) per kg of vegetables for the reason that the products are for most imported from Vietnam. With an official average daily income per person for poorest households in rural areas estimated at 4400 KHR or about 1.1 USD[11] (NIS 2012), purchased vegetable intake was obviously limited.

Previous to Annâdya intervention, we found that vegetable purchases represent a weekly amount of 1.8 kg on average in November (intermediate season), but the median is much lower at 1 kg weekly, which equals to a daily individual amount of about 20 g to 40 g if we look at median and average respectively. Among the poorest group, about 20% of the households declared they could not afford to buy any vegetables at all.

All things considered, it appears that intakes of forestry and purchased vegetables were together well below the recommended daily intake per capita of 400 gr of fruits and vegetables (WHO/FAO); most likely below the average intake found for Southeast Asia (Pomerleau et al. 2004) and even probably below the 200 g threshold (Keatinge et al. 2011), given that locally, people seldom consume fruit.

In this context, quantitative and qualitative surveys show that home gardening made fresh vegetables available to families at a time when wild resource usually decline or disappear. Indeed, 525 out of the 593 households participating in the activity (88.5%) managed the production up to being able to consume their products for several months between January and June 2013, when traditionally vegetables were not available (Hamade 2003). The remaining families were unable to consume vegetables for their gardens had either not been planted at all despite preparing the land for it[12] or their crops had been destroyed by wandering-free animals or by pests, diseases and/or potentially due to improper watering as observed by Annâdya project staff but not reported as such by farmers.

Among producers interviewed, daily consumption of home garden vegetables was on average of 2.2 meals for a period of 3 months. Two-thirds of the farmers managed to have vegetables available for consumption from January to March at least. Among them, more than half could also consume it up to April included and

[9] The most common vegetables cited are: sleuk Kadeo (local kind of blue-green wild leaf); Promaoy Domrei (literally "elephant trunk" leaf); Trao Andaing (literally the "turtle taro" leaf)
[10] Sellers bringing food for sale to the villages on motorcycles
[11] Monthly income of 200 USD for a family of 6 people, in Cambodia Socio Economic Survey report, National Institute of Statistics, 2010 (data from 2009)
[12] One of the basic conditions for them to be registered for technical support and to receive inputs (seeds, watering cans)

20% at least up to May (Fig. 1). This also implies that 1/3 of the households could only consume their products for 1 to 2.5 months[13]. Even if we lack reliable baseline information on 2011 (or “pre-project”) situation for the lean vegetable season, we can pinpoint that this is not far from the 2.6 meals measured through our Mid-Term Evaluation conducted during one of the most plentiful months for vegetables. Though not measurable yet, it gives an indication that the scarcity has been significantly reduced in the lean season.

As targeted, dry-season homestead garden reduced participating households' dependency both on forestry products and purchases. In the households, both women and men tend to value similarly the time and money saved with the activity, even if time-saving is, as one could expect, more often put forward by women then by men. The activity is also perceived by both genders as an easier way to get vegetable to eat “*at any time and as much as one wants*” than any previous strategies.

Currently, precise quantities consumed by participating farmers thanks to home gardens to be checked against a control-group are still to be collected. Nonetheless, a definite quantity increase has been reported by respondents compared to the previous year at the same -lean- period. We can also deduce that the activity is seen by households as alleviating their food insecurity during the dry season from the fact that all the interviewed households but two who lack labor are engaging in the activity for a second year in 2014 while expanding their plot size in order to be able to trade some of their products.

Nutrition

Aside from food security, nutrition security has recently been given an increasing attention since without quality diets providing appropriate nutrients and safe food, dietary needs can't be fulfilled nor can people's health status be acceptable. With such concern in mind, the focus has shifted towards intake of fresh vegetables and fruit as this food group provides dietary fiber, vitamins; minerals and essential phytochemicals.

Previously to the introduction of home gardens, vegetables collected were usually consumed for two days. Even though indigenous vegetables are known to be rich in micronutrients (Chavasit 2012), in the hot conditions that prevail locally, those vegetables were not properly preserved and nutritional properties were affected. In comparison, vegetable intake through home gardening has gained in quality as products are consumed fresh. Moreover, as home garden production is organic, families have also decrease their exposure to chemically contaminated domestic or imported vegetables sold by moto-shops and at market. Food quality was thereby increased through the activity.

From interviews, we could also determine that the activity has increased households diet diversity, which has been proved to impact the nutritional status of children (Arimond and Ruel 2006) and to have positive effects in terms of iron, vitamin A, vitamin C and fiber intake (Bushamuka et al. 2005). Most of our respondents have put forward that they could alternate the vegetables consumed each days, while previously they had to rely on the limited range of vegetables available in the forest at the time (mainly leafy types) when they could found some, and on rice-chili-fish sauce (Jarai also consume some sort of wild garlic called *pakriow* in food-shortage period) otherwise.

[13] Among the most common issues faced, farmers cited in majority pests (especially worms), and to a lesser extend garden small size and water availability.

Refined nutritional benefits from the project activity could not be assessed yet quantitatively as it would require blood testing with the sampled target and control group which was not planned in our monitoring scheme. We can only rely on the fact that nutritional intake of safe vegetables has increased for several months in an usually lean season (Ruel and Levin 2000), based in similar successful experience in Cambodia that were measured (Olney et al. 2009), to say that farmers situation has improved, though probably in range that is still limited. Should nutritionists be interested, further research and measurements would be needed to draw more assertive and quantified conclusions.

Economic benefits

A large majority of the households have been able to gain some economic benefit from the activity.

Savings

Saving the money they previously had to allocate to purchase vegetables is certainly one of the main benefits mentioned by interviewed households. However, since purchases were limited due to poverty, amounts saved are not impressive in absolute value. The monthly average amount saved is 27,000 KHR (6.75 USD) while the median is 17,000 KHR (4.25 USD).

Confirming previous observations in the matter (HKI 2003), households usually reported that the money derived from trade was allocated to daily food expenses, mainly oils and condiments and to a lesser extend to animal proteins (fermented or fresh fish and meat products). One farmer, who with a total declared income of 500,000 KHR or 125 USD belong to the top end of income made, mentioned that apart from daily expenses he allocated the money to his children education.

However, this must be put in perspective to the monthly available budget per households that was evaluated on average between 38.78 and 155.1 USD for the three lowest quintiles of the rural population (NIS 2012). For Annâdya target group, that belongs to these categories, savings as small as those remain valued.

Trade

Despite that the activity was designed for households consumption only at this stage[14], a certain amount of households were able to trade some of the vegetables produced. Consequently, the way sales have been occurring is providing feedback on communities' local approach to markets, as opposed to an induced one the project could have developed.

From our quantitative survey, we gathered that 18% of the producers had been selling products; that women were proportionally more involved in trade than men (20.1% and 16.8% respectively) and that sellers could gain 205,000 KHR (51.25 USD) from their vegetable sales on average. Seven families managed to earn an income equal or superior to 200 USD, which is the monthly average income of households in rural area (NIS 2012), some on plots of 20 m × 20 m (400 m^2). But our qualitative survey showed that sales had been underestimated both in terms of income made and households who managed to sell some products, by not interviewing both men and women in each household. As women are usually in charge of trade at village level, and as they are also usually managing this income quite autonomously,

[14] Risks had indeed to be limited as the practice required a behavior change and the acquisition of new skills among the target group.

registered farmers interviewed -usually men- were unaware of the exact income made by their wives and failed to report it. The reverse situation also occurred, but to a much lesser extent: some women were interviewed because they registered but were unaware of their husband's income from trading vegetables.

If we cannot draw assertive statistical conclusions due to the size of our qualitative sample, we can still put forward a few elements. Firstly, men appeared to be underestimating amounts more frequently than women[15] (7 instances against 3, respectively). Secondly, the qualitative survey showed that 16 households out of the 39 interviewed (41%) had been able to sell products whereas the quantitative information for the same households stated only 9 (23%). Finally, the quantitative data obtained for the total amount gained by the 39 interviewed households through sales was 1,080,000 KHR (270 USD), while through our qualitative study that collected information with both husbands and wives, the total amount surveyed was 1 896,000 KHR (474 USD).

Aside from strong suspicion that amounts derived from quantitative study were underestimated, it appeared from both survey methods that the income was distributed unevenly and to the extent that 25% of the sellers concentrate about 80% of the total income (see Table 1). Nevertheless, this distribution indicates – and so did qualitative survey analyses- that the sales still generally occurred with some level of regularity on a weekly basis and/or involved more than one customer for more than 90% of the sellers.

Based on households income from quantitative data, and with the above mentioned suspicion of significant underestimation, we evaluate that the surplus available to the community formed by our target group by the sellers to be at least 4700 kg of fresh vegetables.

Finally, we noticed that trading mainly took place in the villages, at the initiative of the buyers rather than due to sellers displaying products for sale. Commercial activities at market occurred but were mainly practiced by the households who ranked at the top end of the incomes made. This extremely short production-supply-consumption chain has two advantages. In the first instance, it means that storage and transportation of goods that are among the main bottlenecks for market access to poor people are not a concern for the vast majority of sellers. And as a result, it also means that post-harvest losses, usually in the range of 20 to 50% in hot-wet tropical environments (Hiroyuki 2013; Lumpkin et al. 2005), is reduced to a very minimum.

Community benefits and spill-over effects

Benefits of the action extended further than the producers immediate circle, and the communities could also profit from participating families activity in various ways. Firstly, most producers have been sharing some of their vegetables in a gift/counter-gift process that is contributing to community cohesion. Secondly, as mentioned earlier, neighbors could access cheap and fresh products in the village. Customers indeed were mainly reported as being non-participating farmers, which confirms deductions we could make from the fact that most participating households declared they stopped purchasing vegetables for they could fulfill their own family needs themselves. Finally, producers also shared the knowledge they gained from the project through training and technical advice. We also discovered incidentally that some households shared with neighbors and/or non-registered siblings seeds provided by Annâdya. Such spontaneous dissemination behavior could constitute an interesting indicator for the sustainability of the activity.

Gifts and counter-gifts: the social dimension of the activity

At least about 60% of all participating farmers were able to offer some vegetables to neighbors and relatives, and this was a regular occurrence for half of them and more occasionally for the other half. However, similar to what occurred with sales, qualitative study shows it may be largely underestimated. Indeed, by cross-checking qualitative and quantitative data, it appeared that at least 36[16] out of the 39 households had been offering some of their products and not 19 households.

The general pattern was that each of those producing families was able to share some products on a weekly or monthly basis, to 2 to 4 neighbors or family members. Quantities offered, consistently reported as “small”, varied from 200 g to 3 kg. Likewise for sales, with such amounts, no significant food security impact among recipients has been achieved yet because volumes produced were still limited in this first year of activity.

Nonetheless, qualitative surveys made two trends appear. Firstly, the activity was used primarily as a socialization tool as part of the Maussian gift/counter-gift process (Mauss 1925), and in a secondary instance as an economic tool. Indeed, respondents declared that when they had enough to eat, they would offer their products to relatives and neighbors who would request it because they already benefited from similar types of gifts and knowing that, at turn, they will be entitled to solicit similar support. Typically, interviewees would explain that they “are offering vegetables because [they] also receive some” or because “it is a tradition to share food among indigenous peoples”. In a context where social cohesion is disintegrating and knowing how social cohesion is key for communities to address issues such as protection of land access (Ironside 2008; Alkire 2012), such effects are participating indirectly to food security.

The second trend we gathered is that the way gifts and sales are undertaken indicates thresholds: the most common answer we collected was that gifts take place only when consumption needs are fulfilled: “*I had (not) enough to eat so I could (not) offer vegetables.*” Similarly, sales usually take place only if gifts could also be made. Indeed, none of the 593 participating households offered food without indicating that they consumed it themselves. As far as sales are concerned, only 17% of the families that engaged into trade did not report offering any products.

Knowledge and input sharing

Aside from food traded and offered to the community members, participating farmers also shared largely the knowledge they gained with family and other neighbors. Women seem to have been playing an important dissemination part in the process, which as we will discuss further, is one of the many elements that shows the particular gender orientation of the activity. It also appeared that two interviewed farmers shared some of the seeds they received from the project. As they were reluctant to inform us on this out of an (unfounded) fear that we would have a negative reaction, we are unsure about the scale of such practice, but we expect that this occurred with more than 2 out of 39 families interviewed.

[16] Two of the three households data remaining are missing

Women empowerment

While not specifically designed as a gender-specific activity, it appeared from monitoring and surveys that the activity imposed itself as powerful empowering tool for indigenous women. This is of particular importance since reducing gender gaps within households is positively associated with calorie availability, dietary diversity, child nutrition and education (Sraboni et al. 2013). Our observations confirm results from previous work (Ruel and Levin 2000), and the recently developed index (Alkire et al. 2012) provides a useful tool to capture how this empowerment is articulated. However, our data collection do not allow us to measure the achievements yet, and considerations here under are limited to qualitative aspects until a statistically-significant quantitative survey can be undertaken.

Among the five domains that are constitutive of Alkire's index, indigenous women participating in Annâdya home garden activities appeared to be empowered to some extent in four of them which are (i) the decision-making power about agricultural production; (ii) the control over use of income; (iii) leadership in the community; and finally (iv) the decision-making power on time allocation to workload. The last domain, the access to and decisionmaking power about productive resources, was found less significant.

Decisionmaking and autonomy on production

Following the categorization proposed by Alkire, we noticed a positive impact both on decisionmaking and autonomy of production indicators. Women interviewed reported in majority that they had been the sole decision-maker or that they had at least been equally associated with their husband to the decision, and this meanwhile men are reported to be the main decision makers for other food production (such as staple or animal husbandry and fishery) and cash crops. Secondly, women and men also reported in majority that women were the main decision makers for the choice of vegetables to grow. As far as autonomy in production is concerned, no real empowerment can be put forward as decision-making in that matter was not particularly constrained by social norms.

Control over use of income

In terms of income—that in Alkire's index represents proportionally the most determining empowerment domain—we observed that the activity benefited women specifically in two ways. Women were designated by female and male sellers as the main households member involved into trade activity within the village (both as a costumer and seller); most sellers acknowledged that their trading activities were limited to the village. Women's contribution to households income-generation has therefore been increased. Furthermore, income made thanks to sales in the village was unanimously declared by women and men as managed by women even for households where men were registered for the activity. The gap that appeared between quantitative and qualitative studies, and that showed that income had been underestimated for lack of systematic record of income made by women provided evidence that men are actually not always well aware of the amount women could gain with the activity. This certainly testifies to the extent of women's control over income. Since food purchase and preparation is usually managed by women, it also probably explains that money gained is usually reported to be allocated to food.

Leadership in community

Although not specifically mentioned as a community-empowerment indicator by Alkire et al., we found that the knowledge-dissemination role largely played by women within households, families and communities is to be associated with leadership empowerment. Indeed, women who participated in the training have usually shared the knowledge gained within their households and families and also with their neighbors. It seems to us that such outcome of the activity should be considered under or aside the indicator that encompasses the capacity to speak out in public.

Similarly, and as discussed earlier, women seem to have been the main households member involved in sharing food with neighbors. Sharing food being both embedded into daily community life and a manifestation of the social cohesion that exist within communities, we can deduct that increasing women's capacity to share food by increasing food availability is improving women's opportunities to belong to social groups.

Decisionmaking power on time allocation to workload

If we unfortunately lack elements to evaluate how it was converted (or not) into leisure time, we certainly could measure that gardening reduced women's workloads. When questioned about the reason for engaging in home gardening, women actually pointed out that this was one of their two main motivations. Getting food through gardening was indeed unanimously declared *Sroul* (easy) as compared to forestry collection both by women and men.

Compared to time spent collecting vegetables from forest by women, the gain in hours is probably perceived by women as more important than what it is in absolute values. Indeed, on average, women have declared spending 1 hour per day gardening, while when relying only on forestry products, they had to allocate on average 11 hours weekly (about 1:30 hours daily) to it. But, since forest coverage is dramatically declining, time spent finding vegetables is constantly increasing as it involves longer journeys. Moreover, it appears that the burden of the task is much alleviated, watering being less tiring than long walks and work being spread daily in the morning and evening instead of concentrated in two or three days.

Intra households gender-parity improvements

Both men and women also reckoned the gardening task was mainly managed by women. Although men usually gave a hand for heavier work such as fencing and land preparation at the activity inception and played a more secondary role for watering, fertilizing with rice husk biochar, weeding and collecting from the garden were perceived as "women's tasks". Time spent on the activity was on average 3 to 4 days at inception for men and subsequently 1 hour daily for women. As compared to vegetable collection that is exclusively handled by women, home gardening is moving one step forward to gender parity.

CONCLUSION

Benefits derived from these organic home gardens by participating families and communities are numerous. In the first instance, home gardens proved to be a successful strategy to increase food and nutrition security for a marginalized population suffering from a decline of natural resource, on which they used to be dependent. Through home gardens, families had fresh vegetables available at hand and could consume fresh vegetables daily during at least 3 months of the leanest season, in frequencies that nearly match that of the rainy season, when plentiful vegetables are available. Therefore, and even if water tends to run out in April and impedes most families to bridge the gap up to end of the dry season, stability in food supply was certainly improved. This food production increase certainly has had positive nutritional effects as growers consumed a wider diversity of organic and fresh vegetables, resulting in a more balanced diet than previously.

The activity also had positive community outcomes, as food surplus was used as a socialization tool that is known to increase social bounding; meanwhile cohesion at village level has been identified as a way to increase food security.

Growing vegetables also had positive economic impacts for nearly all the families. Most of them managed to save money they had to allocate up to then on vegetable purchases to compensate for forestry resource decline. A significant amount of households also went beyond consumption needs threshold and sold their products. Some of them demonstrated a potential to earn a 13th month of income with plots no bigger than 400m^2. As inputs required are minimal, as farmers are being trained to save their own seeds and as marketing is done on a very short chain that limits transportation, storage and post-harvest losses, high profitability perspectives can be foreseen for this activity.

Last but not least, the activity has empowered women in a range of ways. Women are usually in charge both of garden work and of vegetable trading at village level. Therefore, vegetable production increased their economic power within their families. And since they were able to manage the income autonomously, income made has been preferentially allocated to food. Home gardening also increased their status within their households and their community through improved decision-making power on production activities and, for those who attended training, a dissemination role played towards other villagers. At an individual level, this activity also gave women an opportunity to reduce the time and burden for getting vegetables for consumption. Finally, the workload created by gardening was to some extent shared between women and men whereas previously vegetable collection was exclusively a female task. Altogether, these benefits are partaking in bridging the gender disparities gap, which is certainly needed locally.

Therefore, as the activity is highly environment-friendly, and until more effective[17] options become available and affordable to indigenous peoples, home gardens seem to be a successful coping strategy in the face of the massive transformation that currently affects the province and its food security.

TABLES AND FIGURES

Table 1 : Distribution, amongst the target group, of home garden size (m^2) and income derived from the sale of vegetables (in USD)

Measurements \ Percentile	P1	P25	P50	P75	P100
Home garden size	5	56	100	200	2600
Income in USD	0.50	7.50	13.75	62.50	500.00

[17] supplementation and or fortified food

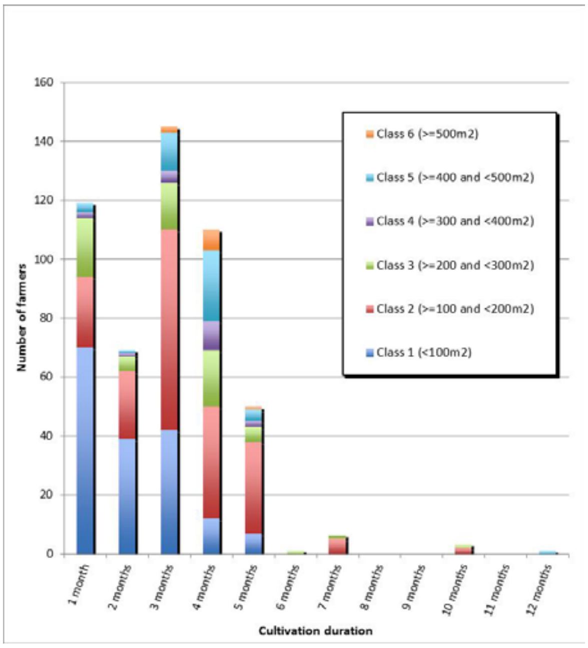

Figure 1: Distribution of farmers according to their land size (in 6 classes) and gardening activity duration (in months per year) among the target group

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Growth and yield of corn as affected by different row inter cropping patterns with indeterminate tomato varieties in Southeastern Ifugao, Philippines

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ABSTRACT
Southeastern Ifugao, Philippines had been monocropping corn for several years, which resulted in soil degradation, environmental pollution and decreased yield. The rapid population growth rate also caused a decrease in the economic family farm unit. Indeterminate tomato intercrop has been shown to provide extra income for subsistence corn farmers. The leaf toxin content and growth habit of indeterminate tomato could help reduce corn borer infestations resulting in increased yield. This study aimed to determine the effect of indeterminate tomato as row intercrops on the growth and yield of corn. The four experimental treatments were conducted in a Randomized Complete Block Design (RCBD) with three replications: T0 - corn without tomato intercrops; T1 - two rows of corn and one row of tomato; T2 - three rows of corn and two rows of tomato; and T3 - four rows of corn and three rows of tomato. Results showed that T2 obtained the least number of corn borer-damaged plants of 9.16 plants per treatment, followed by T1, T3 and T0 resulting in more corn borer-damaged plants with their respective means of 10.54, 12.5 and 17.64 damaged plants per treatment. As to corn yield, T0 outyielded T1, T2 and T3. However, in terms of the combined yield of corn and tomato, higher income was realized per unit area, with T2 producing the highest returns on investment (ROI) followed by T3, T1 and T0 with corresponding ROI of 218.26, 183.74, 179.68 and 41.83, respectively. Based on the results of this study, to increase yield and income, T2 is recommended to corn farmers with limited sized farms.

Keywords
tomato, corn, row intercropping, corn borer, small scale farming

INTRODUCTION
The decrease in the economic family farm unit due to rapid increase in population and urbanization resulted to intensification of land use to increase farm productivity. Southeastern Ifugao, Philippines has not yet reached this situation. However, there is a need to grow other crops with corn because it has been grown for 30 years (2003-2013 as a monocrop in this location. Net profit per hectare of corn is not very attractive nowadays due to high prices of farm inputs, so corn farmers must have to find alternative ways of increasing productivity and income per unit area.

Planting vegetable crops in between rows of corn is of great importance in providing extra income and improving the diets of subsistence farmers. Tomato is highly recommended as a row intercrop for this purpose (DA-LGU 2010). It is considered by vegetable growers as a high value crop and a moneymaker in the

Philippines vegetable industry. High market demand is due to its importance as an ingredient in the preparation of several recipes like *pinakbet*, salad dishes, fish recipes, sandwiches, and many others. The growth habit of an indeterminate tomato variety as row intercrop for corn will enable it to grow without being hampered by the corn plants. Besides, the characteristic odor due to the tomatine content serves as an insect repellent to harmful insects attacking the corn plants. Tomatine, which is synthesized by tomato, functions to protect plants from disease-causing organisms and insects (Koh et al. 2012)

Growing tomato as a row intercrop with corn has a yield advantage over growing corn in pure stands, as shown in a study conducted by Decoteau and Francis (1993) on sweet corn intercropped with peas at different corn plant densities. The seeding rates were low corn, medium corn and high corn densities per hectare. Results showed a higher yield on intercropping than growing in pure stands. Intercropping is a farming system that reduces risks in crops production because the yield from the surviving crop compensates the losses when the main crop fails and the other crop survives. Pest levels are also lowered in intercrops because the diversity of plants hampers the movement of insect pests attacking the main crops.

Voldeng et al. (1997) intercropped corn with soybeans to determine their economic advantages as silage. Results showed that intercropping was more cost effective than pure stands. A slightly higher yield was achieved from full stands of both corn and beans in alternative rows, but the cost of production was higher, thus offsetting the loss in yield.

OBJECTIVE OF THE STUDY

This study was conducted to determine the effect of indeterminate tomato as row intercrops for corn, particularly on the extent of damage by insects on corn, the yield per unit area, and the returns on investment (ROI).

MATERIALS AND METHODS

The study was conducted on a 420 square meter area at the experimental site of the Ifugao State University, municipality of Alfonso Lista, Southeastern Ifugao, Philippines. The experiment was conducted following a Randomized Complete Block Design (RCBD). The area was divided into three equal blocks and each block was further subdivided into four equal plots measuring 7 x 3.6 meters. Each plot represents a treatment and was planted to corn and tomatoes as follows:

T0 Pure stand of corn (no intercrop)
T1 corn + corn + tomato + corn + corn
T2 corn + corn + corn + tomato + tomato +corn + corn + corn
T3 corn + corn + corn + corn + tomato + tomato + tomato + corn + corn + corn + corn

Twenty-one days before planting corn, seeds of tomatoes were sown in seedling trays. A fertilizer mixture rate of 75% organic fertilizer and 25% inorganic fertilizer was applied at the bottom of the furrows and holes before planting. Both corn and tomatoes were applied with urea 21 days after sowing the tomato seeds. Furrows for planting corn and tomato seedlings were set at a distance of 70 cm between rows. The corn seeds and tomato seedlings were planted following the planting pattern as indicated in the treatments. Corn seeds were planted at one seed per hill with a distance of 20 cm along the furrows while tomato seedlings were planted at a distance of 50 cm between plants along the furrows.

Transplanted tomatoes were trellised one week after transplanting. Harvesting was done when the corn plants were 95% mature and the tomato fruits were at their breaker stage. All the harvested ears of sample plants per treatment were composited and placed in one sack and properly labeled to separate it from other treatments. The tomato fruits were harvested and weighed separately per treatment. Harvesting was done at 3-day intervals for a period of 4 weeks.

Sun drying of harvested corn ears was done separately per treatment to facilitate manual threshing. Further drying of the grains was done until a moisture content of 14% was attained.

The vigor of the plants was rated as most vigorous, more vigorous, vigorous, less vigorous and least vigorous. The height of 10 representative corn plants per treatment was measured in cm at 14, 21, 28, 35 and 42 days. Likewise, the weight of 1000 seeds per treatment was recorded for statistical analysis.

The number of corn plants damaged by insects was counted per treatment at 14, 21, 28, 35 days and 42 days after transplanting tomatoes to assess the extent of damage caused by insects on the corn plants. The combined yield of corn and tomato per treatment was recorded on the basis of computing the returns on investment (ROI) per treatment. All data gathered were tabulated and analyzed using the Analysis of Variance for Randomized Complete Block design. The F Test was used to determine the level of significance in all parameters with significant result while ranking was used to evaluate the vigor of the plants.

RESULTS AND DISCUSSION

Vigor of the corn plants

The most vigorous plants were observed to be on the pattern one row of tomatoes planted after every two rows of corn (Table 1). Lesser damage was observed on the corn plants besides the tomato plants, which may be attributed to the repelling odor of the tomatin content of the leaves. The least vigorous were corn plants without tomatoes planted as row intercrops.

Plant height

Figure 1 reveals that growing of tomatoes as row intercrop for corn failed to show any significant difference between treatment means on the height of the corn plants per treatment at the different growth stages of the corn plant. It appears that plants in all treatments were more or less similar in height. Corn plants in Treatment 2 obtained a final mean height of 132.8 cm while plants in Treatment 3 appeared to be the shortest among the treatments with a final mean height of 131.1 cm.

Number of corn plants damaged by corn borer

Table 2 shows that Treatment 0 (pure stand of corn) obtained the highest number of plants damaged by corn borer and aphids followed by those plants in Treatment 2 and Treatment 1. The least number of damaged plants was recorded in Treatment 3. Lesser damage due to corn borer and downy mildew was recorded in corn plants with rows of tomatoes along sides within the rows. More plants were damaged on corn plants in pure stands (Fig. 2).

Result of the study revealed further that tomatoes planted as row intercrops to corn showed a highly significant difference between treatment means, which implies that the different row intercropping patterns reduced the number of plants damaged by corn borer.

Weight of 1000 seeds per treatment

Tomato intercrops significantly affected the weight of 1000 seeds of corn per treatment (Fig. 3). It is clearly indicated the different cropping patterns of tomatoes with corn plants greatly influenced the weight of the harvested seeds per treatment. Treatment 1 obtained the heaviest weight, with a recorded mean weight of 245 g, while Treatment 2 recorded a mean weight of only 172.33 g.

Mean yield per treatment

Result of the study indicated no significant difference between treatment means on the yield of corn in pure stands with those planted with corn in different patterns (Fig. 4). However, there was a remarkable increase on the yield of corn and tomato combined together. The yield of tomatoes greatly increased the income per unit area, with Treatment 2 producing the highest yield in terms of yield of corn and tomato combined together.

COST AND RETURN ANALYSIS

Table 2 provides the data on yield of corn and tomato combined together, the gross income and the expenses from the different cropping patterns, and the returns on investment. Tomatoes planted alongside the rows of corn, whether in single rows or triple rows contributed to the increase in net returns per treatment. It is evident that row intercropping of tomatoes to corn plants is could help corn farmers increase production, because aside from reducing corn borer infestation, the yield is also increased, thus helping small landowners. Of the four treatments, Treatment 2 produced the highest returns on investment of 218.26%, Treatment 0 obtained the lowest ROI of 41.83%.

CONCLUSION

This study shows that row intercropping tomatoes with corn plants showed no significant difference between treatment means on the yield of corn. Corn planted alongside rows of tomatoes resulted in less damage due to tomato intercrops, which served as a repellent to the corn borer, aphids and other insects. Likewise, there was a remarkable increase on the returns on investment for all treatments with tomato intercrops compared to corn in pure stands.

Two rows of tomato as a row intercrop after every three rows of corn is effective in increasing the yield per unit area. It is therefore recommended to farmers to plant two rows of tomatoes after every three rows of corn to minimize damage to corn plants from corn borers and aphids. This practice can help farmers with limited land area to increase their income, and produce a cash crop in time of calamities or corn crop failure.

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Table 1. Vigor of the corn plants

TREATMENT	Vigor	Description
To- pure stand (corn)	4	Least vigorous
T1- c+c+t+c+c	1	Most vigorous
T2- c+c+c+t+t+c+c+c	2	More vigorous
T3- c+c+c+c+t+t+t+c+c+c+c	3	

Table 2. Cost and Return Analysis (25.2 m^2)

Treatments	Yield (kg)		Unit price (Php)		Total Price		Gross Income	Total expenses	Net Income	ROI
	c	t	c	t	c	t				
T0- pure stand of corn	9.16	0	7.60	6.00	69.61	0	20.53	69.61	49.07	41.83
T1- c+c+t+c+c	7.38	27.42	7.60	6.00	56.09	164.52	141.73	220.61	78.88	179.68
T2-c+c+c+t+t+c+c+c	6.77	32.56	7.60	6.00	51.45	195.36	169.26	246.81	77.55	218.26
T3- c+c+c+c+t+t+t+c+c+c+c	6.88	27.76	7.60	6.00	52.29	166.56	141.72	218.85	77.13	183.74

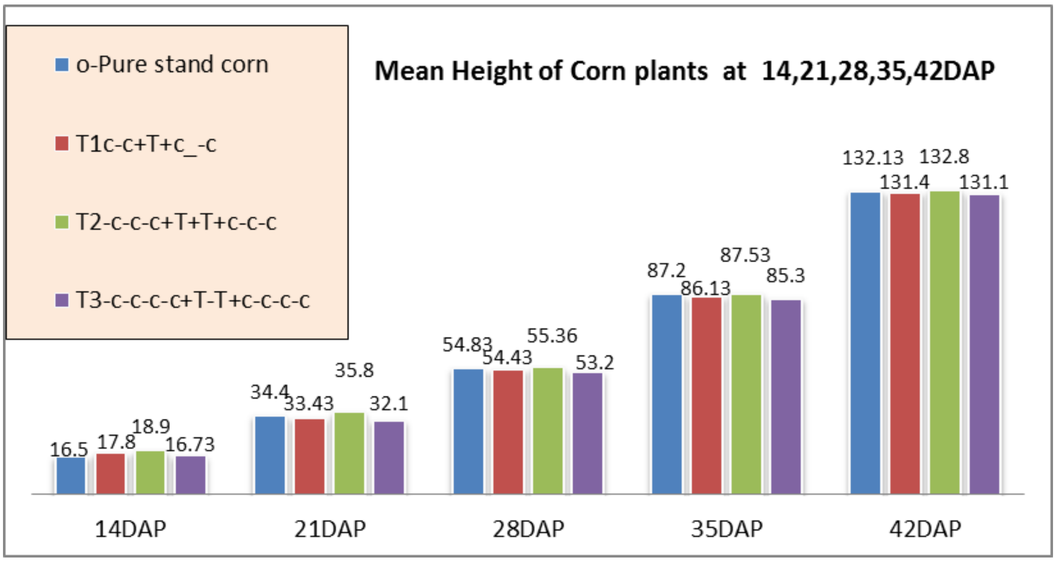

Figure 1. Mean height of corn plants at 14, 21, 28, 35, 42 DAP

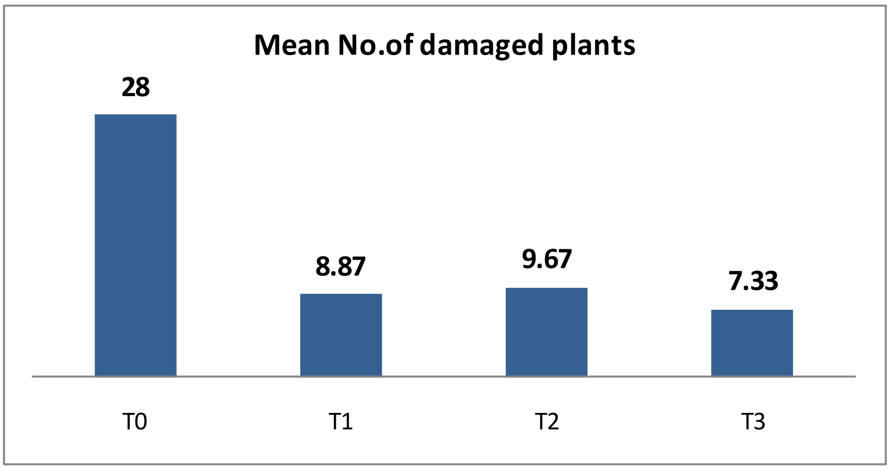

Figure 2. Chart showing the number of corn plants damaged by corn borer

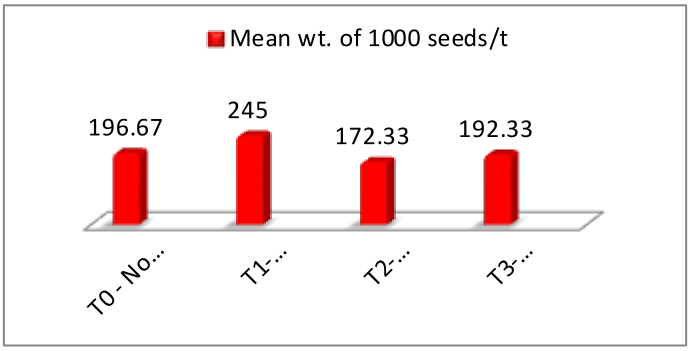

Figure 3. Mean weight of 1000 seeds per treatment

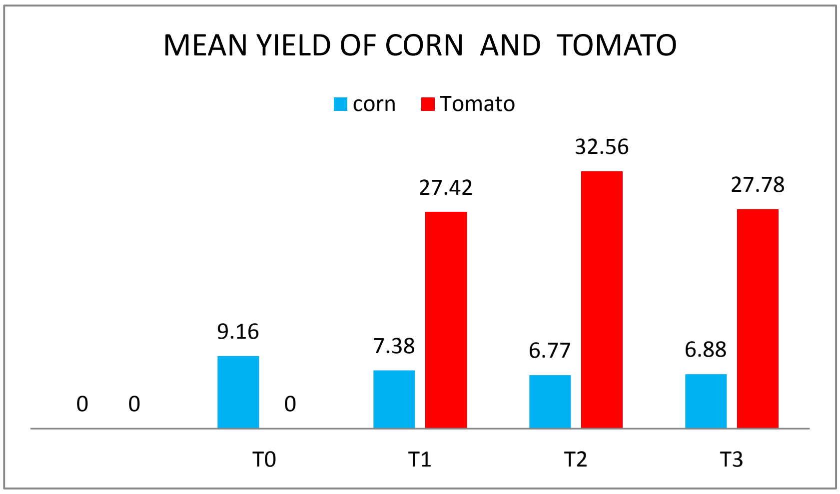

Figure 4. Yield of corn and tomato per treatment combined together

Optimizing home yard spaces for integrated vegetable production: A case study of Bali, Indonesia

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ABSTRACT

Securing food availability in Indonesia requires sustainable food production growth of more than 2% per year. Meanwhile, home yard area that is currently available nationwide is about 10.3 million ha or 14% of the total area of agricultural land. However, people have not optimally exploited their home yards to supply nutritious food for their families. Optimizing available spaces in home yards is one solution that can help solve the food security problem. This study aimed to (1) optimize home yard spaces to integrate vegetables, livestock, and fish; (2) enhance skill of people, especially women, on home yard agricultural production; (3) increase healthy food consumption indicated by expected food pattern value (EFP); and (4) reduce expenses for the family's daily needs, especially for food. The study was conducted during 2012 in Bali Province, covering eight regencies. More than 800 women/families participated as cooperators. The study was conducted on three different subjects: training on organic cultural practices, demonstration plots, and home nursery management.

Commodity groups cultivated by families included about 25 species and/or varieties of vegetables, eight food crops, nine fruits, 25 medicinal and spice crops, four kinds of livestock, and one species of fish. Number and kind of crops planted in each house varied, ranging from three to more than 20 different crops. Half of the families planted 5-10 crops, about 34% planted less than 5 crops, and the rest planted more than 10 crops. People in the community consumed about 17 different vegetables, three of which were consumed daily, whereas the other vegetables were consumed 1-3 times a week. Economic impact of the activities showed family daily savings between IDR 5,000 – IDR 20,000/day/family, equivalent to IDR 150,000 – IDR 600,000 (about US $12.5 - $50) per month. The expected food pattern (EFP, an indicator for composition of foods consumed) value was 82.24, which was higher by 19.46 before optimizing the use of home yard spaces. Optimizing home yard use resulted in significant family daily savings on food expenses, easy access to healthier food, and more proportional food composition, as indicated by greater EFP value.

Keywords

home yard, integrated vegetable production, food security

INTRODUCTION

Increasing agriculture production is constrained by land degradation, climate variability, pest and diseases, declining arable land, high rates of land conversion for infrastructure and housing, and declining yield (Sawit 2008). Industrialization and urbanization have led to increased competition for land and forced agricultural production onto marginal land (Bond et al. 2007b). Declining land area and soil degradation have had a serious impact on agriculture production. Soil degradation is the loss in the productive potential of soil induced by human activities (Mbagwu, 2003).

Further economic growth and industrialization in Indonesia have resulted in a reduction in the contribution of agriculture to GDP, from 49% in 1970 to 13% in 2005. However, the agricultural sector still employs the largest population and the poor, thus playing a primary role in poverty reduction. It is surprising to find that very little effort has been devoted to quantifying the sources of agricultural decline. The only empirical studies evident are for the effects of major price policies as determinants of structural change, separate from those of underlying price trends and the influence of human capital accumulation as a factor in structural change (Martin and Warr 1993; 1994).

Strong income and population growth have resulted in an increase in food demand, yet the growth in domestic rice production, Indonesia's staple food, has slowed since the mid-1990's as the availability of arable land has significantly decreased and yields have contracted. With continued income and population growth, food demand in Indonesia is expected to increase accordingly (Bond et al. 2007a). Furthermore, Bond et al. (2007b) stated that growth in per person income of Indonesian has led to an increase in demand for other food products, especially vegetables, fruit, sugar, beef, dairy products, poultry and seafood. While Indonesia is largely self-sufficient in fruit, poultry, and seafood, imports have become an increasingly important source of vegetables, sugar, beef, and dairy products.

Home yards offer space that could be exploited for agriculture, especially vegetable production for the family. When intensively managed, home yards can contribute to domestic consumption needs as well as household income. Home yards are multifunctional, producing vegetables and fruit, poultry, small livestock, fish, and also herbs, spices and aromatic plants, crafts materials, as well as cash (Sajogyo, 1994). Home yard space available in Indonesia is about 10.3 million hectares, which is equivalent to 14% of total agricultural land. Indonesia's president stated in an October 2010 speech that national food self-sufficiency and food security must begin in the household. The most important advantages of home yards are sustainability of food supply for household members (Salikin 2005). Home yard agriculture has been well known and applied in Nigeria (Ndaeyo 2007) and Bangladesh (Rahman et al. 2009).

Integrating agriculture, livestock and fisheries can make best use of home yards when adjusted to the availability of resources, knowledge, and social behaviour of the local community. However, people, especially women, have not been able to optimally utilize their home yards to provide family food, and often pay less attention to the nutritional value of the food consumed. Studies on the utilization of home yards for agriculture showed that crops and animals in home yards contributed significantly to the family income (Arifin 2010). Monthly revenue earned from the home yard in Sambirejo village, Yogyakarta, for instance, ranged from IDR 335,000 to IDR 2,246,428 or about US$28-$187 (Rahayu 2010). With better management, home yards can provide revenue up to IDR 3,236,821 (about US $270) per month or IDR 38,841,848 (US $3,237) per year (Mardiyanto 2009). Home yards can be promoted as an effective resource to support food security programs in urban as well as rural areas.

Integrated agriculture in home yards contributes to the family income and food sufficiency, and also provides healthier food and better balanced diets. Careful management of home yards can produce continuous yields and additional value, providing family food sufficiency and increasing family revenue.

RESEARCH METHOD

Target groups

The study was conducted during 2012 in eight regencies in Bali Province. Target groups were village women's organizations. Each village was represented by one group, which had from 25 to 50 women. All members from each group were the main cooperators, beyond those many women/families that actively participated in the project. More than 800 women/families were involved in the project. Those households were from eight districts, ranging from 25 to 200 households in each district.

Partners

This project collaborated with other institutions, such as Agricultural Extension Services (*Dinas Pertanian*) both at the province and regency level, field extension workers, NGOs, and Food Security Office (*Kantor Ketahanan Pangan*), with the aim of creating synergy among all partners.

Activities

The activities were conducted simultaneously on three different topics:

1. Training on organic cultural practices

Target groups (cooperators only) were trained in organic vegetable and food production, livestock and fish farming techniques, waste management, environmental safety, and integrated farming prior to field implementation. Aside from the training, we also discussed any important concerns that cooperators might encounter in their home yards. Experts taught each section of the training. Many constraints to crop production were discussed, but the most interesting subjects were pests and diseases and their control using botanical pesticides.

2. Demonstration plots

Demonstration plots were arranged in accordance with the space availability and location. Availability of space related to appropriate technologies was applied, for examples, verticulture for small-scale spaces; livestock and fish farming for large-scale spaces. Demonstration plots were usually set in public places where people often gathered, such as schools, village halls, headman's office, etc. The demonstration plots were expected to entice people in the community to voluntary participate and support the home yard activities. About 10 – 20 houses and one or two public places were considered as demonstration plots. Crops planted in the demonstration plots were prioritized local varieties, and others were open-pollinated crops. Numbers of crops (kinds or species/varieties) planted were in accordance with local preferences.

3. Home nurseries

Home nurseries were built on community or personal land in each village to continuously supply seed and/or seedlings to the community. Cooperators were trained in nursery management and simple techniques to produce seeds and seedlings of common crops preferred in the community.

Collecting data

Data were collected through direct observations and a survey. Data recorded included diversity of crops planted in home yards, growth variables, yields, food consumption, and EFP (Expected Food Pattern). EFP is a calculation of the food consumed through the contribution of energy of each food group to fulfil the needs of nutrition, both in quality and quantity. The maximum value of EFP is 100; it means that composition of foods is proportional or very healthy.

RESULTS AND DISCUSSION

Training on organic cultural practices

Training on organic cultural practices began from media preparation, seedling preparation, planting, crop maintenance, harvesting, and saving seeds. Media preparation was introduced at the same time with seedling preparation, followed by planting crops. At the beginning of the project, training was conducted every week; after the cooperators became familiar with cultivation techniques, training was conducted only when necessary. One crop maintenance person was trained to provide botanical pesticides based on local resources.

Demonstration plots

The demonstration plots included vegetables (4 groups), beans and nuts, tubers, medicinal crops, fruit crops, estate crops, poultry, and fish (Table 1). However, the number of crops (kinds or species/varieties) grown in each home yard were not the same due to individual preferences. Among the vegetables, eggplant, chili, and tomato were the most preferred by all families (Fig. 1). The number of kinds/species of plants grown in each household ranged from 3 up to more than 20, but most grew 5 kinds/species (26%), followed by 4 kinds/species (20%), 3 kinds/species (14%), and 6 kinds/species (10%) (Fig. 2). This may be related to the knowledge and experience of each cooperator. Each family preferred particular crops. Spaces utilized in household yards for integrated vegetable production varied from 30% to 68%.

Home nurseries

Development of home nurseries was an important breakthrough. Home nurseries continuously produce seeds and seedlings that can be easily distributed to the community. Local people in community (cooperators or not) can get seeds or seedlings for free, but people from other villages have to pay. Home nurseries also functioned as field schools.

Consumption

Data from the consumption survey indicated that rice is the most common food items consumed by most people in Bali, about 1–2 kg per household (average 1.39 kg/household/day). Average per capita consumption of rice reached 326 g/day, equivalent to 117.4 kg/yr. This number is still higher than the national rice consumption level in 2011 (113 kg/yr; BPS 2012). Other carbohydrate sources from tubers were also consumed, such as sweet potato, cassava, taro, and potato. These results indicated that the diversification of food has become a habit, although rice is still the main food.

For protein, Balinese people consume meat, fish, eggs, tofu, and tempe. Among these protein sources, fish is the most consumed; consumption of fish is about double the consumption of meat, eggs, tofu, and tempe. The type of fish consumed varies, and includes cob, anchovies, catfish, carp, and shrimp.

For vitamins, minerals and fiber, Balinese people consume about 17 different vegetables, 5 of which were consumed by all respondents, 9 were consumed by more than 50% of respondents, and the remaining 3 consumed by less than 50% of respondents (Table 2). Onion, garlic, and hot chili were consumed every day, while other vegetable were consumed only 1-3 times a week. Although onion, garlic, and hot chili were consumed every day, the volume was relatively small (less than 100 g). Based on volume, kangkong is the most widely consumed vegetable, followed by eggplant and cassava leaves. The least consumed vegetables were red chili, followed by cucumbers, beans, and bean sprouts.

Optimizing home yards for agriculture can save household expenses and lead to higher EFP value. Households saved between IDR 5,000–IDR 20.000/day/household or equivalent to IDR 150,000–IDR 600,000 (about US $12.5 - $50) per month, with an increase in EFP value from 62.78 to 82.24 (+19.46). Achievement of this EFP has exceeded the national EFP, which is only 75.70. Meanwhile, Saliem (2011) reported that house yards in Kayen Village, East Java were able to save household expenses of IDR 125,000–IDR 445,000 (about US $10-$37) per month, with an EFP of 87.5.

CONCLUSION

Optimizing home yard spaces for integrated vegetable production in Bali can contribute to saving family expenses on food purchases and diversifying diets for healthier food consumption. Savings of up to US $50/month/family (US $600/year) can be realized. Healthier food consumption was reflected by the increased EFP value from 62.78 to 82.24.

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Table 1. Diversity of crops, livestock, and fish in Bali home yards

No.	Commodity Group	Kinds/Species	Number of Kinds/Species
1.	Fruit vegetable	eggplant, tomato, hot chili, red chili, zukini, corn	6
2.	Leafy vegetable	caisim, kangkong, pakchoy, mustard, lettuce, spinach, basil, moringa	8
3.	Flowered vegetable	cabbage, cauliflower, broccoli	3
4.	Vine vegetable	cucumber, winged bean, bitter gourd, eel gourd	4
5.	Beans/Nuts	jack bean, cowpea, yard-long bean, pigeon pea	4
6.	Tubers	sweet potatoes, cassava, taro, potatoes, carrots, onions, garlic	7
7.	Medicinal crops	citronella, powder, turmeric, galangal, ginger, rosella, etc.	25
8.	Fruit crops	banana, mango, citrus, soursop, kepundung, jackfruit, pineapple, lanzones, rambutan	9
9.	Estate crops/annual	coconut, areca, bamboo, palm, albizia	5
10.	Poultry	domestic poultry, pigs, cows, ducks	4
11.	Fish	catfish	1

Table 2. Vegetable consumption preferences in Bali Province

No.	Vegetable	Volume of consumption (g)	Frequency/ week	Preference
1.	Kangkong	466.41	2	100.00%
2.	Eggplant	463.52	2	100.00%
3.	Onion	241.33	7	100.00%
4.	Garlic	120.92	7	100.00%
5.	Hot Chili	61.92	7	100.00%
6.	Spinach	187.26	2	85.71%
7.	Yard-long bean	255.10	1	85.71%
8.	Tomato	194.01	2	85.71%
9.	Cassava leaf	343.88	1	85.71%
10.	Cabbage	327.38	2	78.57%
12.	White mustard	339.29	1	71.43%
13.	Caisim	273.21	3	71.43%
11.	Young jack fruit	188.78	1	57.14%
14.	Cucumber	29.17	1	50.00%
15.	Red Chili	7.67	2	35.71%
16.	Snaps bean	46.43	1	21.43%
17.	Beansprouts	46.43	1	14.29%

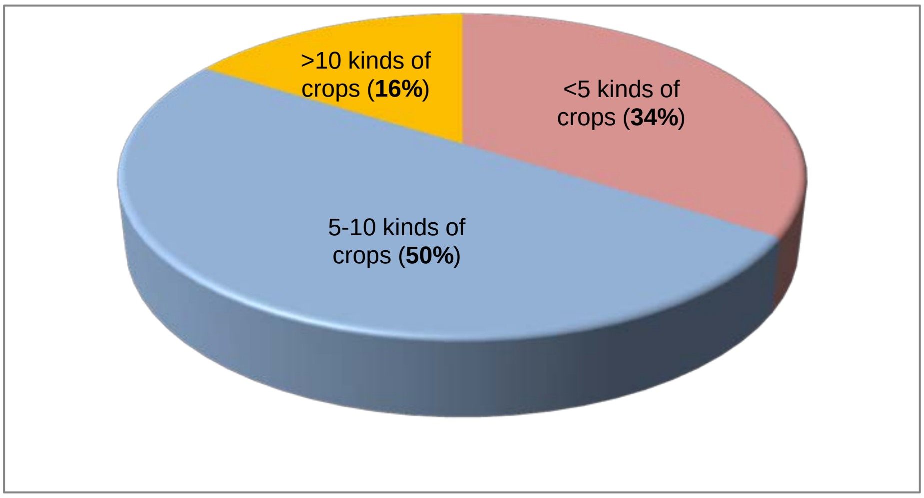

Figure 1. Number of kinds/species of crops grown in each household in Bali.

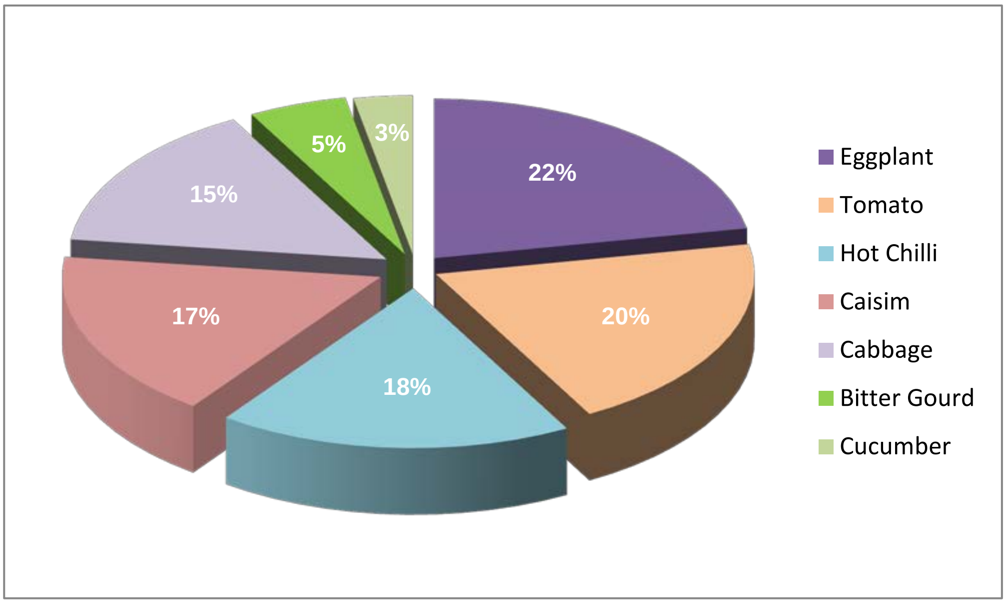

Figure 2. Preference of vegetable crops planted by cooperators in Bali.

Trained Master Gardeners promoting vegetable production in urban households and schools

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ABSTRACT

The Master Gardener of Greater Kansas City is a University of Missouri Extension program serving Jackson, Clay, Platte and Cass Counties of Missouri, USA. The program started around 1990. The Master Gardener program is a popular volunteer program throughout the United States and Canada. The Master Gardener Program was started to meet a high demand for urban horticulture and gardening advice. Thousands of people across the United States have been trained as Master Gardener volunteers. It is a two-part educational effort, in which gardeners are provided many hours of in-depth horticulture training, and in return they help local university extension agents through volunteerism. Master Gardeners assist with garden lectures, exhibits, demonstrations, school and community gardening, phone diagnostic service, research, and many other projects in urban and suburban areas.

During the last few years, the demand for information and skills on vegetable production in urban households and public schools has increased considerably as a result of the increased interest in healthy local food. The Master Gardeners are increasingly involved with Kansas City midtown and downtown residents, especially among the minority population and public schools. Part of the Kansas City midtown and downtown areas are designated as food deserts, because these areas are devoid of grocery stores and quality foods, including fresh vegetables and fruits at affordable prices. With the help of vegetable demonstration gardens, community gardens and school gardens, the Master Gardeners are promoting small scale home and school vegetable production for consumption.

Keywords

Master Gardeners, volunteers, research-based knowledge, nutrition garden volunteers, vegetable garden

INTRODUCTION

The Master Gardeners of Greater Kansas City program provides the metropolitan Kansas City area with information, suggested solutions to current or anticipated problems, demonstrations, and programs designed to educate the public about gardening topics. The Master Gardeners of Greater Kansas City are especially interested in providing environmentally sound, responsible, and reliable information to the public based on research and approved practice.

The Master Gardeners of Greater Kansas City program is an important liaison between the University of Missouri and the public and intends to provide access to the information resources of the university. The primary propose of the University of Missouri is to serve the people of Missouri by reaching out and extending research-based knowledge and resources from the University of Missouri system throughout the state. The metropolitan Kansas City area includes a large and diverse urban, suburban, and rural area, and encompasses the four Missouri counties of Cass, Clay, Jackson, and Platte.

Prospective Master Gardeners are required to attend a course in home horticulture, taught by University of Missouri faculty and other qualified professionals. Classes meet for approximately three hours, one day per week for 16 weeks. The subject covered are introduction to soil, introduction to plants, home lawn, woody ornamental, ornamental perennials, vegetable production, fruit production, trees, garden insects, plant diseases, plant propagation, annual flowers, organic gardening and basic landscaping. Prior to training, prospective Master Gardeners have to go through an application process and orientation. They also sign a volunteer agreement form. After completion of training, they provide 45 hours of volunteer time to become certified volunteers and thereafter they have to provide 25 hours of volunteer time and 6 hours of continuing education to maintain their certification every year.

After completion of training, Master Gardeners help their local university extension agent provide home gardening information to public through various activities such as the hotline (telephone/e-mail), giving talks on diverse gardening subjects at various organizations and local garden clubs in the community. Master Gardeners also volunteer at program sponsored community gardens, demonstrations gardens, school gardens and other partner-sponsored gardens, providing hands-on help and training. They also participate in gardening events such as flower, lawn and garden shows, health shows and provide gardening information. Master Gardeners are also involved in fund raising through a garden tour and a plant sale for their program.

In 2012, Master Gardener volunteers answered more than 2114 hotline calls and gave 67 talks and provided unbiased, research based information on home gardening topics. They distributed more than 1,000 University of Missouri Extension technical guide sheets. The 321 Master Gardeners donated more than 19,529 hours of volunteer service. A total of 29 new volunteers were trained.

DEMAND FOR INFORMATION AND SKILLS ON VEGETABLE PRODUCTION

During the last few years, the demand for information and skills on vegetable production in urban households and public schools has increased considerably as result of increased interest in healthy local food. Urban agriculture is one component of local food systems, and includes community gardens, commercial gardens, community supported agriculture, farmer’s markets, personal gardens and school gardens. The Kansas City metropolitan area has seen tremendous growth of urban agriculture activates in the last few years. Community gardens and non-profit “partner” gardens associated with Kansas City Community Gardens have increased from 125 in year 2010 to 230 in 2013, school gardens have increased from 80 in year 2010 to 140 in 2013, and urban farms have increase from 74 in year 2008 to 125 in 2013 (Horsley 2013).

The decline in city populations due to massive flight to suburban areas is very common in the USA. Consequently, cities have had significant housing vacancies. As vacant houses fall into disrepair they are often demolished, thereby becoming vacant lots. The decline in urban population has resulted in poor infrastructure and services. Approximately 23.3 million Americans, including more 6 million children, live in impoverished areas with no access to quality food choices. Many neighborhoods in Kansas City have been labeled food deserts. According to USDA, food deserts are defined as urban neighborhoods and rural towns without ready access to fresh healthy and affordable food. In Jackson County, Missouri 36,713 residents are living more than one mile from a grocery store (USDA Food Environmental Atlas). Many people living in food deserts lack the means, resources, and information necessary to properly nourish themselves. Many cities are promoting urban agriculture and community gardens in vacant lots to improve the supply of fresh vegetables to residents. In Kansas City, the Master Gardeners are helping in this effort. The Master Gardener's 325 m^2 demonstration garden in the Ivanhoe neighborhood vacant lot produced 625 kg of vegetables in 2011, 503 kg in 2012 and 507 kg in 2013. With the help of this demonstration garden, a small weekly farmers' market has been attracting an average of 10-15 neighborhood residents per week. Master Gardeners provide workshops at this garden on a regular basis. For this effort, Master Gardeners received the President's Award in 2012 from the Ivanhoe Neighborhood Council.

MASTER GARDENER VOLUNTEERS PROMOTE VEGETABLE PRODUCTION IN URBAN HOUSEHOLDS AND SCHOOLS

Besides providing home gardening information through the hotline and Speakers' Bureau, the Master Gardeners are involved in the following community projects to promote vegetable production in urban households and schools:

18 Broadway is a sustainability demonstration site in the heart of Kansas City, featuring renewable energy, storm water management, and food production. More than 120 production beds (10 ft x 4 ft) are maintained on site by volunteers from various organizations, including the Master Gardeners of Greater Kansas City. The Master Gardener volunteers have 10 production beds that are mainly used as demonstration beds for teaching other volunteers.

Atkins-Johnson Farm and Museum is a 22-acre farmstead located on the eastern edge of Gladstone, MO. The Master Gardeners of Kansas City have partnered with Atkins-Johnson farm and the City of Gladstone to establish a heritage garden to produce vegetables, herbs and flowers grown before the 1900s for demonstration and education to visitors.

Blue Springs Community Gardens is located in downtown Blue Springs. There are approximately 50 beds (10 ft x 10 ft). The Master Gardener volunteers have 3 production beds mainly used as demonstration beds for teaching other community garden members.

Kansas City Community Gardens is located in the heart of Kansas City. The area surrounding the garden is designated as a food deserts The main objective of Kansas City Community Gardens is to promote community gardening for low income residents. Master Gardeners have adopted 2 plots (20 ft x 25 ft) for the purpose of demonstration and education. New crops and varieties are grown every season to demonstrate the suitability of various crops and varieties in the Kansas City area for the benefit of community garden members.

Harvesters Demonstration Garden is also located in the heart of Kansas City in a food desert. It is a unique garden at the Harvesters Food Bank. Harvesters is a clearinghouse for the collection and distribution of food and related household products to underserved populations. Volunteers have used everyday materials to build a low cost fruit and vegetable garden. Food bank clients and visitors tour the garden to learn about inexpensive methods to grow their own food. Harvest from the garden is distributed by the food bank.

Ivanhoe Demonstration Garden is located in the heart of Kansas City in a food desert. Master Gardener volunteers built a large demonstration vegetable garden in the Ivanhoe neighborhood at 3700 Woodland in a vacant lot next to the Ivanhoe Community Center. The main objective of this garden is to demonstrate to residents how to grow healthy food with minimal expense. The neighborhood has donated the land and watering system for the development of this garden. Residents are encouraged to participate in all gardening activities and training classes organized by the volunteers.

Pendleton Heights Demonstration Garden was started in spring 2013 in a vacant lot with the help of Pendleton neighborhood volunteers and Master Gardener volunteers. Pendleton neighborhood is also designated as a food desert. The city donated the land and the neighborhood association installed the water system. The garden has a range of fruit and vegetables plots that demonstrate to residents how to grow healthy food with minimal expense. Master Gardeners provide classes and participate in education opportunities at neighborhood events. Two neighborhood elementary schools, Scuola Vita Nuova and Garfield, are located nearby and participate in the University of Missouri Extension sponsored Eating from the Garden Program.

Platte County Community Gardens is located in the northern part of Kansas City. This community garden is a partnership between the Master Gardeners, the YMCA and The National Golf Course. The 36 plots are open to the public with the YMCA administering the program. The National Golf Course donated the land, the fence and the watering system. Master Gardeners have four demonstration plots and harvests from these plots are donated to charity. Additionally the Master Gardeners offer classes and workshops for the plot holders.

Urban Green Dreams is an urban garden in a vacant lot sponsored by Master Gardeners, neighborhood volunteers and Kansas City Power and Light (KCP&L) in Palestine of Kansas City, which is designated as a food desert. The main objective of this garden is to promote vegetable and fruit production for local consumption and to expose children to locally grown vegetables.

Watkins Woolen Mill Kitchen Garden is located in the northern part of Kansas City, inside the Watkins Woolen Mill State Park. The heritage 1860 kitchen garden include herbs, flowers, fruits and vegetables. The main objective of the garden is to demonstrate to visitors the type and varieties of vegetables that were grown during the 20th century. Master Gardeners plan, plant and maintain the garden alongside state park staff. Master Gardeners also help in organizing two fun and educational events for the public: namely, Spring on the Farm and Fall on the Farm. Master Gardeners also help in heirloom seed collection.

EATING FROM THE GARDEN

The goal of Eating from the Garden is to reduce the risk of overweight in youth (Enrich 2011) by encouraging them to eat more fruit and vegetables and to make healthier food choices for meals and snacks. The Eating from the Garden program is implemented in 40 schools and community centers and reaches approximately 2000 elementary students.

The program was started by the University of Missouri Extension's Family Nutrition Education Program (FENEP), in conjunction with the Master Gardeners of Greater Kansas City. The program got a major boost when it received a Healthy Lifestyle grant of more than one million dollars from the Health Care Foundation of Greater Kansas City.

The Eating from the Garden curriculum has been developed for grades 4 and 5 and has been published by the University of Missouri. Trained Nutrition Garden volunteers deliver the program.

Nutrition Garden Volunteers are an important component of the program. The volunteers and teachers and /or site coordinators receive 30 hours of training in nutrition and gardening. The subjects covered include: introduction to nutrition and healthy eating, food safety, introduction to plants and soil, fruit and vegetable production, and practical horticulture. Volunteers are expected to return at least 30 hours of time per year with the schools and community centers to implement the program. Many Master Gardeners have participated in this training and supported this program.

As part of this program, students plant and maintain an outdoor vegetable garden, and engage in numerous hands-on activities related to nutrition and plant science/horticulture, including growing seedlings indoors using a grow light. They are also able to taste fresh fruit and vegetables and are introduced to food safety and food handling practices.

CONCLUSION

This paper provides background information about the Master Gardeners of Greater Kansas City. It is a University of Missouri Extension program serving Jackson, Clay, Platte and Cass Counties of Missouri, USA. It is a two-part educational effort, in which gardeners are provided many hours of in-depth horticulture training and in return they help local university extension agents promote horticulture education through volunteerism. Trained Master Gardeners are promoting vegetable production in urban households and schools through many demonstration plots around the Kansas City metropolitan area. This popular program could be adapted and used in other parts of world, especially in developing countries where there is a shortage of trained extension agents.

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An agronomic and economic study of plastic shelters for tomato production during the hot season in Kediri, East Java, Indonesia

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ABSTRACT
Production of tomatoes during the hot-wet season in tropical climates is limited by unfavorable conditions such as high temperature, flooding, strong winds and high incidence of diseases. These conditions can significantly reduce tomato yields. Shading will reduce incoming radiation, but it may decrease production or quality. This study aimed to understand the effects of plastic shelters. The study was conducted in Kayen Kidul Subdistrict, Kediri District, East Java during July to November 2013. There were three treatments: farmers' practices, integrated pest management practices, and plastic shelters, in three locations as replications. 'Timoti,' a tomato variety usually grown by farmers, was selected. Financial and agronomic aspects including plant height, number of leaves, percentage of disease and tomato production were used as performance measures. The study showed that tomato plants under plastic shelters grew higher and better in terms of number of leaves than those without plastic shelters. Tomatoes under plastic shelters showed a lower level of viral disease incidence. Financially, tomatoes under plastic shelters required higher cost, but the profit almost doubled compared to those without plastic shelters, due to a higher level of fruit production.

Keywords
plastic shelter, tomato production, integrated pest management, hot season

INTRODUCTION
Tomato is one of the most popular vegetables for Indonesians due to its fresh and slightly acidic favor. Furthermore, ripe tomatoes contribute vitamin A, vitamin C, and small amount of vitamin B to the diet. However, compared to watermelon, tomato contains 2-3 times more vitamin B. Tomato is a horticultural commodity with high economic value. Nevertheless, it still benefits from improvement in production practices and quality. Tomato production in Indonesia is constrained by hard soils, poor micronutrients and hormones, imbalanced fertilization, pests and diseases, the effects of weather and climate, and cultivation techniques of farmers. Farmers apply pesticides intensively to reduce the tomato crop loss from pests and diseases. They typically use pesticides or a mixture of several pesticides with a dose that exceeds the

recommendation, which can be harmful to the farmer, the environment and consumers. Integrated pest management (IPM) is an approach to integrate crop protection based on ecological and economic considerations. The concept of IPM does not merely increase production but also environmental conservation. According to the Environmental Protection Agency (2013), IPM is an effective and environmentally sensitive approach to pest management that relies on a combination of reasonable practices. IPM programs use comprehensive information on the life cycles of pests and their interaction with the environment. This information, in combination with available pest control methods, is used to manage pest damage by the most economical means, and with the least possible hazard to people, property, and the environment.

As the number of communities that cultivate tomato plants increase, they require improved cultivation techniques. Shade to protect tomato plants from direct sunlight is one factor that can improve tomato production in the tropics and subtropics. Shade structures can be prepared by making a plastic tunnel from plastic mulch or fabric (Erwin 2012). According to Palada and others (no year), production of tomatoes during the hot-wet season in tropical and subtropical climates is limited by unfavorable conditions such as high temperature, flooding, strong winds, and high incidence of disease. These conditions can significantly reduce tomato yields. High temperatures cause high evaporation from plants, and the soil water is reduced.

Rain shelters generally consist of a frame covered with polyethylene film or rigid plastic panels on the top, and possibly screened on the sides and ends. Rain shelters usually do not contain active heating or cooling devices, and do not have electrical power. However, irrigation is often used. Lumber and metal are the most common framing materials. Plastic materials such as PVC pipe and locally available materials such as bamboo have been used as framing materials (Kratky 2006). Protective structures shield plants against temperature extremes, heavy rainfall or hot climates, and also help protect plants from biotic stress due to pests and diseases. Protective cultivation for off-season vegetable production in hot or wet climates in the tropics is becoming important and popular worldwide. According to Mat Sharif and others (2008), the internal environment of a plastic shelter depends on radiant heat received by the structure; excessive radiation will cause heat stress to the plants and depress the physiological functions. This excessive heat must be removed through proper ventilation. Environmental patterns can be used to determine the strategic steps in controlling the effects of heat stress and to design more effective environmental control systems. The objective of this experiment was to compare the agronomic and economic study effects of shelter shade treatments and IPM treatments with the habits of farmers for tomato production during the hot season in East Java, Indonesia.

METHODS

The research was conducted in the subdistrict of Kayen Kidul in Kediri district. The elevation is about 95 m above sea level. The research was conducted from July to November 2013. The research design used a randomized complete block design (RCBD) with three treatments and three replications. The treatments included farmers' practices, IPM practices, and UV-resistant plastic shelters. The study selected 'Timoti' tomato, which was commonly grown by farmers. Farming with farmers' practices was considered as control check, compared to two recommended treatments.

Agronomic indicators included plant height, percentage of pest attack and production. Economic analysis of farming followed the procedure of Soedarsono (1992). Production cost included rental land, labor cost and material costs. Costs and revenue ware calculated at prevailing market prices. Following Gomez and Gomez (1984), the indicators were analyzed using analysis of variance (ANOVA) and the least significant difference at 0.05 standard error for mean comparison of each treatment.

RESULTS AND DISCUSSION

Table 1 shows the development of tomato. Up to 21 days after transplanting (dat), there was no difference in plant height. Starting at 28 DAT, tomato under plastic shelter was highest among treatments. The tomato with farmers' practices and IPM practices showed no significant differences. However, at 56 DAT the IPM treatment showed a significant difference in tomato plant height. Figure 1 provides a visual description of tomato development in terms of plant height.

A shelter covered with a transparent UV stabilized low density polyethylene film of 200 micron thickness created a microclimate inside the tent by regulating temperature, relative humidity and partially cutting ultraviolet rays (Athul 2012). These shelters serve to reduce sunlight intensity. Excessive sunlight interferes with the development of chlorophyll cells. Kamaluddin and Grace (1992) demonstrated that shade leaves increased their chlorophyll per unit area and leaf thickness when transferred from 40 µmol. ppF $m^{-2}s^{-1}$ to 1200 µmol. ppF $m^{-2}s^{-1}$ in *Bischofa javanica* Blume. Evidence exists concerning cell wall degradation of existing leaf tissue as an acclimation from high light.

Table 1. Plant height of tomato (cm)

	Age (day after transplanting)							
Treatment	7	14	21	28	35	42	49	56
Farmers' practices	7.0a	7.4a	10.0b	15.0a	18.1a	21.0a	26.2a	30.3a
IPM practices	7.0a	7.0a	11.0ab	15.0a	18.2a	21.0a	26.4a	31.3b
Plastic shelter	7.0a	8.0a	11.6a	17.2b	22.0b	23.6b	29.8b	36.3c

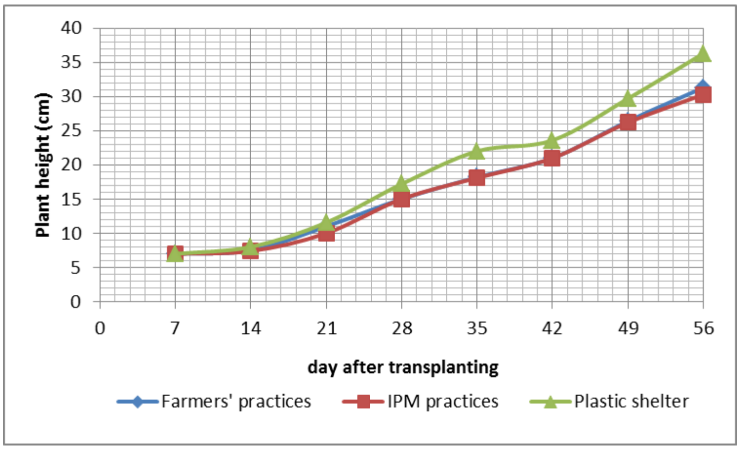

Figure 1. Plant growth

Table 2 shows the implementation of this IPM in the early growth up to 39 days after transplanting. The IPM and shelter treatment at the age of 25 to 39 DAT decreased the number of thrips. Compared to the other treatment (farm habit) during that period, the population of thrips increased as well as the percentage of intensity of their attacks. After 39 up to 50 DAT, the percentage of virus attack was not increased for all treatments. The lowest percentage of virus attack was in tomato plants that receive IPM treatment followed by shelter protection, and the highest attack percentage was in the farmers' practices treatment.

Table 2. Disease and population attack percentage of plant pest organisms

		Treatments					
		IPM		Non IPM		Shelter	
Age (dat)	Pests and diseases	Intensity (%)	Pop (number)	Intensity (%)	Pop (number)	Intensity (%)	Pop (number)
10		0	0	0	0	0	0
25	Thrips	5	30	7	35	6	40
39	Thrips	5	16	8	40	6	20
39	Viruses	10		15		5	
50	Viruses	10		15		5	

Table 3 shows the level of production. There is significant difference in production. The highest production was given by plastic shelters. At the beginning of harvesting season, the number of fruits was almost the same, because tomato plants under plastic shelters had a longer life than other treatments.

Table 3. Tomato production

Treatment	Production (kg/plot)
Farmers' practices	61.833a
IPM practices	65.867b
Plastic shelters	77.467c

Plastic shelters also reduce soil temperatures. If the soil temperature is too high, it decreases photosynthesis, translocation and accumulation of photosynthetic from source organ to organ recipients as well as increasing cellular respiration, which will eventually reduce photosynthesis. Nanggroe (2011) studies of pepper plants showed optimal agroclimatic conditions such as high relative humidity, low temperature, and optimum pH value, as well as low light intensity as a result of providing shade. Shade reduced falling flowers and fruit, and increased the productivity and quality of bell pepper (as seen from fruit weight, fruit diameter, fruit length, fruit water content and total sugar content). The use of plastic shelters gave the best results in some instances. According to Midmore et al. (1997) management practices such as application of fruit set regulator, protection structures, and shading may improve productivity of tomato under hot wet conditions.

Table 4 shows the economic aspect of each treatment. In absolute value, tomato under plastic shelters provided the highest income. But, in terms of investment, tomato farming with IPM practices was the best, which was shown by the highest R-C ratio. Priced at Rp 2,500/kg, the total production of this treatment gave the most significant result. Lower R-C ratio of plastic shelters was due to the purchase of UV-resistant plastic sheeting, which is more expensive (See appendix for component of costs).

The highest result of the R-C ratio was IPM treatment, followed by the plastic shelter and farmers' practices treatments. IPM treatment indicated the highest R/C.

According to Sharma et al. (2012), global warming is as a major threat for all living beings on the earth. Agriculture plays a significant role in global warming because of the large quantities of chemical fertilizers and pesticides used to increase yield. Increasing use of nitrogen fertilizer, which is added at a rate of 1 billion tons per year, contributes to the already existing amount of reactive nitrogen. IPM is one of the most suitable programs for reducing chemical use.

The R-C ratio of 2.2 resulting from the IPM treatment means that every investment of Rp will generate Rp 2.2. R-C ratio obtained ranged from 1.94 to 2.2, which indicates that the RC-value ratio is greater than 1, meaning farming is profitable. The price of a technology is an important determinant in a farmers' decision to adopt it. At present, a huge amount of pesticide supply comes from the public sector, often provided at subsidized prices under IPM programs. The evidence shows that the benefits of IPM adoption are marginally higher than conventional chemical pest control (Birthal 2003).

Table 4. Financial aspects (per 0.1 ha basis)

Description	Cost (Rp)		
	IPM practices	Farmers' practices	Plastic shelter
Total Cost	449,100	509,100	573,900
Revenue	988,005	927,495	1,162,005
Profit	538,905	448,590	588,105
R-C Ratio	2.20	1.82	2.02

CONCLUSION

Tomato grown under UV-resistant plastic shelters has the highest rate of plant growth compared to other treatments. This treatment also provided the highest production rate and absolute profit. However, in terms of R-C ratio, the IPM practices treatment was the most profitable. This is because there is an initial investment required for plastic shelter materials. Thus, in terms of investment, tomato farming with IPM practices was the best. In terms of the amount of profit, plastic shelters were the highest.

ACKNOWLEDGMENT

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Appendix: Component of costs

Description	IPM practices		Farmers' practices		Plastic shelter	
	Volume	Value (Rp)	Volume	Value (Rp)	Volume	Value (Rp)
Rental land	60 m^2	65000	60 m^2	65000	60 m^2	65000
Land preparation		80000		80000		80000
Organic fertilizer	70 kg	35000	70 kg	35000	70 kg	35000
Plastic mulch	1.6 kg	3200	0.8 kg	35200		
Labor for mulching		30000		30000		
Bamboo stick		10000		10000		
Seedling	162 unit	32400	162 unit	32400	162 unit	32400
Labor for planting		30000		30000		30000
Phonska fertilizer			6 times	45000	6 times	45000
Labor for stacking		20000		10000	20000	
Pesticides		15000		51000		51000
Labor for spraying		50000		60000		60000
Labor for weeding		2500		2500		2500
Irrigation cost		15000		15000		15000
Rope and labor		8000		8000		8000
UV-resistant plastic					6 kg	100000
Bamboo						20000
Power plug shelter						30000
Biological agents		21000		0		0
Total Cost		449100		509100		573900
Production	395202	988005	370998	927495	464802	1162005
Price	2500		2500			
Profit		538905		448590		588105
R-C Ratio		2.20		1.82		2.02

Role of vegetables for solving micronutrient deficiency (hidden hunger) in Bangladesh

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ABSTRACT

Nutritional deficiencies have long been a problem in Bangladesh. Out of a population of 140 million, about 1.5 million are hungry (deficient in calories and protein), 40 million suffer from 'hidden hunger'—micronutrient deficiencies—and about 2.5 million experience over-nutrition (obesity). About 40% of children suffer from vitamin A deficiency (night blindness); 35% of rural women suffer from vitamin A and iron deficiency (anemia). This situation can be overcome by producing and utilizing vegetables on a large scale. Although vegetable production has almost doubled with the introduction of hybrid improved seeds and heat-tolerant lines from AVRDC – The World Vegetable Center, non-uniform production times, an erratic market system, unplanned production, and inconsistent production patterns prevent fresh produce from reaching consumers. Most vegetable production occurs in winter (50%) and in summer (35%), with less production during the lean periods: August to November, and April to May. A production and crop selection model for the lean period has been developed. This model is now being used successfully in southern Bangladesh, particularly in saline belts where vegetable production is limited. A number of antioxidant-rich colored potato, sweet potato, sweet gourd, and carrot varieties are being registered for Bangladesh in collaboration with the University of Wisconsin, Madison, USA with financial assistance from United States Department of Agricultre-Agricultural Research Service. Indigenous vegetables also contribute to alleviating malnutrition and poverty alleviation in Bangladesh. Bangladesh Agricultural University has established the largest vegetable germplasm repository including a number of underutilized, tropical, subtropical, indigenous and temperate vegetables in Mymensingh. In this paper, we review the contribution of vegetable crops in the nutrition of poor people and to alleviate poverty in coastal, hunger-prone (monga) and flood-affected areas. We also focus on future policy for the sustainable management of vegetable crops in Bangladesh to improve the country's economy, strengthen nutrition and food security, and alleviate poverty.

Keywords: Bangladesh vegetables, malnutrition, poverty alleviation, national economy, climate change, biodiversity

INTRODUCTION

Agriculture contributes 32% of the gross domestic product of Bangladesh (BBS, 2012). Horticultural crops, particularly vegetables, play a vital role in crop diversification, human nutrition, food self-sufficiency, and poverty alleviation. The government of Bangladesh has put much emphasis on the production of vegetables, spices and flowers to diversify rice-based diets. Although there has been considerable success in development of improved varieties of potato, tomato, brinjal, cauliflower, and cabbage in Bangladesh, the uptake has not been adequate.

Vegetable production in Bangladesh

Total arable land is 14.06 million hectares, of which 4% is under vegetables (Fig. 1). The present total production of vegetables in Bangladesh is about 1.88 million tons on 0.278 million hectares of land. The major vegetable growing areas are in the North-west and South-west regions. Present daily consumption of fruits and vegetables is 35 g and 45 g, compared to daily requirements of 80 g and 220 g (Fig. 2; BBS, 2012). Aroids, ivy gourd, bathua, *Dioscorea*, etc. are considered minor vegetables, and most are underutilized. These underutilized vegetables are grown and sold in markets almost everywhere in the country and can be used as raw materials for processing.

Role of vegetables

Nutrition: Crop production in Bangladesh is dominated by cereals, and the per capita consumption of cereals in the country is much higher than in other countries. Vegetables availability and consumption is low, which causes severe malnutrition. Almost 86% of the country's population suffers from malnutrition (Fig. 4). About 10 million children suffer from vitamin A deficiency, leading to complete/partial blindness (Hossain 1998). An increase in production of major and underutilized vegetables can substantially contribute to overcoming malnutrition.

Poverty alleviation: Around 71% of rural poor households in northern Bangladesh depend on horticulture to provide opportunities for day labor, compared to 52% in other parts of the country (Anonymous 1990). Poor farmers produce vegetables at the homestead, which can increase the family income, nutrition and food security.

Overcoming Monga: Monga, a famine-like situation, is a local term used to indicate acute deprivation caused by the erosion of purchasing power from lack of lucrative employment opportunities. A major recurring crisis strikes the rural poor each year in northern Bangladesh, especially in the greater Rangpur – Dinajpur districts. Twice each year (September to November and March to May), people in these areas suffer severe hardship when household food availability declines and farm employment decreases after the rice harvest. Hardship in the March to May lean season is less severe due to recent crop diversification with maize, potato and winter vegetables. Homestead and kitchen vegetable gardens incorporating underutilized crops such as aroids, *Dioscorea*, and luffa can help families overcome monga.

Employment and women participation: Agriculture is the dominant sector for employment in Bangladesh. Due to continuous expansion of the population, the overall supply of labor is far in excess of demand. Most unemployed people live in rural areas where vegetable production can create job opportunities. Out of 20 million rural households, about 17 million unemployed women (average 2.26 women/households; BBS 2012) could employ themselves producing vegetables in the homesteads.

Export potential: Bangladesh exports different kinds of vegetables to different countries. Most exports go to the United Kingdom and the Middle East (United Arab Emirates, Saudi Arabia, Qatar, Kuwait and Oman), where a large population of Bangladeshi and Indian migrant workers live (FAO 2012; EPB 2012). Fresh vegetables are mostly exported through members of the Bangladesh Vegetables and Allied Products Exporters' Association which employs about 10,000 peoples (EPB 2012). About 400 companies are involved in vegetable exporting activities.

Commercial markets: Demand for vegetables in the kharif season (March – August) season is increasing with the urbanization and migration of people from villages to cities. Vegetables are a source of higher income compared to cereal crops.

Vegetables production in the homestead

Almost two-thirds of arable land in Bangladesh is flooded during the rainy season (mid-June to mid-September). Only some homesteads remain dry during floods. Vegetable production in the homestead has a significant role in socioeconomic conditions in Bangladesh, where more than 60% of the farmers are landless. Intensive homestead vegetable production is possible throughout the year. Homesteads can be 'lifeboats' for rural and urban populations through cultivation of vegetables for household food and nutrition security.

Vegetables in coastal areas: The coastal zone covers 32% of the total landmass of the country (Islam 2004). Field crop production has decreased in coastal areas due to a lack of fresh water and soil degradation from an increase in salinity. Rice production (16%) in the coastal area is lower in comparison with total rice area (64%). The coastal zone is very important for the production of pulses and oil seeds, which are also declining due to the increase in salinity. Production of salt-tolerant vegetables should be emphasized in the coastal parts of Bangladesh, including aroids, *Dioscorea*, ivy gourd, sword bean, bathua, Indian pennywort, red sorrel, *Moringa*, etc.

Vegetables in hilly areas: Hilly areas in the northeast occupy about 10% of the total land of Bangladesh, and most of the country's tribal peoples inhabit these areas. Horticultural crops and forest trees are the main source of their income. They cultivate the hilly land following traditional cultivation techniques (i.e. shifting cultivation) only for subsistence. These areas have potential for year-round vegetable production.

Constraints to vegetable production in Bangladesh

- Seasonality: heavy rain, high heat, unavailability of dry land during summer
- Poor soil management, including inadequate irrigation practices.
- Lack of quality planting materials
- Unavailability of good quality seeds of improved vegetables varieties (Razzak 1999)
- Vulnerability to many diseases and pests
- Few postharvest quality controls
- Produce handling and marketing mainly in the hands of the middlemen who do not follow maturity standards, grading and scientific packaging
- High cost of packaging material and other inputs
- Lack of market intelligence and information services

CONCLUSION

Vegetables play an important role in the national economy and nutrition of Bangladesh. The climate and soil of Bangladesh are favorable for production of vegetables. The Bangladesh Agricultural Research Institute, Bangladesh Agricultural University (BAU), Department of Agriculture Extension and some NGOs have been implementing development projects to increase vegetable production. Vegetable production will help increase the income of rural people, solve the nutrition problem and generate employment.

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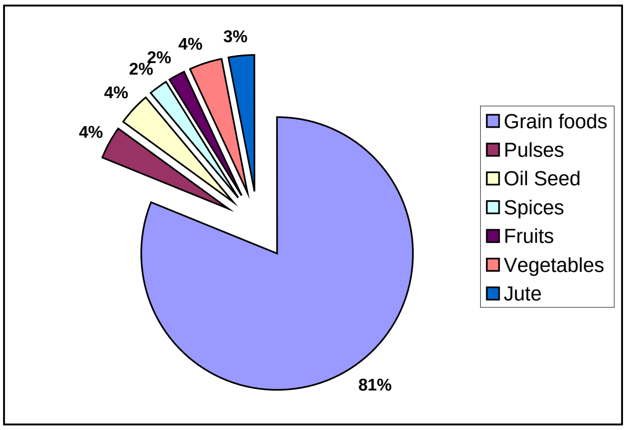

Fig. 1. Share of vegetables in Bangladesh food production

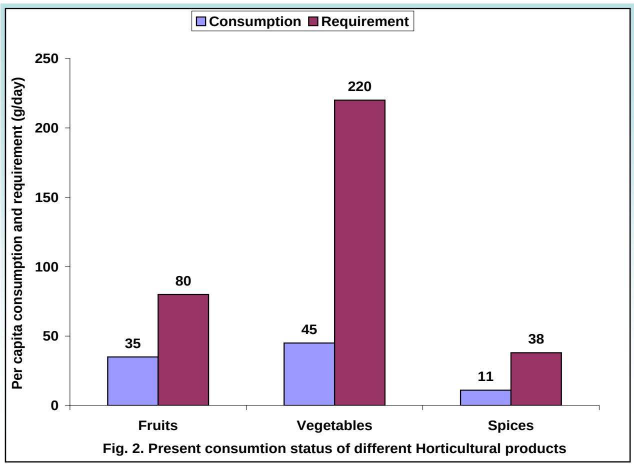

Fig 2. Consumption status of fruits, vegetables and spices in Bangladesh

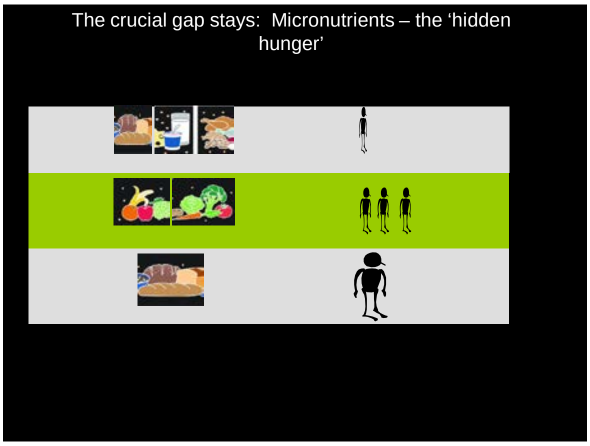

Fig. 3. Status of nutrition deficiency in Bangladesh

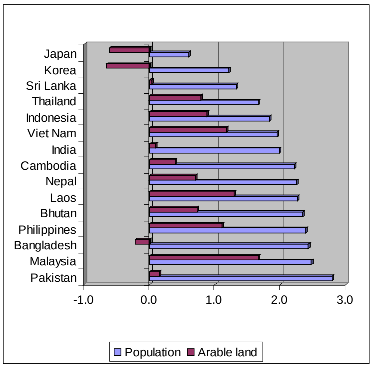

Fig. 4. Land availability in Bangladesh compared to other countries

Improving supply chain for high value vegetable in Indonesia: Smallholder vegetable production systems in East Java

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ABSTRACT
Food and agricultural markets are undergoing a rapid transformation towards high value products. This shift presents smallholders with new opportunities to participate in high value supply chains to improve their income. However, there are some challenges in producing high value agricultural products such as vegetables. This study aims to investigate the problems and opportunities of vegetable production and marketing in East Java, Indonesia. Vegetable farmers, traders, and agribusiness managers were interviewed from August to December 2012. The study shows there is a new channel emerging for vegetable marketing: supermarkets. However, the supermarket supply chain is still very small and underdeveloped. The main obstacles faced by producing and marketing vegetables are pest and diseases, soil fertility, plant nutrition management, postharvest handling, market access and market information such as consumer preferences. Vegetable producers are not yet able to rapidly respond to the demands of the modern domestic market, especially supermarkets, hotels and restaurants. To improve the supply chain for high value vegetable production, it is important to build partnerships between supply chain actors; provide training and technical assistance to small farmers; and facilitate market access and information about chain actors. Implications for policy makers, particularly technical assistance, for improving the high value vegetable supply chain in Indonesia are highlighted.

Keywords
smallholders, high value product, supermarket, modern market, supply chain, vegetable

INTRODUCTION
East Java province is Indonesia’s second largest producer of vegetables, contributing shallot (28% of national total), chili (18.6%), cabbage (11.7%) and spring onion/leek (11.3%). This area also produces a variety of other vegetables such as garlic, string beans, eggplant, tomatoes and carrots (Agricultural Statistic Database 2012).

Kediri and Blitar districts are the main vegetable production area for large chili, small chili, tomato and leek in East Java (Secretariat Director General of Horticulture 2010). The largest vegetable planting area in Kediri from 2006 to 2010 was small chili (2,682 ha), followed by large chili (958 ha), shallot (634 ha), green beans (529 ha) and tomatoes (373 ha) (Kediri Agricultural Office 2010). In Blitar in 2008, vegetable production area included small chili (5,899 ha), large chili (598 ha), yard-long beans (515 ha), eggplant (114 ha) and tomatoes (128 ha) (Blitar Agricultural Office, 2009).

In East Java, vegetables are produced on small landholding and are labor-intensive, thus offering opportunities for small farmers to diversify production and generate employment to increase revenue for all actors in the value chain (Mariyono and Bhattarai 2010). Diversification of vegetable produce can benefit poor farmers and farm workers who do not have land to increase production and employment (Mariyono 2007).

However, food and agricultural markets are undergoing a rapid transformation towards high value products and modern markets (Juttner et al. 2007). This rapid transformation presents smallholders with new opportunities to participate in high value supply chains to improve their income (Sahara et al. 2011). However, there are some problems and challenges for high value vegetable production on farm and off farm, including agronomy, infrastructure, management, distribution and marketing (Kwon and Suh 2004). This study investigates problems and opportunities of vegetable production and marketing in Indonesia.

RESEARCH METHODS

We observed some aspects of the supply chain and examined prospects of improving vegetable production (especially for high value vegetables such as chili, shallot and tomato) in the central production area of East Java. The study was conducted from August to December 2012 in the districts of Kediri and Blitar. The location was chosen because these areas are vegetable production centers in East Java. Initial data collection was done through marketing research surveys to explore qualitative aspects of social and institutional factors in the agricultural sector. Interviews based on the questionnaires, and information provided by the farmers/traders, was directly recorded on the same sheet.

Questions for farmers covered demographics, the reasons why farmers grow vegetables, and where they sell their crops. Questions for traders covered their reasons for selling particular vegetables, where they bought and sold the vegetables, marketing channels, and how market prices were determined. Fifty farmers and 20 vegetable traders were interviewed.

RESULTS AND DISCUSSION

The agricultural system in studied areas

In general, agricultural practices in both locations were similar. For example, when producing chili and tomatoes, farmers started by preparing the land using plows and rakes before making beds and covering the beds with plastic mulch. The farmers prepared nurseries for chili, tomatoes and cabbage seedlings, but not for carrots, squash or beans. Some farmers used local seed varieties and some used hybrids. Weeding and spraying were done manually using a hand sprayer. Harvesting was done by hand. The frequency of spraying depends on the season and crops. Farmers sold their products to the market directly or through intermediaries, depending on the crop. Most farmers applied a complete fertilizer including N-P-K and micronutrients. Some farmers also applied organic fertilizer. Farmers had no difficulty obtaining fertilizers, including organic materials. Related to nutrient management, some farmers observed plant nutrient deficiencies, but agricultural officers who conducted soil analysis and diagnosis did not inform the farmers on how to handle soil nutrient problems.

Table 1. General Information about conditions of agricultural system in study areas

Components	Kediri	Blitar
Reason of growing vegetables	Profit promising, part of their culture and heritage, easy to cultivate, high yield, easy to intercrop with other crops	More profitable, short duration compare to rice, meet market demand
Source of seeds	Local seeds: save their own seeds Hybrid: Kiosk	Local seeds: save their own seeds Hybrid: Kiosk
Source of irrigation	Irrigation channel	Rain-fed: Estate forest land Irrigation channel: non-Estate forest
Plant rotation	Paddy, maize, peanut and vegetable	Paddy, maize, potato and vegetable
Results	Local chili : 4- 5 t/ha Hybrid chili: 6 t/ha Long beans: 17 t/ha Gambas: 28 t/ha Tomatoes: 20 t/ha (only 20% can be harvested)	Curl chili: 17.5 t/ha Potatoes: 35-50 t/ha Small chili: 4-7 t/ha Cabbage: 62 t/ha Tomato: 127 t/ha
Time of selling	Immediately after harvesting	Immediately after harvesting
Target of selling	Middlemen and directly to the market	Middlemen and directly to the market
Harvest time	Morning	Morning
Type of packaging	Chili: used fertilizer bag Gambas: used fertilizer bag, boxes Long beans: rope Tomatoes: bamboo baskets	Chili: used fertilizer bag Cabbage: plastic baskets Carrots: plastic baskets Tomatoes: wooden box
Activities to reduce the temperature influence	Putting the vegetable crops in a shady place and selling it as soon as possible	Selling the products as soon as possible, avoiding rainfall, harvesting is not being done during the rainy season
Sorting and grading	Only clean and healthy vegetables	Chili and tomatoes: indicator the color of the ripe fruit Chili: anthracnose symptom indicator

Source: Field survey, 2012

Pests and diseases are the major limiting factors when other productivity factors have enough inputs (Mustafa et al. 2000). In Kediri, tomato was planted in the rainy season; in Blitar, in the dry season. That is why there was a difference in our results, because the incidence of pests and diseases for tomato and other vegetables is commonly high in the rainy season (Table 1). In Kediri, anthracnose and gemini viruses were the main diseases on chili. Viruses and late blight on tomatoes and sponge gourd (*gambas*) led to losses of up to 100% and 90%, respectively. Most farmers used synthetic pesticides, sometimes combined with botanical pesticides. In Blitar, anthracnose was a major disease on chili, and late blight is the most destructive disease of tomatoes. Fruit flies lead to loss of yield up to 100% on chili. On cabbage, diamondback moth and leaf feeders are the most damaging pests. Potential yield loss due to pests can reach 100%.

Terracing and water distribution across farmers' fields was well coordinated. Vegetables are planted as monocultures. For harvest and postharvest activities at the research site, farmers typically harvested in the morning. Harvested produce was put in the shade, and sold as soon as possible to maintain quality. Sorting and grading of chili and tomato was based on color and healthy fruit (Table 1).

Vegetable production supply chain

Kediri and Blitar are important districts for vegetable production, but crop yields are still far below their potential to meet customer demand for East Java. To make up the difference in supply, traders bought chilies from remote areas such as Banyuwangi, Jember, and Probolinggo (about 150-350 km from Kediri). The price was more expensive, because the traders added transportation and storage cost to the price. Traders must avoid loss from produce damaged during transport, and spend more in storage to maintain quality.

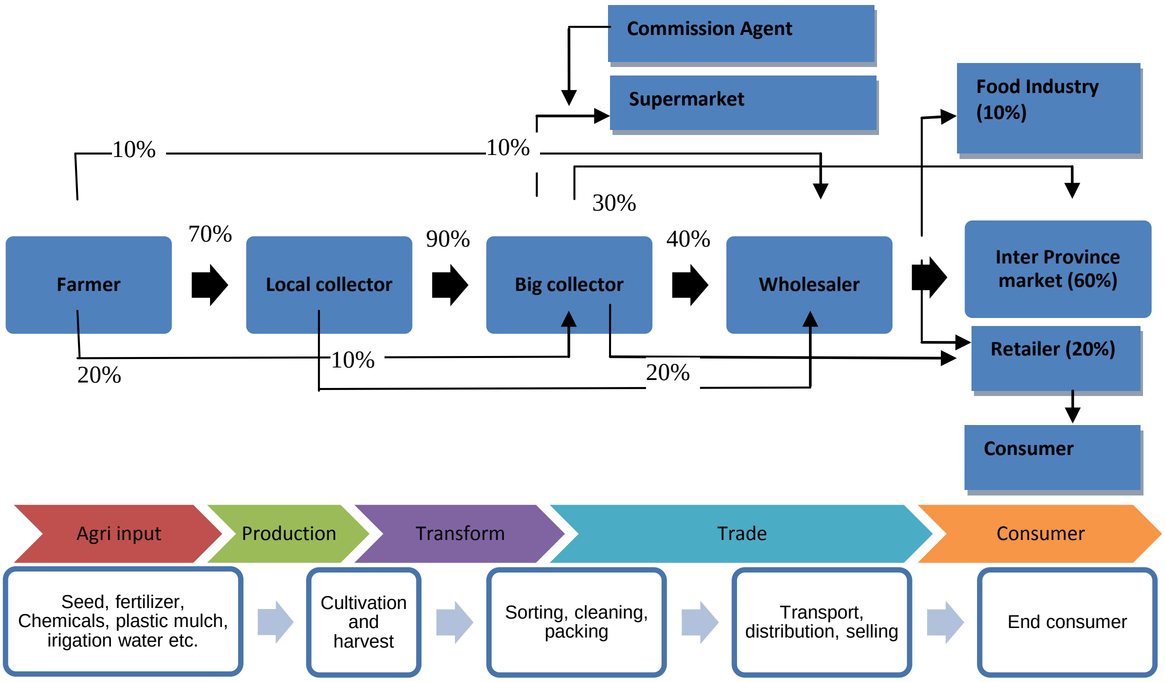

Figure 1. Supply chain and value chain of vegetable agribusiness in the studied areas
Source: Field survey, 2012

In Kediri, village traders/local collectors collected vegetables from farmers around the production centers. The vegetables were then sold to wholesalers in Pare, then brought to local markets around Kediri, or to supermarkets. In Blitar, local collectors purchased vegetables from farmers and vegetable production centers, which were generally sold to the local market (70%) at Pasar Wlingi, Pasar Induk Pare, Pasar Gadang (Batu Malang) and outside markets (30%) such as Jakarta, Bali (tomato) and Kalimantan (chili). Vegetable traders from other regions marketed vegetables to other islands such as Bali and Kalimantan because vegetable vendors in Kediri and Blitar did not know trade systems outside Java (Fig. 1).

The freight transport of vegetables was borne by collectors. Collectors used their own trucks, or hired trucks. Trucks could be rented for about Rp 300,000. One truck could carry approximately 3 tons of vegetables. Farmers also brought their crops to the collectors' barn on a motorbike or other vehicle, and paid for their own transportation costs.

Vegetables are highly perishable, which makes postharvest losses high during transport with poor handling and poor road infrastructure (Genova et al. 2006). Farmers only did sorting to cull decaying produce. Traders did a second sorting for quality grading. Some traders sold poor quality produce at a lower price, or threw it away. Market intermediaries do not have storage and special packaging for vegetables. The margin that they put in their selling price is to cover sorting, transportation and packaging (Fig. 1).

There are three main channels of vegetable marketing: farmer-wholesaler, farmer-local collector, farmer-big collector.

1. **Farmer-Wholesaler**

This channel is very effective. A farmer can get a higher price from wholesalers because if every trader puts in a margin Rp 500, the farmer can get a wholesale price. But wholesalers usually need large quantities of vegetables to purchase, and so buy from bigger traders. The sub-channel of this channel:

   a. Farmer→Wholesaler → Food Processor
   b. Farmer →Wholesaler→Inter Province Market
   c. Farmer →Wholesaler→Retailer

2. **Farmer-Local Collector**

Farmers sell their vegetables to local collectors because they are far from markest and do not have transportation to sell their commodities directly in the market. Before they sell their vegetables, they usually check the supply in that area and check the price in the market, so they know at what price they should sell their product. The sub-channel of this channel:

   a. Farmer → Local Collector → Big Collector → Wholesaler → Retailer
   b. Farmer → Local Collector → Big Collector → Wholesaler → Inter Province Market
   c. Farmer → Local Collector → Big Collector → Wholesaler → Food Processor
   d. Farmer → Local Collector → Big Collector → Inter Province market
   e. Farmer → Local Collector → Big Collector → Retailer
   f. Farmer → Local Collector → Big Collector → Commission Agent → Supermarket

3. **Farmer-Big Collector**

Some farmers sold their vegetables directly to big collectors in the market, because they were near the market, and had established relationships with big traders.

The farm gate prices received by farmers are based on the distance from farm to the main market (channel), the volume of the produce at the time of the transaction, and the availability of a specific marketing channel outlet or ability to access the channel in the farmer's community. The sub-channel of this channel:

   a. Farmer → Big Collector → Commission Agent → Supermarket
   b. Farmer → Big Collector →Retailer
   c. Farmer → Big Collector →Wholesaler → Food Processor
   d. Farmer → Big Collector →Wholesaler → Retailer
   e. Farmer → Big Collector →Wholesaler → Inter Province Market

Both farmer and trader decide the price based on the supply in the market. If a trader wants to purchase, they choose an area with a big supply, because the price in that area will be lower than in an area with limited supply. Farmers will observe the harvest in their area to estimate how many tons to harvest before they decide on the price to sell.

Vegetable prices varied based on the type of vegetable. For chili, the price was determined by the prevailing market price at the time. Both traders and farmers had open access to information on chili prices. Information could be obtained via telephone contact with farmers through traders in the local market as well as in the wholesale market. Vegetable prices were also determined by the quality of vegetables, based on grading. Vegetables with the highest quality fetch the best price (Schnepf

2009). For example, chili grading was based on the external appearance of chili (smooth, bright and fresh); traders assessed the quality of chili based on a cursory physical examination. Tomatoes were graded by size (large, medium, small) and external appearance (smooth or not). Cabbage was graded on freshness. Price was determined by agreement between the merchant-farmers. Some traders in Kediri cooperated with farmers to provide capital assistance in the form of fertilizers and pesticides. After harvest, farmers sold vegetables to the capital providers according to prior agreement.

Chili prices were volatile in the two regions. When supply was high, prices were Rp 10,000/kg (farm level) and Rp 17,000/kg for consumers. When supply was low, chili farmers received Rp 70, 000/kg and consumers paid Rp 100,000/kg. Table 9 illustrates vegetable prices for farmers, retailers and consumers. For merchant collectors, the average net profit earned from the sale of vegetables was between Rp 300-500/kg. Merchant transactions with farmers are based on good relations. Model merchants paid farmers in cash 2-7 days after the transaction took place (Table 2).

Table 2. Prices of vegetables based on quality products, Kediri Market, November 2012

Vegetable	Grade A (Rp/kg)			Grade B (Rp/kg)		
	Farmers	Wholesaler	Retailers/Consumer	Farmers	Wholesaler	Retailers/Consumer
Chili	10,500	12,000	14,000	7,000	10,500	14,000
Tomatoes	2,800	3,000	3,500	1,300	1,500	3,500
Cabbage	700	900	1,100	600	800	1,000
Carrot	1,500	2,500	2,800	1,500	1,500	1,700
Spring Onion/Leek	2,000	3,000	3,500	-	-	-
Long beans	1,200	1,800	2,000	-	-	-
Kapri/snow peas	9,000-10,000	14,000	17,000	-	-	-

Source: Field Survey

Socioeconomic aspects

Most of the large chili farms in the two study areas used hired labor. Hired labor can account for 35% of total production cost. Three out of our five respondents use 100% hired labor to manage their large chili farms, especially in Kediri. These large farmers are often village or sub-district collectors. From a gender perspective, it seems that there is a great difference between farms; at one farm women made up 16% of the total labor, and at another farm, 67%. In general men and women share the work almost equally.

Most farmers applied both fertilizers and crop protection chemicals. On an intensive farm, fertilizer and crop protection chemicals could account for up to 60% of production costs. On average, fertilizers and crop protection chemicals claimed 40% of the production cost (Table 3).

The return on production of large chili ranged between Rp 35 to 113 million/ha, with Rp 79 million/ha the average. On average, net return on land is approximately 40% of total revenue. For the family, the return on their one day labor is very high, Rp 0.5 - 2 million per day, with the average being Rp 1.3 million per day. Return to total labor is between Rp 125,000 to 300,000, which is still higher than the labor cost of the location, which ranged between Rp 50,000 to 80,000 per day (Table 3).

Table 3. Comparative on vegetables economic and social indicators (average)

Commodities	Large Chili N=15	Small Chili N=15	Tomato N=10-?	Shallot N=10
Economic indicators				
Yield (t/ha)	17.6	2.2	57.3	10.8
Price (IDR/kg)	8,300	11,000	1,750	7,383
Revenue (million IDR/ha)	137	20	78	81
Cultivation and harvesting cost (million IDR/ha)	58	10	40	39
Net income (million IDR/ha)	79	10	38	42
Return on family labor (000 IDR/ workday)	1,307	248	190	331
Return on total labor (000 IDR/ workday)	211	57	108	145
Labor, environment and gender				
% women labor	41%	55%	43%	48%
% family labor	8%	40%	34%	20%
% of fertilizer cost	24%	14%	21%	8%
% of agro protection chemical cost	18%	9%	17%	19%

Source: Field Survey, 2012

Small chili farmers use a higher percentage of family labor, although hired labor is still a significant contributor to labor cost. One respondent used 100% family labor in Blitar, because he owned a small plot of land. Family labor contributes approximately 40% of total labor use in small chili farming. Most farmers applied both fertilizers and crop protection chemicals, although the cost of fertilizers and crop protection chemicals are not significant. Combined together, the total cost of fertilizers and crop protection chemicals was around 20% of the total production cost. This is supported by our observation that small chili farmers in Blitar only use a few crop protection chemicals. Input shops in Blitar typically have limited choices of fertilizers and crop protection chemicals (Table 3).

For gender issues, it seems that men and women share the work almost equally. Women contribute 55% of total labor cost in small chili.

Return on small chili ranged between Rp 1 million loss to Rp 20 million profit/ha, with Rp 10 million/ha the average. Average net return on land is approximately about 50% of total revenue. For the family, the return on one day of work is highly varied, ranging from Rp 22 thousand loss to Rp 1 million profit. The return on total labor is between Rp 10,000 loss to Rp 200,000 profit per day. The average return on family labor and total labor is Rp 250,000 and Rp 60,000 respectively (Table 3).

Return on tomato ranged between Rp 4 to 120 million/ha, with Rp 40 million the average. Net return on land is approximately about 50% of total revenue. We observed that some tomato farms use 100% of family labor, some use 100% hired labor, and others in-between. In general, in tomato farming only around 40% used women labor and only 35% use own family labor (Table 3).

Most farmers applied both fertilizers and crop protection chemicals, which contributed up to 40% of the total production cost. For the family, the return on their one day work is highly varied, ranging from Rp 60,000 to 340,000 per day. The return on total labor is between Rp 6,000 loss to Rp 340,000 profit per day. The average return on family labor and total labor are Rp 190,000 and Rp 110,000, respectively (Table 3).

Hired labor is a significant factor in the cost of shallot farming. Family labor contributes only 20% of total labor in shallot farming. It was common that farmers hired a group of people from their area; this group migrated temporarily to the next district to farm shallot. Men and women share the shallot workload almost equally. Women in Blitar lead groups of men to migrate temporarily to the next district to farm shallot (Table 3).

Most farmers apply both fertilizers and crop protection chemicals; combined together, the total cost of fertilizers and crop protection chemicals are around 30% of total production cost. Farmers moving from one area to amother in search of fertile land explains why shallot farmers in Blitar have low costs for fertilizers and crop protection chemicals. However in some cases, the cost of crop protection chemicals accounted for 50% of total production cost. It should be noted that the knowledge of chemicals and fertilizers depends on the area; even though farmers may migrate temporarily to the next district, they bought inputs from their home base (Table 3).

Shallot is a high return - high risk crop. Return shallot ranged from Rp 7 million loss to Rp 185 million/ha, with Rp 78 million/ha the average. Average net return on land is approximately 45% of total revenue. For the family, the return on one day work varied, from Rp 350,000 loss to Rp 800,000 profit per day. Return on total labor was between Rp 27,000 loss to Rp 400,000 profit per day. Average return on family labor and total labor was Rp 300,000 and 150,000 respectively, which is still well above the daily wage standard (less than Rp 100,000/day) (Table 3).

Opportunity to access modern markets

Modern retail markets are reorganizing food chains. They require product homogeneity; specific standards in sorting, grading and packaging; and consistency in supply (Claro and Claro 2010). A closer relationship between small farmers and their buyers may enable them to coordinate supply and demand in the markets, exchange information with respect to price information, and meet specific requirements in modern markets (Confort 2004). This will reduce transaction costs and increase opportunities for small farmers to compete in markets (Li 2007). In the studied area, chilies, tomato and shallot are priority crops commonly produced by small farmers. In this study about 20% of the vegetables produced were marketed in modern markets (Fig. 1) such as supermarkets and restaurants, or sold on contract to food processing industries such as ABC, Indofood, Wings, etc. Chili, tomato, shallot, and leafy vegetables are important for cash flow income for small-scale producers in this market. Some modern market sellers may gain larger profits by charging different prices to different groups of consumers. However, market intermediaries face several constraints when attempting to obtain vegetables to supply modern markets (Table 4).

Table 4. Challenge and constraints on supply chain and value chain of vegetables to modern markets

Types	Constraints on Value Chain
Vegetable cultivation technology	• Only a few farmers implement good agricultural practices and cultivate according to the recommendations of the Department of Agriculture or research institutions to get high quality produce. • Pests and diseases are endemic and farmers have difficulty in control. • Handling and packaging are still implemented traditionally. Farmers did not use cases or boxes. • In general, farmers sold vegetables in bulk, dirty and fresh, only a few that were cleaned and processed. They lack postharvest technology. Processing and marketing costs are high.
Production input	• Some production facilities are considered expensive (seeds / seedlings, fertilizers, chemicals, etc.
Market access of vegetables	• Farmers could easily access local and national markets. but lack access to modern markets and manufacturers (food industry)
Organizations of farmers	• Farmers' organizations such as farmer groups, associations / groups and existing marketing run well, but need support: weather information, modern market information, information on acreage planted, etc.
Regulations	• Timing of planting was carried out independently by the farmers, often resulting in an oversupply that decreased the selling price.
Finance	• Although some farmers used banking institutions and traditional institutions for credit, most farmers do not understand how to access the banking system.
Infrastructure	• Contracts with modern markets and the food industry exist, but should be more intensive and accurate • Transportation infrastructure is poor

Source: Field Survey, 2012

CONCLUSION

Vegetable productivity at the study sites is still below potential. Some production constraints encountered in the region are partly due to endemic pests and diseases in certain plants, such as bacterial wilt in tomato and anthracnose in curly chili. There are some problems of soil fertility and plant nutrition related to soil conditions. Postharvest handling is still carried out in traditional ways. Thus there are opportunities to increase the production of vegetables in the area with improved technologies and better access for farmers to appropriate technical and market information.

To reduce marketing risk, the government should develop consistent policies to ensure the quality of vegetables, and facilitate access to capital for farmers and traders so that they can participate in modern market channels, which provide higher margins. Farmers and traders need information and training, especially in postharvest handling methods. Market infrastructure needs improvement, including cold storage facilities and warehouses in strategic markets and improved transportation facilities. Farmers need access to a steady supply of quality, disease-free vegetable seed.

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Identifying objectives for breeding improved vegetable varieties: Hard but vital choices

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SYNOPSIS
The vegetable breeding experience confirms that identifying objectives of breeding is prelude and key to successful results of a breeding programme in developing improved varieties. To identify the objectives, the views of choice makers must be considered, which will ensure acceptance and popularity among the farmers and consumers.

Keywords
Choice, choice makers, introduction, objectives of breeding, vegetable breeding.

INTRODUCTION
For some time, I was wondering why several of the new vegetable varieties developed by the public research institutions and universities did not become popular among growers and why many of the varieties developed by national and multinational private companies became so commercialized in India and in some other countries. Contrary to this, most of the vegetable varieties developed by the public or private sector were acceptable to both growers and consumers in western countries.

To me, it looks like once a crop is identified for improvement by breeding the author and his/her research team must thoroughly investigate various objectives of breeding and be fully convinced of the objectives before launching the breeding project. The main focus and goal will be to develop a variety suitable not only for growers, but for growers and consumers. Hence, the choice of objectives becomes hard but vital. The failure of a new improved variety in terms of time and economic loss has been colossal, which seems to have gone unnoticed by research communities.

SEARCH FOR OBJECTIVES
During my research career as a vegetable breeder, I considered myself as an architect. The breeder constructs a beautiful and useful plant, whereas the architect constructs a beautiful and purposeful building. It takes many years to develop a plant variety, whereas an architect takes only a few years only to construct a building, but the fruitful life of the former is shorter than the latter. At the end, the critical and vital role of breeder/architect must not neglect the choice or choices of the beneficiary or client. Breeding cannot be launched unless the objectives are defined clearly; these vary from crop to crop, season to season, location to location, client to client. This is the beginning of research by the breeder concerned: the task of narrowing down the choices of objectives that matter most. Like a building blueprint, a plant blueprint needs to be prepared including height and morphological structure, fruit bearing capacity, resistance or tolerance to something, taste of consumers, suitability in cropping pattern, and most important, the location. Any of these lapses may result in the failure of the outcome.

CHOICE OF OBJECTIVES

In my experience, it is important to know from where the choice originates. It could be a national/state priority to grow the crop. It could be a programme/project to augment vitamin availability among the masses. It could be a popular color and shape among consumers, or a variety more profitable for growers, or one with good transport quality for marketing, or resistance to disease, and so on. It boils down to the fact that, directly or remotely, decision makers of choices are policy makers, growers, traders, consumers and lastly the researchers. This is hard, because the grain breeders do not often deal with many of these choice makers. It makes it easier for the vegetable breeders to reach directly to the choice makers, listen and note their choices, and narrows them down to define objectives for a breeding programme.

CHOICE MAKERS

1. **Nation or State:** Either national or state government agricultural policies have priority crops, which include both major and minor crops. Some crops are already popular and commercialized, whereas less utilized crops are still to be popularized for obvious benefits to health. Hence, the choice has already been made and the researchers need to follow.
2. **Consumers:** The consumer's choices largely depend on the quality of the crop. Hence, the breeder has to be very cautious in identifying their choices. If the new brinjal variety has no traditional popular color or cooking quality or shape, it will be rejected outright in most of the cases.
3. **Growers:** It may happen that a new pumpkin variety has a longer growing period that does not fit in the cropping pattern. A new watermelon variety may be susceptible to serious viral diseases and so on.
4. **Traders:** Introduced good quality tender French beans from peri-urban areas to the city of Bangalore could not retain freshness during local transport, but the local variety of string beans did. The Alphonso mango became overripe in a few days in Rome, when shipped by air overnight from Mumbai.
5. **Researchers:** It is apparent that the shopping list of choices largely depends on government agencies, communities and individuals. Breeders come last to really narrow down the choices, but they are the master architects to decide upon the choices and define the objectives of a particular breeding project. The breeder will be the leader to prepare the blueprint of the new plant structure with both hardware (morphological) and software (disease resistant and high vitamin content). It is also very important for the breeder to decide upon the breeding method, long or short, and its economic value. During the research/construction process, the breeder may make any modification necessary and will finally evaluate the new plant in the field with based on the blueprint prepared on paper.

The researcher has to follow-up to review the new variety's field performance year by year to conclude whether the new variety has (a) maintained its performance and (b) for how long a period it has retained its genetic characters or uniformity.

SUCCESS AND FAILURE OF CHOICES: TRUTHFUL EXPERIENCE

Okra (*Abelmoschus esculentus* L. Moench): During 1962, as a young scientist I joined the Indian Agricultural Research Institute (IARI), New Delhi, and was assigned to breed okra varieties. In this connection and context I met Mr. Harbhajan Singh, the father breeder of the yellow vein mosaic resistant variety (YVMV) Pusa Sawani, which became the pride of farmers nationwide for decades. He with his wealth of knowledge on vegetables, particularly okra, was kind enough to explain me in detail about his work on okra development and breeding. He provided me with all germplasm including wild species of okra. By that time 'Pusa Sawani' had become susceptible to YVMV. During 1964, I left IARI but the research was continued by my former colleagues.

By the time I joined the new Indian Institute of Horticultural Research (IIHR) in 1969 in Bangalore lot of research work on breeding okra resistant to YVMV had progressed at IARI and in the universities in India, but the result was far from complete. My colleague Dr. O.P. Dutta, a very energetic young scientist, joined me in initiating research on breeding okra against virus diseases. After many years of research with interspecific crosses, Dr. Dutta and his team developed the variety ‘Arka Anamika’ which became a commercial variety nationwide. After several years, the disease resistance broke down and the search for development of an YVMV resistant variety continued. In India and in neighboring countries the main objective of okra breeding still remained YVMV resistance.

During 1977, I had an opportunity again to develop okra for the southern region of Nigeria, which was hot and humid with heavy rainfall. The indigenous okra crop was both grown and voluntary. The plants were dwarf and lower branches more or less trailing on the ground, very prickly on fruits, stem and leaves. Fruits relatively small, medium to plump, commonly six ribbed, light green mixed with pink red, prickly and fibrous. The plants looked very hardy and fresh fruits very slimy on cutting. From the breeder’s point of view the plant shape could be improved to be more efficient, prickly character could be removed, fruit size and quality could be improved and yield could be enhanced tremendously. For scientists and elites, yield and quality were important.

Based on a survey of okra almost nationwide in Nigeria, I decided to have a two-pronged approach to develop okra: One relatively short-term approach to introduce good varieties from tropics and one long-term breeding effort to improve indigenous strains by borrowing acceptable genes from abroad. After couple of years of trials with introduced varieties, the selected ones were compared with the local ones and fresh fruits put to the test for judging by the housewives for consumer acceptance. While I was confident that ‘Pusa Sawani’, ‘Pakistani Long’ or ‘Senegal’ would be accepted in that order, I was shocked completely by the judges’ scores. After repeated observation, the judges accepted the selected indigenous varieties and rejected all the introduced varieties even though they were tender, long and bright colored. My counterpart in Nigeria, Dr. Lawre Denton, was also convinced with our approach of improving okra varieties, but he could not convince the judges of their value. In absence of any clear explanation, we all sat together for a long discussion and I analyzed the views of each judge and identified that the basis of judgment commonly depended on the methods of cooking and the taste acceptable to the common people. After few minutes of pondering, I realized the mucilaginous property that connected plate and mouth was what satisfied these consumers. After some years breeders improved indigenous lines that produced high yielding, tall non-prickly plants with short internodes, medium-sized attractive green fruits—and high mucilage.

Eggplant (*Solanum melongena* L.): During my early days at the IIHR Bangalore, a new grower with 10 acres land, some covered with grapes, approached me for advice on growing vegetables. Since the young institute had not recommended yet any improved variety, I thought of suggesting IARI varieties popular in different states. In brinjal, the variety was ‘Pusa Purle Cluster’ that was close to local popular variety ‘Kengeri’ in terms of single fruit. After a few months, the grower took me to the field and I was pleased to see an outstanding healthy crop at the bearing stage ready to be harvested next week. After a week, she returned to me with a very sad face, and I was surprised that her truckload of brinjal was not accepted at the city wholesale market and that she had no choice but to dump the fruits because she refused to pay for the transport back. She further promised not to grow vegetables again. I had no answer for her. The next morning, I sat down in the research field with my colleagues and soon we found the difference: the fruit of ‘Pusa Purple Cluster’ had a purple calyx, whereas ‘Kengeri’ had green calyx. ‘Kengeri’ was dark purple in color; ‘Pusa Purple Cluster’ was medium light purple in color. I realized late that one objective of the color character can fail the crop, not in the field but in the market.

Melons: During the late 1960s at the University of Udaipur (UOU), Jobner, Rajasthan, we had done a vigorous field survey and made one of the largest indigenous collections of watermelon (*Citrullus lanatus* (Thumb)) and muskmelon (*Cucumis melo* L.) germplasm in Rajasthan. With bright, sunny dry days and water particularly at the river beds, the TSS value of the muskmelon collections reached up to above 14, whereas in watermelon it was up to 13 and 14. Diseases were minimal, except some mildew. Melons with thick rinds could withstand transport better than thin-skinned ones, which cracked easily during local transport. Here the objectives of improvement were relatively high sugar, good taste, good texture, and adequate transport quality.

During my postgraduate research (1959-62) at Kansas State University (KSU), Manhattan, Kansas, USA we evaluated hundreds of watermelon breeding lines which led to the selection of the breeding line Kansas-62 as most outstanding in yield in several USA states in 1961 and 1962; it was later named ‘Crimson Sweet.’ This variety became popular not only in the USA but also in many European and Asian countries. The objectives of breeding were better fruit quality, high yield, medium size and multiple disease resistance. The dark green striped fruit is round in shape, and is thick-skinned with good transport quality, with bright pink, very crisp flesh, and a few very small seeds distributed uniformly in a line near the skin, providing a large heart of seedless flesh, easy to eat and very sweet (TSS 12-14) depending on the location.

During watermelon breeding (1969-1976) at the IIHR, ‘Crimson Sweet’ did not perform well in yield but was utilized in breeding ‘Arka Manik’ with the same skin color as’ Crimson Sweet.’ It remained popular in many states of India for a number of decades because of its quality, high yield and disease resistance.

Summer Squash (*Cucurbita pepo* L.): In India, I was not familiar with squash, but on arrival at KSU, the first crop I saw was the left-over of the squash crop at Ashland Farm in August 1959. After a number of years, I realized that it was a instrumental moment at the beginning of my research career.

During my first encounter with Prof. Charles V. Hall, he arranged my credits/courses and helped me register. On the next day he drove me to the Ashland Horticulture Farm and we stopped at the experimental plots of cucurbits. Before reaching the plot I experienced a strange unknown smell in the air. The squash crop had been harvested, and most of the plants were either dead or going to die soon with some damaged fruits. Soon I realized that I was trampling not only damaged plants but also foul-smelling insects crawling all over the plants and plots. Prof. Hall explained that it was the serious insect pest, squash bug, and he took to various plots of watermelon, muskmelon, pumpkin and so on. I forgot about the visit, but occasionally I would think about the crop and the pest. Whenever I had chance to visit library, I used to go through literature on squash. On my own, while collecting literature on squashes, I conferred with Prof. Hall. After one or two semesters, it was time to decide on my thesis research work and I myself said, "I wish to work on squash" and by that time I knew the serious problem threatening the squash crop was insect pests. I knew that the objective of breeding was resistance to squash bug damaging fruit, and spotted and striped beetles feeding on young seedlings. After four years, I completed the work on studying inheritance of insect resistance (spotted and striped beetles) in squash plants. I was very pleased that I had taught myself how to identify the objectives of breeding squash. On my return to India, I encouraged my postgraduate students to identify and propose their objectives for research.

During research at IIHR, I introduced some varieties of squash and identified the American variety 'Patty Pan,' an attractive white type that yielded well in the experimental plots. A large-scale trial was held at the Shimsha River bed near Maddur, Karnataka, India, in collaboration with the Department of Horticulture. The results were outstanding with regard to plant growth, health and yield. Piles of fruits were on sale on the highway roadside near the field plot and at the gate of the Horticultural Experiment Station in Maddur. The visitors and farmers were curious to know about this new wonder crop, which did not look like any other crop. We researchers were pleased with our success and thought it would become the new crop of the future. But today, even after 40 years, 'Patty Pan' is hardly known in Karnataka. The reason is that neither growers nor consumers know the utility of this crop; they do not know how to grow it or consume it, although some of them cooked it in sambhar as they would pumpkin or ash gourd. Here the objectives of improvement in quality, yield and adaptability in the field were not wrong. But the extension team failed to popularize this short duration, bushy (space-saving unlike any other vine cucurbits) and high yielding crop among the farmers, and its good cooking, nutritive qualities among consumers. However, now some long type squashes have started coming into food stores, and perhaps 'Patty Pan' will get its due very soon, if popularised.

Roundmelon (Tinda) (*Citrullus vulgaris* var. *fistulosus* Watt): The roundmelon or tinda common to northern states of India was introduced at the IIHR for southern states, similar to the introduction of squash from the USA. On conclusion of the breeding work, the high yielding variety 'Arka Tinda' was released nationwide during 1970s. The National Seeds Corporation Ltd. multiplied the seeds on a large scale. The northern states utilized it very well, whereas in the southern states it did not take off. 'Arka Tinda' had the same fate as of 'Patty Pan,' because of the lack of support from the extension wing. After about 40 years, I am surprised to see locally grown roundmelon along with other vegetables on some of the streets and in the food stores of Bangalore. I think the increase in local demand for this crop is caused more by the increase in the cosmopolitan population of the city.

Pumpkin (*Cucurbita maxima* (Duch)): During research at the IIHR in the 1970s, the pumpkin variety 'Arka Suryamukhi' was bred and released. Breeding objectives were to develop small "family size", attractive in color, good flesh, high in food value, long shelf life, high yield, medium plant growth and resistance to red pumpkin beetle. The fruit of 'Arka Suryamukhi' has a very distinct color. It is very surprising that 'Arka Suryamukhi' is still available in all parts of Karnataka, and can be seen in the vegetable markets of Kerala, Tamil Nadu, Andhra Pradesh and Maharashtra.

It is surprising that (a) this cross-pollinated variety has retained its characters, and (b) sustained the demand of the consumers through four decades. I think the objectives of improvement were right and the success was more than expected. The growing trend of smaller families and demand for small fruit and suitable cooking ability (with no cut fruit requiring refrigeration), long shelf-life matched very well with the original objectives of breeding. My former colleague Dr. O.P. Dutta made further genetic studies on 'Arka Suryamukhi.' I hope other breeders are lucky as this in breeding other crops.

Spinach (Palak) (*Beta vulgaris* var. *bengalensis* Rox): Some of the semi-arid and arid regions of Rajasthan had near salinity or high salinity of soil and water leaving little choice of crops for the farmers to grow. At the UOU, Jobner campus, we faced this problem and tried to mitigate it by introducing improved technology by selecting salt-tolerant crops, by improving crop management practices and by developing salt tolerant varieties. Some of the crops susceptible to relatively high pH were grown successfully with improved management technology. The melons performed well. Palak grew well and was much liked by the local consumers. Hence, the objective was to breed high yielding, salt-tolerant palak high in vitamins A and C. In due course, the variety 'Jobner Green' was developed, which became popular with farmers both in saline and non-saline soils. The increased yield was obtained by its large-size leaves, and vigorous tall growth with prolific branches allowing 2-4 harvests. depending on the size of plant growth. Some years ago, I saw 'Jobner Green' in the experimental plot at one of the research institutes, where it was being utilized as a donor parent in the breeding programme.

For the last couple of years, I have been observing some changes in palak either on street carts or in food stores in Bangalore. During the 1970s palak was seldom seen in Bangalore because it was neither grown nor consumed, but people like me who used to consume it, still looked for it. By 2000, palak was available both on the streets as well as in the food stores in the form of cut large leaves. But for the last couple of years, the fresh, very tender palak seedlings with small leaves and small roots have started coming in at a high price. It cooks easily and is much tastier. Would the researchers change their objective of breeding?

PROSPECTS

It is clear that consideration and selection of choices are prelude to define the objectives of any vegetable breeding project. No breeding project for improved varieties will succeed in commercial production unless objectives are properly and correctly designed, based on choices.

Further, it is preferable and economical to use breeding techniques that will save time and money. In the developing world, the introduction and selection of vegetable crops has been tremendously successful in enhancing crop production. The introduction of new germplasm will save time and money when improved varieties are available to farmers relatively earlier.

Of course, cross breeding must be undertaken for the long term as necessity demands, and where previous introduction efforts have not succeeded. I have seen breeders struggling to incorporate disease resistance for years in some countries without success. In one Asian country, my visit to the Experiment Station revealed that they could not succeed in developing a tomato variety resistant to bacterial wilt even after 8 years of research—and they did not know that the resistant variety was already available in another Asian country.

In another country, an extension agent was worried about the complaint of a farmer that a *Capsicum* variety had run down and the once-sweet fruit had become pungent and unacceptable to consumers. On a visit to this large field of *Capsicum*, I discovered it was being grown alongside highly pungent chilies. The farmer had been repeating this practice for the last 4-5 years, and collecting the seeds of *Capsicum* every year. Chili was traditional crop of the area; *Capsicum* was introduced not long ago. The farmer was advised to grow the crops separately, in isolation, to produce good seeds. This indicated clearly that it is not only important to use improved varieties, but it is also necessary that progressive growers are allowed first to learn about its cultivation for others to follow.

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Genotype x environment interaction and stability analysis for yield and component traits in French bean (*Phaseolus vulgaris* L.)

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ABSTRACT
Selection of stable and high yielding genotypes is important not only for increasing the agricultural production but also for use in regular breeding programmes. Twenty-seven French bean genotypes were evaluated in three different agroecological zones of Himachal Pradesh comprising four environments to study their stability in performance by following the model of Eberhart and Russell (1966) during summer 2008 and 2009. Analysis of variance, means, regression co-efficient (bi) and deviation from regression (s^2di) of the individual genotypes were estimated to evaluate the stable performance of the genotypes. The mean squares due to genotypes, environments and genotype-environment interaction were significant for most of the characters studied, which suggests variability among the genotypes for various characters over the environments. Genotype × environment interaction was also found significant for a majority of the traits. The stability analysis showed significance of linear component of variation for important traits including fresh pod and seed yield. On the basis of regression coefficient and mean values, the genotypes 'Arka Suvidha', 'DWDFB-1', 'DPDFB-1(M)', 'DPDFB-2(M)', 'IVRFV-1', 'IVFB-1', 'MFB-2' and 'MFB-3' showed stability below average (bi>1) for fresh pod yield, which indicated their specific adoption to favourable environments. Genotypes 'DWDFB-53', 'MFB-4' and 'Aparna' were found to be desirable and stable for high fresh pod yield under unfavourable environments stability above (bi<1) average. Genotype 'MFB-2' was observed to be the most stable for seed yield per plant and days to seed maturity over the environments

Keywords
Phaseolus vulgaris L., genotypes, environment, stability, yield and traits.

INTRODUCTION
French bean (*Phaseolus vulgaris* L.) is an important leguminous vegetable; it is grown for fresh pod consumption and for processing as a frozen vegetable in many countries (Biswas et al. 2010). Its average yield is low despite continuous breeding efforts due to unsuitable cultivars, biotic and abiotic stresses, genetic drift in the cultivars, and development of new pathogen races. Further, in dealing with instability and uncertainty of yield, genotype-environment interaction is a challenging issue for plant breeders (Raffi et al. 2004) and plays a major role in developing improved varieties (Akhtar et al. 2010). Generally, genotypes with consistent yield over environments are preferred over those with high yield in selected environments. It is essential to select cultivars that are adapted to inconsistent environmental conditions by evaluating them over locations and years. This allows the estimation of genotype × environment (G×E) interaction and selection of desirable germplasm, and helps to increase and stabilise agricultural production with utilization in regular breeding

programmes (Ali and Sarwar 2008). The identification of stable and high yielding lines is urgent for commercial exploitation in farmers' fields for boosting production and productivity of this crop. Keeping this in view, our studies were conducted to understand genotype-environment interaction and to identify stable and high yielding, dual-purpose (fresh and seed) lines of French bean genotypes under changing environments. The results may be useful for breeders and farmers to select suitable genotypes for sustainable French bean production.

MATERIAL AND METHODS

Twenty-seven genotypes of French bean from different public and private institutes were used in this study. These genotypes were raised in a Randomized Complete Block Design with three replications in three locations constituting four environments namely, Palampur (1, 290.8 masl; 32^0 6′ N and 76^0 3′ E) during 2008 and 2009, Bajaura (1,090 masl; 31^0 08′ N and 77^0 E) during 2008 and Kukumseri (2,672 masl; 31^o 44′ N and 76^o 41′ E) during 2008. The plot size consisted of two rows of 2.7 m length each and plants were spaced 0.45 m between rows and 0.15 m within rows. To investigate the stability, data were recorded on yield and yield related traits *viz.*, days to 50% flowering, pod length (cm), pods/plant, plant height (cm), seeds per pod, pod yield/plant (g) and seed yield per plant (g). Combined analysis of variance was used to detect G×E interactions and their magnitude. Stability components were determined by using the procedure given by Eberhart and Russell (1966) in which stability of varieties was defined by high mean yield and regression coefficient (bi = 1.0) and deviations from regression as small as possible (s^2 di = 0) as described below:

Regression	Stability	Mean yield	Remarks
bi=1	Average	High	Well adapted to all environments
bi=1	Average	Low	Poorly adapted to all environments
bi>1	Below average	High	Specifically adapted to favourable environments
bi<1	Above average	High	Specifically adapted to unfavourable environments

The significance of regression coefficient (bi) and deviations from regression (S^2di) were tested using t-test and F-test respectively.

RESULTS AND DISCUSSION

The mean sum of squares due to genotypes and environments were found significant for days to flowering, green pod length and seed yield per plant (Table 1) which validates considerable variation among genotypes as well as environments. However traits *viz*., pods per plant, plant height and fresh yield per plant were found significant only for the environments. The genotype x environment interaction tested against pooled error was found to be significant for all the traits under study. Hence, these varieties showed inconsistency in performance across the environments and satisfied the requirement of stability analysis. The partitioning of G×E interaction into linear and non-linear components showed that both components played an important role in total G×E interaction for different characters. G×E (linear) mean squares were found significant for days to flowering, pods per plant, plant height, fresh pod yield and seed yield per plant, which indicated the presence of predictable components, whereas the variation due to pooled deviation was found highly significant for all the traits. This suggests that performance of different varieties fluctuated from their respective linear path of response to environment, and thereby indicate difficulty in predicting the performance of these varieties over environments for these traits. Patel et al. (2009) also found similar observations for some of these traits with their genetic material.

In interpreting the results of the present investigation, S^2_{di} was considered as the measure of stability (Breese 1969). Once the genotype was found to be stable based on nonsignificant deviation from regression (S^2_{di}=0), then the type of stability (measure of response or sensitivity to environmental changes) was based on regression coefficient and mean values. Regression coefficient (b_i) values above 1.0 define genotypes with higher sensitivity to environmental alteration. Regression coefficients below 1.0 ensure a greater resistance to environmental variation, and hence, increasing specificity of adaptability to low yielding environments (Kilic et al 2010).

In French bean, early maturing genotypes are ideal both from fresh and seed yield point of view to capture early market share and to fit into different cropping sequences. From average of all the environments, genotypes 'Arka Suvidha', 'DPDFB-1(M)', 'KPV-2' and 'MFB-4' were found early for day to 50% flowering (Table 2). They had values lower than population mean, b_i>1 and nonsignificant regression value (S^2_{di}), which showed its high stability and response to favourable environmental condition. Pod length of genotypes ranged between the highest 16.06 cm in genotype 'DWDFB-1' and lowest 12.55 cm in 'Falguni' across the environments. For pod length, four genotypes namely, 'DWDFB-53', 'HAFB-1', 'HAFB-3', and 'VLB-8' produced stable and desirable pod length below average performance of the genotypes, whereas 'Arka Suvidha', 'DPDFB-2 (M)', 'HAFB-2', 'IVRFB-1' and 'MFB-3' indicated better performance under favourable environments. For seeds per pod, 'Arka Anoop', 'DPDFB-1(M)', 'DPDFB-2(M)', 'DWDFB-57', 'HAFB-4', 'Aparna', 'Arka Komal' had shown above average mean value, average regression value (bi<1) and least deviation from regression (S^2di=0) and thus showed resistance to varied environmental conditions.

Number of pods per plant has a direct bearing on total productivity. In this regard, 'DWDFB-1', 'IVFB-2' and 'Aparna' showed their stability (bi ≤ 1) as potential genotypes with above average performance for number of pods per plant (Table 3). In addition, 'DPDFB-1(M)', 'DPDFB-2(M)', 'HAFB-1', 'HAFB-3', 'IVFB-1' 'MFB-2', 'MFB-3', 'VLB-8' and 'VLFB-130' may show stable performance under favourable environmental conditions (bi>1). Plant height in bush bean is desirable to the extent that it does not add to the cost of staking. Accordingly, genotypes 'Arka Suvidha', 'DWDFB-1', 'DPDFB-1(M)', 'DPDFB-2(M)', 'DWDFB-53', 'IVRFV-1', 'IVFB-1', 'IVFB-2' 'MFB-2' and 'MFB-3' and 'MFB-4' had more plant height over the standard checks, which might have resulted in significantly higher fresh pod yield per plant. However, based upon the stability parameters, genotypes 'IVRFB-1', 'IVFB-3', 'VLB-8', 'VLFB-2003' and 'Arka komal' were found more stable across the environments for this trait (Table 3).

For fresh pod yield per plant, however, all the genotypes were found with significant regression (S^2_{di}) except 'IVFB-3' (Table 3). On the basis of regression coefficient and mean values, the genotypes 'Arka Suvidha', 'DWDFB-1', 'DPDFB-1(M)', 'DPDFB-2(M)', 'IVRFB-1', 'IVFB-1', 'MFB-2' and 'MFB-3' showed stability above average (b_i>1) for high fresh pod yield, indicating that these genotypes are specifically adapted to favourable environments. Similarly, genotypes 'DWDFB-53', 'MFB-4' and 'Aparna' showed stability below (bi<1) average for high fresh pod yield, indicating their adaptation to unfavourable environments. Among the environments 'MFB-2' was observed to have the highest seed yield per plant with bi<1 and non-significant S²di value, indicating its stability under unfavourable environments with predictable performances.

Hence, it can be concluded that stability analysis helps to identify and select the most stable, high performing genotypes/varieties that are best suited under a given set of environmental conditions. Based upon the stability parameters, genotypes namely 'Arka Suvidha', 'DWDFB-1', 'DPDFB-1(M)', 'DPDFB-2(M)', 'DWDFB-53', 'IVRFB-1', 'IVFB-1', 'MFB-2' and 'MFB-3' were found stable across all environments. The wider adaptability of these genotypes can be attributed mainly to their wider adaptability for component traits like pods per plant, pod length, plant height, fresh and seed yield per plant. These genotypes are recommended for hybridization programmes to develop high yielding varieties with stability in performance.

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Table 1: Stability analysis of variance for yield and component characters in French bean

Source	df	Days to flowering	Pod length (cm)	Seeds per pod	Pods per plant	Plant height (cm)	Fresh pod yield per plant (g)	Seed yield per plant (g)
Environments (E)	3	761.81*	10.45*	0.39	1451.41*	1719.40*	40815.92*	3733.62*
Genotypes (G)	26	35.28*	8.56	1.07*	82.68	117.13	2728.70	711.27*
G × E	78	11.36*	2.52*	0.45	94.51*	75.00*	2686.83*	305.09*
E.+(G × E)	81	31.86*	1.20	0.16	84.09*	87.75*	2374.13*	236.02*
E (linear)	1	2285.43+	31.35+	1.16+	4354.23+	5158.15+	122448.1+	11200.89+
G × E (linear)	26	7.25+	0.79	0.17	48.84+	25.63+	1007.92+	184.72+
Pooled deviation	54	1.98*	0.83*	0.14*	21.96*	23.77*	808.33*	57.93*
Pooled error	208	0.75	0.31	0.04	0.84	1.32	7.43	3.95

Where, * Significant at P = 0.05; + Significant against pooled deviation at P=0.05

Table 2: Mean values and stability parameters for days to flowering, pod length and seeds/pod in French bean

Genotypes	Days to flowering			Pod length (cm)			Seeds per pod		
	Mean	b_i^2	S^2_{di}	Mean	b_i^2	S^2_{di}	Mean	b_i^2	S^2_{di}
Arka Suvidha	43.50	1.19	0.54	14.21	1.14	0.04	5.16	3.87	0.02
Arka Anoop	46.83	1.11	1.17	15.30	1.64	1.42*	5.57	2.43	0.02
DWDFB-1	46.25	0.93	0.36	16.06	0.49	0.74	5.81	-0.50	0.05
DPDFB-1(M)	44.08	1.28	0.62	14.96	1.98	0.20	5.56	3.50	0.10
DPDFB-2(M)	43.92	0.90	1.51	14.25	2.02	0.43	5.46	2.17	0.03
DWDFB-53	47.00	1.11	2.52*	13.55	0.82	0.65	5.05	1.50	0.26*
DWDFB-57	47.92	0.85*	0.27	15.21	0.37	0.39	5.01	2.29	0.21*
HAFB-1	45.67	0.99	2.39*	14.05	0.97	0.52	5.55	0.77	0.13*
HAFB-2	45.58	1.43	0.14	13.46	1.57	0.62	5.33	0.06	0.03
HAFB-3	46.17	1.01	0.77	13.70	0.53	0.65	5.43	-0.23	0.06
HAFB-4	46.25	1.10	0.56	14.03	-0.38	1.11*	5.73	1.25	0.02
IVRFB-1	48.42	1.37	12.05*	13.88	1.96	1.10*	5.65	-0.49	0.07
IVFB-1	44.25	0.86	0.70	15.07	1.56	0.17	5.50	0.45	0.05
IVFB-2	45.50	0.98	1.62	15.68	1.00	0.08	5.38	1.64	0.01
IVFB-3	45.08	1.11	4.50	15.15	1.36	0.49	5.57	0.20	0.09
KPV-2	43.08	1.10	0.85	13.56	0.22*	0.15	5.28	-2.77*	0.02
MFB-2	46.83	1.28	3.28*	14.89	1.10	3.17*	5.54	2.18	0.17*
MFB-3	43.58	0.98	0.38	14.13	1.11	0.10	5.81	-0.27	0.20*
MFB-4	44.25	1.10	0.67	15.10	2.00	2.93*	5.81	-0.54	0.59*
MFB-5	43.25	0.59*	1.79	15.47	0.85	0.18	5.84	0.39	0.26*
VLB-8	43.17	0.28*	5.49*	13.69	0.71	1.13*	5.60	3.42	0.40*
VLB-2003	42.67	0.70*	1.14	14.07	0.52*	0.04	5.03	0.94	0.04
VLFB-130	43.42	0.91	0.34	14.92	0.85	1.74*	5.08	1.20	0.52*
Aparna	45.92	1.69	3.90*	13.14	-0.47	2.37*	5.58	1.29	0.02
Falguni	46.67	1.09	1.68	12.55	-1.10*	0.54	6.21	-2.63*	0.09
Arka.Komal	42.83	0.64*	0.16	14.20	1.95	0.91	5.68	4.89	0.10
Contender	42.50	0.54*	3.87*	14.06	2.24	0.55	5.05	0.11	0.17*
Population mean	44.98	-	-	14.38	-	-	5.49		
CV (%)	3.84	-	-	7.69	-	-	6.31		

*Significant at P=0.05

Table 3: Mean values and stability parameters for pods per plant, plant height and yield (pod and seed) in French bean

Genotypes	Pods per plant			Plant height (cm)			Fresh yield per plant (g)			Seed yield per plant (g)		
	Mean	b_i^2	S^2_{di}	Mean	b_i^2	S^2_{di}	Mean	b_i^2	S^2_{di}	Mean	b_i^2	S^2_{di}
Arka Suvidha	14.82	0.70	21.32*	34.35	0.93	45.81*	104.72	1.21	591.17*	28.03	0.75	65.77*
Arka.Anoop	12.64	0.69	6.52*	33.69	1.19	9.66*	78.10	0.70	356.03*	17.57	0.34*	19.52*
DWDFB-1	16.96	0.82	5.42	34.90	0.57*	6.02*	113.74	1.14	76.99*	32.94	0.69	70.91*
DPDFB-1(M)	19.83	1.64	20.69*	35.62	1.01	4.69*	116.88	1.68	241.61*	44.27	2.36	284.22*
DPDFB-2(M)	18.56	1.87	40.02*	32.50	1.49	16.47*	105.06	1.71	643.82*	40.36	2.41	149.34*
DWDFB-53	17.63	0.57	60.16*	35.42	0.66	7.29*	104.47	0.38	2112.45*	28.16	0.56	132.73*
DWDFB-57	10.98	-0.19*	12.46*	32.15	1.18	13.19*	78.19	0.02	1503.90*	15.34	-0.28*	10.12
HAFB-1	18.57	1.21	55.73*	30.09	0.85	15.48*	109.01	1.00	1961.32*	31.69	1.10	83.71*
HAFB-2	15.94	1.22	22.81*	32.23	0.15*	12.43*	92.53	1.25	1622.09*	22.48	0.84	53.70*
HAFB-3	16.57	1.28	8.98*	32.28	1.20	6.03*	93.42	1.26	274.10*	21.56	0.93	39.71*
HAFB-4	13.73	0.87	1.09	36.38	1.32	9.80*	77.37	0.65	193.73*	21.05	1.10	11.12
IVRFB-1	14.84	1.19	14.80*	33.93	0.81*	0.80	104.21	1.37	934.08*	23.34	1.00	5.18
IVFB-1	18.13	1.38	13.64*	41.91	0.10	298.40*	106.41	1.32	823.58*	31.72	1.13	55.46*
IVFB-2	18.24	0.73	34.78*	36.46	0.82	9.57*	104.92	0.77	424.57*	28.51	0.72	61.66*
IVFB-3	15.99	0.61*	1.83	35.32	1.10	0.45	85.89	0.44*	2.70	24.72	0.54*	14.49*
KPV-2	14.74	1.40	28.89*	30.06	1.09	6.51*	69.73	1.04	1103.40*	21.19	0.98	27.07*
MFB-2	21.60	1.89	21.93*	35.08	1.46	19.25*	113.35	1.42	1126.30*	36.07	0.20*	9.42
MFB-3	22.31	1.80	2.31	34.39	0.66*	4.07*	128.69	1.91	129.74*	43.17	1.95	62.94*
MFB-4	14.87	0.61*	5.70*	34.73	1.08	19.35*	99.11	0.78	1305.56*	30.26	0.92	83.40*
MFB-5	15.38	1.24	12.02*	30.98	1.05	10.70*	91.62	1.02	373.82*	28.93	1.16	94.77*
VLB-8	16.39	1.25	2.91*	30.01	0.73	4.06	88.22	0.93	681.26*	28.20	1.14	26.69*
VLB-2003	11.91	0.37*	11.85*	29.00	1.21	1.09	70.28	0.47*	256.48*	22.33	0.05*	4.45
VLFB-130	16.65	1.52	7.92*	34.55	1.43	40.30*	82.33	1.39	626.27*	22.07	1.18	7.90
Aparna	17.52	0.78	100.53*	32.45	1.34	5.29*	96.87	0.91	2324.28*	23.68	0.46	143.47*
Falguni	16.89	-0.25*	11.59*	29.43	0.97	37.85*	78.45	0.04*	1090.37*	14.15	0.06*	0.72
Arka.Komal	15.84	0.63	54.30*	30.12	1.16	0.11	94.03	0.94	1014.02*	21.22	0.70	14.53*
Contender	14.49	1.11	12.86*	26.27	0.96	37.11*	85.81	1.22	643.29*	25.58	1.13	31.13*
Population mean	16.37	-	-	33.12	-	-	95.31	-	-	26.98	-	-
Coefficient of variation (%)	11.19	-	-	6.94	-	-	5.72	-	-	14.75	-	-

*Significant at P=0.05

Screening for high beta carotene and lycopene in tomato

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ABSTRACT
In recent years, beta-carotene and lycopene have become widely available as dietary supplements and are included in a number of popular multivitamin formulations and health food products. These carotenoids protect human tissue from oxidative damage. They are found in many fruits and vegetables. Beta-carotene and lycopene are the most abundant pigments in ripe tomatoes. Tomato fruit samples were collected from various sources in the North and Northeast of Thailand. They were planted and selected for desired characteristics. Two hundred and forty three tomato samples were evaluated for high beta-carotene and lycopene by spectrophotometric method. All tomato fruits were harvested at the red mature stage. Beta-carotene was extracted with a solution of hexane: ethanol: acetone (ratio 3:1.5:1.5). The absorbance was measured at 449 nm. Lycopene was extracted with a solution of hexane: ethanol: distilled water (ratio 5:3:1). The absorption of hexane phrase was measured at 471 nm. There were two samples with high beta-carotene, 126-1 and 229, with 3.49 and 3.30 mg/100 g fresh weight, respectively. The samples showing high lycopene were 126-1, 303 and 337, with 10.70, 10.89 and 11.62 mg/100 g fresh weight. The best tomato sample was 126-1, which showed high beta-carotene and lycopene. These numbers will be subjected to further analysis for a breeding program.

Keywords
Tomato, Beta-carotene, Lycopene, Beta-carotene extraction, Lycopene extraction

INTRODUCTION
Tomato (*Solanum lycopersicum* L.) is one of the most widely consumed vegetables worldwide. It is a member of the family Solanaceae. It is consumed fresh or in processed products such as canned tomato, sauce, juice, ketchup, paste, puree and soup (Lenucci et al. 2006). Tomato is a major source of antioxidants including carotenoids such as beta-carotene, a precursor of vitamin A, and mainly lycopene, which is largely responsible for the red color of fruit, vitamins such as ascorbic acid and tocopherols, and phenolic compounds. Tomatoes also contribute carbohydrates,

fiber, flavor compounds, minerals, proteins, and glycoalkaloids to the diet. (Stommel 2007).

Lycopene is one pigment in a large family of plant pigments known as carotenoids. Carotenoids produce colors ranging from the yellow color of squash, to the orange color of pumpkins, to the red color of tomatoes. Some carotenoids also possess provitamin A activity and have shown potent antioxidant activity. There are two primary types of carotenoids: hydrocarbon carotenoids and xanthophylls. Hydrocarbon carotenoids including lycopene and beta-carotene are composed entirely of hydrogen and carbon. Beta-carotene can be enzymatically cleaved to form vitamin A, an essential nutrient for proper eyesight and immune function. Vitamin A deficiency is a major cause of childhood mortality and is also a likely contributing factor to maternal deaths in developing countries. Lycopene lacks provitamin A activity because of the absence of a terminal beta ionone ring (Rao and Rao 2007). In contrast, xanthophylls, such as lutein, contain oxygen in addition to carbon and hydrogen (Story et al. 2010). The tomato crop makes a significant dietary contribution to human health. Current research on improving phytonutrient content includes greater focus on the study of health-promoting micronutrients as well. A vast number of phytonutrients have been identified, which are believed to impart health benefits. Varietal development programs have long focused on selection for yield and disease resistance. Enhancement of constituents that are not major yield components take on new importance today in crop improvement programs as market demands support these efforts (Stommel 2007).

In Thailand, tomato is produced for the fresh and processing markets on proximately 6,199 hectares, with an average yield of 24.2 t/hectare in 2009 (Office of Agricultural Economics 2009). Commercial varieties for processed tomato are imported by individual companies. Most fresh tomato varieties are table tomatoes called ‘Si-da’, used in papaya salad and in many condiments. Currently, consumers are interested in the potential health-protecting role of lycopene. Fresh tomato consumption is more popular than processed tomato. Many cherry tomato varieties with high lycopene content have been introduced and developed such as ‘Tomatoberry’. This variety contained two-fold lycopene content than beta-carotene content in the fruit (Matichon News 2013). The development and production of crops with higher nutritional value is presently important. This study focused on evaluation of tomato germplasm for high beta-carotene and lycopene content. These tomato samples will be used for the development of specialty tomato cultivars.

MATERIALS & METHODS

Tomato sampling and sample preparation

Two hundred and forty three tomato samples were collected from various locations in North and Northeastern Thailand. The tomatoes were grown in the field of Sisaket Horticultural Research Center from December 2012 to February 2013. Freshly harvested, uniformity ripened healthy fruits were taken for analysis. Three to five fruits of each sample were selected randomly to study the variation in content of various biomolecules such as beta-carotene and lycopene in tomato pulp. The ripe tomato fruits were chopped and pooled. These samples were homogenized by hand homogenizer without adding water for 5 min at room temperature. The tomato puree was used for extraction.

Beta-carotene extraction

The extraction method followed was by Thomnuad (2008). One gram of the puree was extracted using 3 ml mixture of hexane: ethanol: acetone (1.5:0.75:0.75, v/v/v) The samples were mixed vigorously and centrifuged at 5000 rpm for 10 min. The 100 μl of hexane on the top layer was separated from residue and 900 μl of hexane were added. It was assayed for beta-carotene content by measuring the absorbance at 449 nm. Concentration of beta-carotene was calculated using beta-carotene standard curve. Results were expressed as mg/100 g fresh weight (fw).

Lycopene extraction

Lycopene was extracted as described by Suwannalert (2006). One gram of the puree was transferred into a test tube and 3 ml of hexane: ethanol: distilled water (5:3:1, v/v/v) were added. After mixing vigorously for 1 min, the extract was centrifuged at 5000 rpm for 10 min. The 100 μl of phase was separated into the new tube and 900 μl of hexane were added. Optical density of the hexane extract was measured by spectrophotometer at 471 nm. The lycopene concentration was calculated using lycopene standard curve. Results were expressed as mg/100 g fw.

RESULTS AND DISCUSSIONS

Beta-carotene content

The variation of beta-carotene content was found in these samples. The lowest beta-carotene content was 0.6 mg/100 g fresh weight (fw), and the highest was more than 3 mg/100 g fw. The beta-carotene content was divided into 6 groups (Table 1).

Table 2 shows some characteristics of tomato samples with high beta-carotene content. The highest beta-carotene level was found in 126-1. This sample had beta-carotene content of 3.49 mg/100 g fw. It is a fresh market tomato with red fruit color and 6% TSS.

A few tomato cultivars with increased levels of beta-carotene have been reported. The Agricultural Research Service of the United States Department of Agriculture announced the release of two new cherry tomato breeding lines designated 02L1058 and 02L1059. These lines are orange-pigmented and produce fruit with high beta-carotene content. Fruit of lines 02L1058 and 02L1059 accumulate predominantly 46.5 and 41.8 $\mu g g^{-1}$ tissue fresh weight, respectively (Stommel 2005). AVRDC – The World Vegetable Center has two improved high beta-carotene lines, CLN2366A and CLN2366B. These lines have been evaluated for adaptation to the semi-arid conditions in West Africa. They yielded 23 and 28 t/ha, respectively under hot-wet conditions. The fruit of both lines is orange in color, an indication of their high beta-carotene content. High beta-carotene tomato could be a principal crop in the battle to fight vitamin A deficiency in sub-Saharan Africa (AVRDC 2009).

Lycopene content

The lycopene content analysis is shown in Table 3. Table 4 shows some characteristics of tomato samples with high lycopene content. There were 5 samples with high lycopene content between 10.22-11.62 mg/100 g fw. Samples 322, 357, 126-1 and 337 are fresh market types with red fruit and 4.0%, 5.0%, 6.0% and 7.0% TSS. They had lycopene content of 10.22, 10.22, 10.70 and 11.62 mg/100 g fw respectively. Sample 303 is a cherry tomato type with red fruit and 6.0% TSS. The lycopene content was 10.89 mg/100 g fw. The highest lycopene level was found in 337. These results are also confirmed that high-pigment tomato is characterized by a very high lycopene content (>200 mg/kg fw) (Lenucci et al. 2006).

The lycopene content of tomato samples depends on the cultivar and maturity stage, and is affected by growing conditions, temperature and humidity. Garcia and Barrett (2006) studied the variation in lycopene content in processing tomato grown in nine California counties. Tomato cultivars were harvested during the early season (mid-July through mid-August), mid-season (mid-August through early October). The results showed the smallest lycopene concentration detected in the juice was 55.0 mg/kg fw, obtained with tomato harvested during the early season. The largest lycopene concentration obtained was 181.4 mg/kg in the juice of mid-season tomatoes, reflecting a 3.3-fold variation in lycopene concentration.

This study showed that most of the tomato samples were low in beta-carotene and lycopene content. Large variation in the lycopene of the cultivars can be attributed to factors such as plant nutrition, environment and genotype, which together markedly affect the biosynthesis of carotenoids (George et al. 2004). Carotenoid content differs in tomato germplasm, ranging from accessions with high beta-carotene and low lycopene contents, low beta-carotene and low lycopene contents (yellow fruits), and high lycopene content at the expense of beta-carotene (Adalid et al. 2012).

Our results showed that 126-1 exhibited the highest value of beta-carotene and lycopene. This indicated that the high amount of beta-carotene was associated with a high amount of lycopene. Lycopene represents the most abundant carotenoid in red-ripe tomato (approximately 90-96% of the total pigments). The amount of beta-carotene was also measured. The results were similar to those of Ilahy et al. (2011), who studied six high-lycopene tomatoes in Italy. All high-lycopene tomatoes showed high lycopene and beta-carotene content. The cultivar HLY18 showed the highest lycopene and beta-carotene content with 232.9 mg/kg fw and 19.4 mg/kg fw, respectively.

CONCLUSIONS

Our results indicate that beta-carotene and lycopene content vary in tomato samples. Carotenoid accumulation in tomatoes is affected by cultivar and maturity, as well as the environment. Sample 126-1 presented the highest beta-carotene and lycopene content. This sample is a potential parent in breeding programs for developing hybrids with high beta-carotene and lycopene content.

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Table 1. Beta-carotene content in tomato samples

Beta-carotene (mg/100 g fresh weight)	Number of samples
0.60-1.00	123
1.01-1.50	89
1.51-2.00	20
2.01-2.50	8
2.51-3.00	1
> 3.01	2
Total	243

Table 2. Characteristics of tomato samples with high beta-carotene content

Sample no.	Beta-carotene (mg/100 g fresh weight)	Fruit type	Fruit color	Total soluble solids (%)
047	2.43	cherry	red	6.0
303	2.44	cherry	red	6.0
037-9	2.60	cherry	red	5.6
299	3.30	fresh market	red	6.0
126-1	3.49	fresh market	red	6.0

Table 3. Lycopene content in tomato samples

Lycopene (mg/100 g fresh weight)	Number of samples
8.00-8.50	193
8.51-9.00	29
9.01-9.50	10
9.51-10.00	5
10.01-10.50	3
>10.51	3
Total	243

Table 4. Characteristics of tomato samples with high lycopene content

Sample no.	Lycopene (mg/100 g fresh weight)	Fruit type	Fruit color	Total soluble solids (%)
322	10.22	fresh market	red	4.0
357	10.22	fresh market	red	5.0
126-1	10.70	fresh market	red	6.0
303	10.89	cherry	red	6.0
337	11.62	fresh market	red	7.0

The selection of onion varieties for off-season production

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ABSTRACT

This study was conducted on a farmer's farm located in Chiang Mai and at the Khon Kaen Agricultural Production Science Research and Development Center in Khon Kaen during the off-season 2012-2013. All experiments were laid out using a RCBD, four replications and ten treatments (nine varieties of F1 seed onion imported from Netherlands; Cavalier, Sirius, Minerva, Buccaneer, Colossus, Annika, Sweet Uno, Lucinda and Fernanda, and one variety commonly used by Thai farmers, Superex). Performance variables including growth, yield, physical characteristics and quality attributes were recorded. The productivity of Fernanda, Colossus and Buccaneer (270, 250 and 220 kg/ha) varieties were higher than the other varieties in all locations. The bulb shape of their varieties was different such as rhomboid, broad, globe, broad elliptic and spindle shapes. The bulb diameter and length of Fernanda and Colossus were bigger than other varieties. Number of leaf bases of all varieties were 5-8 scales. The total soluble solid of Lucinda and Minerva (8.70 and 7.88 ^{o}Brix) was the highest relatively to other varieties. Further investigation on the selection of onion varieties in season, postharvest handling, the nutritional quality, satisfaction of farmers and consumers, and marketing acceptance should be conducted in the future.

Keywords

Variety, production, quality, off-season, onion

INTRODUCTION

Onion (*Allium cepa* L.) is classified in the Amaryllidaceae family, monocotyledonous, herbaceous biennial, cool season vegetable crops (Khan et al. 2007), cross-pollinated, and diploid chromosomes number 2n=16 (Dawar et al. 2007). Onion is a source of vitamins and minerals (Condé Nast 2013). In Thailand, onion is a high value vegetable crop. In 2012, onion productivity was 24.6 t/ha, and total production was 39,909 tons. Chiang Mai is the largest onion producer (approximate 34,261 tons), followed by Chiang Rai (3,624 tons), Nakorn Sawan (1,463 tons), and Kanchanaburi (564 tons). Onion varieties are generally classified by day length (short, intermediate, and long). Most types of onion sold in local markets are short-day varieties that have 5-7% soluble solids and 2-6 moles/kg of pyruvic acid (2-6 moles kg) and high pyruvate ratio, which causes the onion to be sweet (Smith et al. 2011). Superex is the only short-day onion available in Thailand. From 2012 to 2014, Thailand annually imported 3.15 tons (6,944 pounds) of onion seed from Japan under the tariff quota with zero percent tax. In turn, Thailand exports fresh onion back to Japan (Daily News Thailand 2012). Under the tariff quota, the Onion Growers Cooperative of Thailand is the only importer of onion seeds from Japan. Onion seeds are distributed o members to reduce production costs. The tariff for those outside the tariff quota is 218% according to the World Trade Organization (WTO) obligation (Bank of Thailand 2001). Due to limits on onion seed importation, farmers cultivate onion only once a year after rice harvesting from December to April. Onion bulbs are stored from May to October. As a result of import limits, seed from the black market is smuggled to Thailand. This increases onion production costs and leads to decreased prices. The government has tried to reduce excess supply and improve quality to serve consumer demand and increase the onion price.

Although the government has helped farmers obtain higher onion prices, in the early harvesting season onion prices are low. This study analyzed high potential production areas and investigated the onion production system. Results will be used to improve and develop onion production system.

MATERIAL AND METHODS

Ten varieties of onion (*Allium cepa*)—nine varieties of F1 seed onion imported from the Netherlands (Cavalier, Sirius, Minerva, Buccaneer, Colossus, Annika, Sweet Uno, Lucinda and Fernanda), and one variety used by Thai farmers, Superex (control). Seedlings of uniform size on visual observation were transplanted on February 7, 2013 on a flat bed system. The plot size was 1 m × 5 m for each treatment. Row-to-row and plant-to-plant spacing were 20 and 15 cm, respectively. Well-rotted field manure at the rate of 6.25 t/ha and lime at 1.25 t/ha were incorporated to the soil 30 days before transplanting the seedlings. The recommended dose of N, P and K fertilizers was applied at the ratio of 62.5-93.75 kg (21-0-0) ha, 68.75 kg (0-46-0) ha and 31.25-62.5 kg (0-0-60) ha. All the fertilizers were applied three times and same dose in 7, 25 and 50 days after transplanting. All the cultural and management practices like hoeing, weeding, irrigation and sprays for insect pests and disease control were carried out uniformly for all treatments. Onions were harvested at maturity, about 90 days after planting (DAP). The plants showed neckfall from three locations in Chiang Mai (MaeWang, Praow, Fang) and one location in Khon Kaen, Thailand during 2012-2013. The onions were then transported to Chiang Mai Royal Agricultural Research Center (CMRARC) within 2 h at 30-32^{o}C. After grading for uniform size and shape, data on the growth, physical characteristics, yield, and quality attributes were recorded. Ten bulbs were selected for physical characteristics evaluation.

METHODS

Bulb yield

Total yield (kg/ha) was calculated for each variety.

Physical characteristics

The bulb weight was measured gravimetrically using a precision balance model Sartorius ELT 2001.3. It was expressed in grams (g).

The bulb diameter and length were measured using a vernier caliper model Mitutuyo Absolute Digimatic CD-12″. It was expressed as centimeters (cm).

The bulb shape was measured on a 1-9 scale of mature onion. The following scale (IPGRI, ECP/GR, AVRDC 2001): 1 = flat oval, 2 = flat globe, 3 = rhomboid, 4 = broad, 5 = globe, 6 = broad elliptic, 7 = ovate (elongated oval), 8 = spindle and 9 = high top.

Number of leaf bases and number of scale leaves were measured for each onion variety.

Peel color was measured using the Royal Horticultural Society (RHS) Color Chart. Readings were taken in three positions of fruit area. Pulp color was determined following the Royal Horticultural Society (RHS) Color Chart.

Quality attributes

Bulb firmness was measured using a fruit hardness tester (Nippon Optical Works FHR-5) and a 5 mm-base diameter cylinder. Readings were taken in three positions of bulb area, averaged and recorded in newtons (N).

Total soluble solids (TSS) was measured by direct readings of onion juice using a hand-held digital refractometer (Atago Pocket refractometer PAL-1) with results expressed in ^{o}Brix. The measurement was taken in three positions of fruit area.

Statistical analysis

The experiments were laid out using a completely randomized design (RCBD). Ten treatments and four replicates per treatment were evaluated for their growth and development. The data were analyzed using Analysis of Variance (ANOVA). Where possible, mean comparisons were made using Duncan's multiple range tests (DMRT) at $p \leq 0.05$. Statistical analysis was carried out using the SAS system.

RESULTS

Bulb yield

In Praow, the total bulb yield of Fernanda, Colossus and Buccaneer varieties (1689, 1564 and 1320 kg/ha) were significantly higher than the other varieties (Fig. 1). At the Fang site, the variety Fernanada (1368 kg/ha) was observed to have the highest bulb yield. Praow is the most suitable area to cultivate these varieties, followed by Fang.

Physiological characteristics

Bulb weight

The maximum bulb weight of Fernanda, Colossus and Buccaneer in Praow were 62, 53 and 53 g/bulb, respectively (Fig. 2). The bulb weights of these varieties grown in the Praow site were significantly higher than the same varieties grown in MaeWang, Fang and Khon Kaen.

Bulb diameter and length

Measures of bulb diameter and length of the Fernanda and Colossus varieties grown in Praow were larger than the other varieties grown in other areas (Table 1).

Bulb shape

All varieties have similar shapes that span from rhomboid, broad, globe, broad elliptic and spindle (Table 1, Fig. 3). However, Fernanda and Buccaneer varieties in all areas have shapes ranging from globe to broad elliptic, while the Colossus variety is broad ellipse and spindle.

Number of leaf bases

Number of leaf bases found in all varieties varied between 6 to 8 scales (Table 1). Varieties grown in Praow including Fernanda, Buccaneer and Colossus have a greater number of leaf scales (8 scales) than onion grown in Mae Wang (7 scales) and Fang (6-7 scales).

Peel and pulp color

All varieties showed peels with light colors; however, the pulp color varied from pale orange to pale yellow (Fig. 3). Minerva has white peel and pulp color.

Quality Attributes

Bulb firmness

The bulb firmness of Sirius, Buccaneer and Colossus in Khon Kaen were 3.54, 3.53 and 3.51 N, respectively, which was higher than MaeWang and Praow (Table 2).

Total soluble solids (TSS)

TSS of Lucinda and Minerva in MaeWang (8.70 and 7.88 ^{o}Brix, respectively) and Praow (8.13 and 7.63 ^{o}Brix, respectively) were higher than all varieties in Khon Kaen (Table 2).

CONCLUSION

Total bulb yield of Fernanda and Buccaneer and Colossus varieties in all sites were significantly higher than the yields of other varieties. Varieties such as the Fernanda, Buccaneer and Colossus showed desirable physiological characteristics such as bulb weight, size, shape, fleshy scale leaves, and peel and pulp color. The quality attributes of bulb firmness and TSS in these varieties were better than Superex. However these quality attributes were different in each variety and each area. Our findings suggest that the varieties Fernanda, Buccaneer and Colossus are the most appropriate to grow in all areas.

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Table 1. The average bulb weight, bulb size (width and length), bulb shape and fleshy scale leaves of each onion variety after harvest at three locations in Chiang Mai (MaeWang, Praow and Fang) and one location in Khon Kaen.

Varieties	Bulb shape[1/]				Number of leaf bases[1/]									
	Diameter (mm)				Length (mm)									
	MaeWang	Praow	Fang	Khon Kaen	Mae Wang	Praow	Fang	Khon Kaen	Mae Wang	Praow	Fang	Mae Wang	Praow	Fang
Cavalier	32 dc	40 c	33 bc	38 a	30 g	47 cd	46 ab	37 a	4,5,6,8	6,8	4,5,6	6 ab	7 c	5 d
Sirius	32 dc	41 bc	32 c	38 a	41 cde	54 ab	46 ab	37 a	6,8	6,8	5,6	6 ab	7 bc	5 cd
Minerva	37 abc	41 bc	35 b	38 a	34 efg	48 cd	48 a	37 a	5,6,8	6	5,6	7 ab	7 bc	5 cd
Buccaneer	41 a	44 bc	33 bc	39 a	38 def	55 ab	47 a	38 a	3,4,5,6	5,6,8	4,5,6	7 a	8 a	6 bc
Colossus	36 abcd	45 ab	33 bc	39 a	33 fg	57 ab	45 ab	38 a	3,6,8	5,6,8	5,6,8	7 a	8 ab	6 ab
Annika	30 d	40 c	32 c	37 a	46 abc	52 bc	47 a	37 a	6,8	6,8	4,5,6	6 b	7 bc	5 cd
Sweet Uno	41 a	43 bc	40 a	38 a	44 bcd	47 d	41 c	38 a	4,5,6,8	4,6,8	4,5,6	7 a	7 ab	6 ab
Lucinda	34 bcd	41 bc	33 bc	38 a	49 ab	48 cd	43 bc	37 a	5,6,8	6,8	5,6	7 ab	8 ab	7 a
Fernanda	38 ab	48 a	33 bc	38 a	52 a	58 a	47 a	38 a	3,4,5,6,8	5,6,8	5,6	7 a	8 ab	7 a
Superex	34 dc	43 bc	32 bc	34 b	46 abc	44 d	43 bc	35 b	5,6,8	5,6	5,6	7 ab	7 c	5 cd
P≤0.05	**	*	**	**	**	*	**	**				*	*	*
CV.	11.49	6.08	5.15	4.03	11.35	6.48	4.28	3.71				11.03	4.26	8.09

1/ = Means followed by the same letter in a column are not significantly different but means followed by different letters in a column are significantly different at 95% (P≤0.05) by DMRT.

Table 2. The average bulb firmness and total soluble solids (TSS) of each onion variety after harvest at three locations in Chiang Mai (MaeWang, Praow and Fang) and one location in Khon Kaen.

Varieties	Bulb firmness (N) [1/]			TSS (^{o}Brix) [1/]		
	MaeWang	Praow	Khon Kaen	MaeWang	Praow	Khon Kaen
Cavalier	2.25 ab	2.28 ab	3.18 c	7.43 bc	7.13 bc	4.84 ab
Sirius	2.28 ab	2.26 b	3.54 a	6.83 cd	6.50 cd	7.20 a
Minerva	2.33 a	2.27 b	3.47 ab	7.88 ab	7.63 ab	6.56 ab
Buccaneer	2.25 ab	2.32 ab	3.53 a	7.38 bc	7.25 b	5.66 ab
Colossus	2.21 b	2.32 ab	3.51 a	6.33 d	6.13 d	5.82 ab
Annika	2.24 ab	2.32 ab	3.44 ab	7.05 bcd	6.38 d	4.33 b
Sweet Uno	2.22 b	2.28 ab	3.37 abc	7.05 bcd	6.13 d	6.68 ab
Lucinda	2.26 ab	2.23 b	3.28 bc	8.70 a	8.13 a	5.42 ab
Fernanda	2.29 ab	2.30 ab	3.47 ab	6.38 d	6.00 d	4.51 ab
Superex	2.28 ab	2.37 a	3.42 ab	6.63 cd	6.13 d	5.83 ab
P≤0.05	*	*	*	**	**	ns
CV.	2.27	2.58	4.22	8.04	6.73	34.87

[1/] = Means followed by the same letter in a column are not significantly different but means followed by a different letter in a column are significantly different at 95% (P≤0.05) by DMRT.

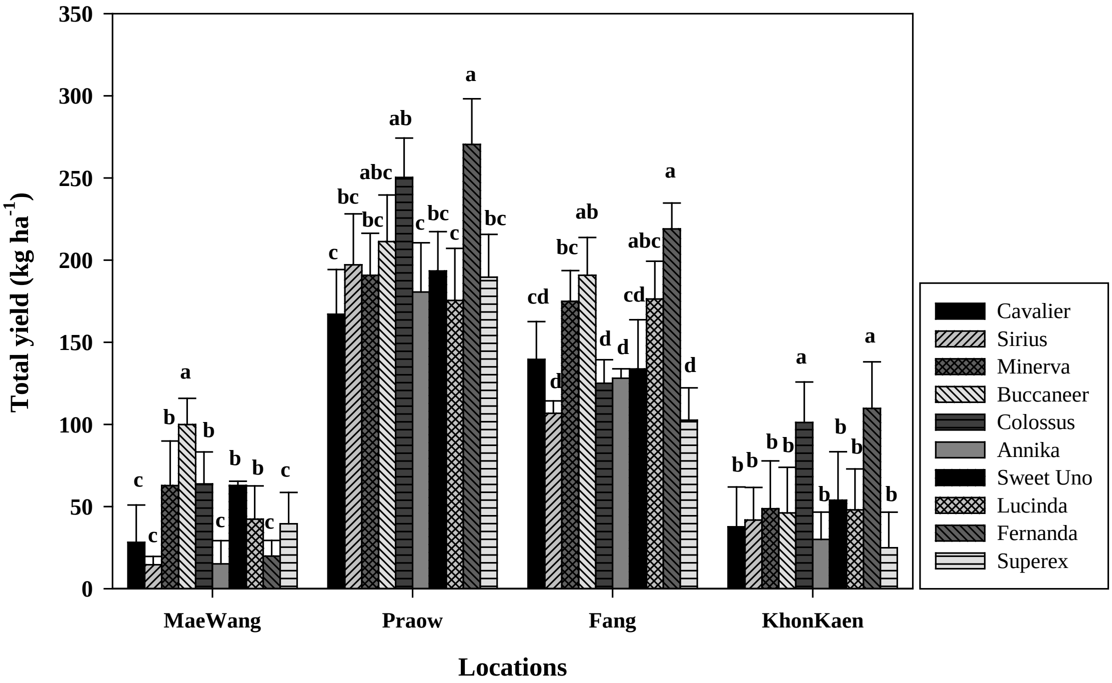

Figure 1. The total yield of each onion variety after harvest at three locations in Chiang Mai (MaeWang, Praow and Fang) and one location in Khon Kaen. Symbols labeled with different letters are significantly different at 95% (P≤0.05) by DMRT.

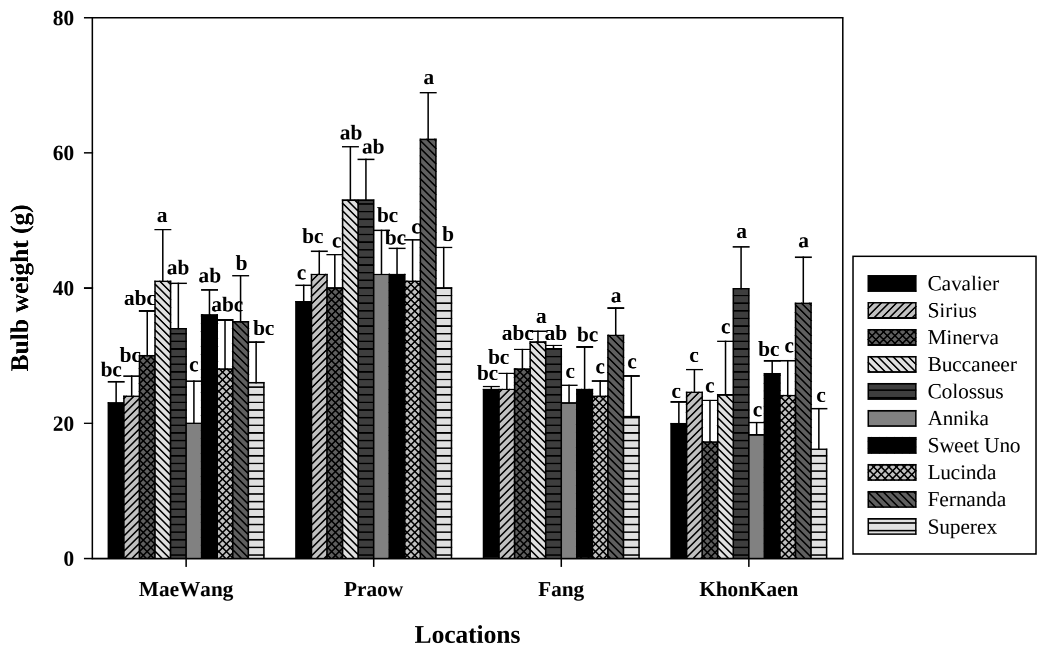

Figure 2. The average bulb weight of each onion variety after harvest at three locations in Chiang Mai (MaeWang, Praow and Fang) and one location in Khon Kaen. Symbols labeled with different letters are significantly different at 95% (P≤0.05) by DMRT.

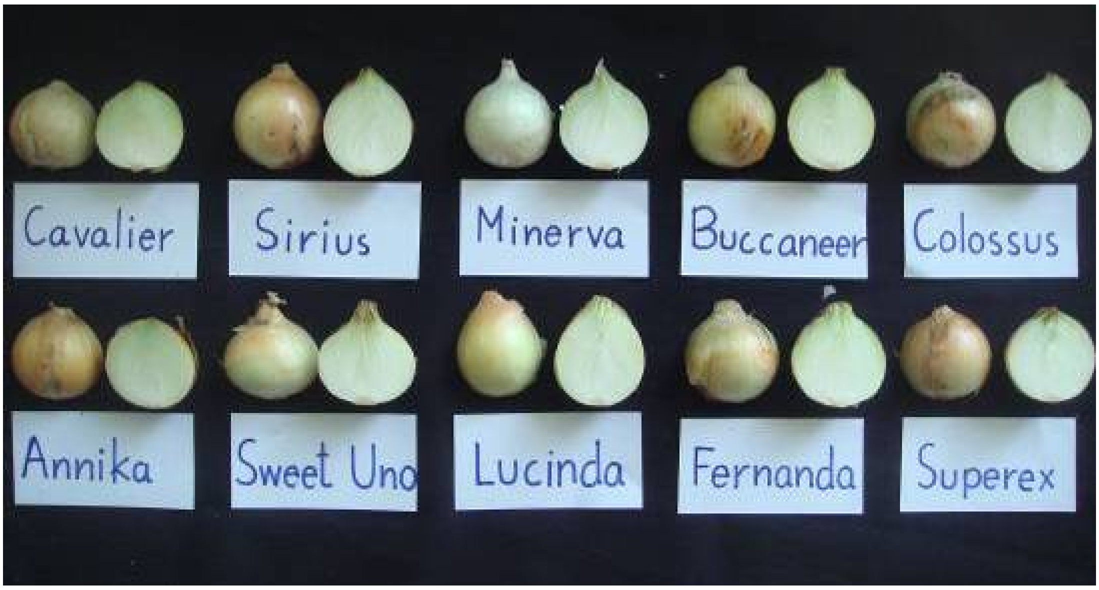

Figure 3. The bulb shape, size and peel-pulp color of each onion variety after harvest at three locations in Chiang Mai (MaeWang, Praow and Fang) and one location in Khon Kaen.

Varietal evaluation, on-farm trials and seed production of organic vegetables in Central Luzon, Philippines

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ABSTRACT

Nine tropical vegetable crops were identified and considered in this project: eggplant, okra, yard-long bean, squash, tomato, pechay, onion and melon. Each crop had five entries per variety, which were obtained from IPB-UPLB (Institute of Plant Breeding-University of the Philippines, Los Baños, Laguna), landraces from farmers of various localities of Central Luzon, and other research and breeding institutions in the Philippines based on high yield, acceptability to consumers, resistance to pests and diseases as well as abiotic stresses.

The initial evaluation was conducted in 2 × 5 m plots and was exposed to less application of cultural management methods and farm inputs, and subjected to environmental stress including less irrigation. Crops that performed well under these stressors were selected. During replicated yield trials, commercial varieties were used and planted along with the crop selections in organic production systems. All selections that out-yielded the yields or were at par with the yields of the commercial check were further evaluated both on-station and at the farmer's field level.

To ensure a high degree of acceptability of these varieties among target end-users participatory selection was undertaken involving organic farmers. A simple survey on the fruit appearance quality was undertaken with organic vegetable growers, also traders and consumers. This information guided the identification of crop varieties for further development of production and varietal management technologies.

There were at least three promising selections for each crop mentioned above. Seed was produced and is ready to release for use as organic vegetable seeds for Central Luzon, Philippines.

Keywords

organic vegetable seeds, participative crop selection

INTRODUCTION

The local and export markets for organically grown products are increasing and the Philippines is not taking advantage of this opportunity, especially in vegetables. Multinational companies are taking the lead as well as the risks and gains in this sector but mainly on fruits, namely, banana and pineapple. In vegetables, the Organic Producers and Traders Association (OPTA) is the trailblazer but the other sectors, especially the Government, should take part. There is very little research and development being done on organic vegetables, which should be the main function of government institutions for the industry aside from regulation and extension.

Since most of the varieties available commercially are conventionally produced, it is timely to develop varieties under local and organic conditions. The fact that the same varieties are being used in organic farms as in conventional farms does not mean that these are the best varieties for organic farming systems. Part of developing varieties is the selection under low input and organic conditions. The variety to be used should be suited for organic cultivation, that is, it is generally resistant to insect pests and diseases. While some varieties perform well across locations, it is best to do the selection where the crop will be produced commercially to take into account the genotype x environment interaction. Growers and the consumers should do the selection eventually, to be sure that the varieties selected or developed will be commercially viable.

Among the constraints in organic agriculture in the Philippines is “lack of farm inputs for organic production including fertilizer, pest control and seeds” (The State of the Sector Report - Philippine Organic and Natural Products 2004 Pearl Project). The other constraints are lack of financing, training, technologies for conversion, processing equipment, storage facilities, and marketing system and information. Organic gardens should use organically produced seeds, but these are not yet commercially available in the country. The organic farmers need propagating materials designed specifically for their type of farming system.

With the increasing demand and enthusiasm for organically grown vegetables and the need for organically produced seeds as stipulated in the Philippine National Standards (PNS) for Organic Agriculture there should be a sustainable supply of organically grown seeds of varieties suitable for organic production systems. There is also a need to test the varieties selected under different locations. These will help spur the growth of organic production in the Philippines.

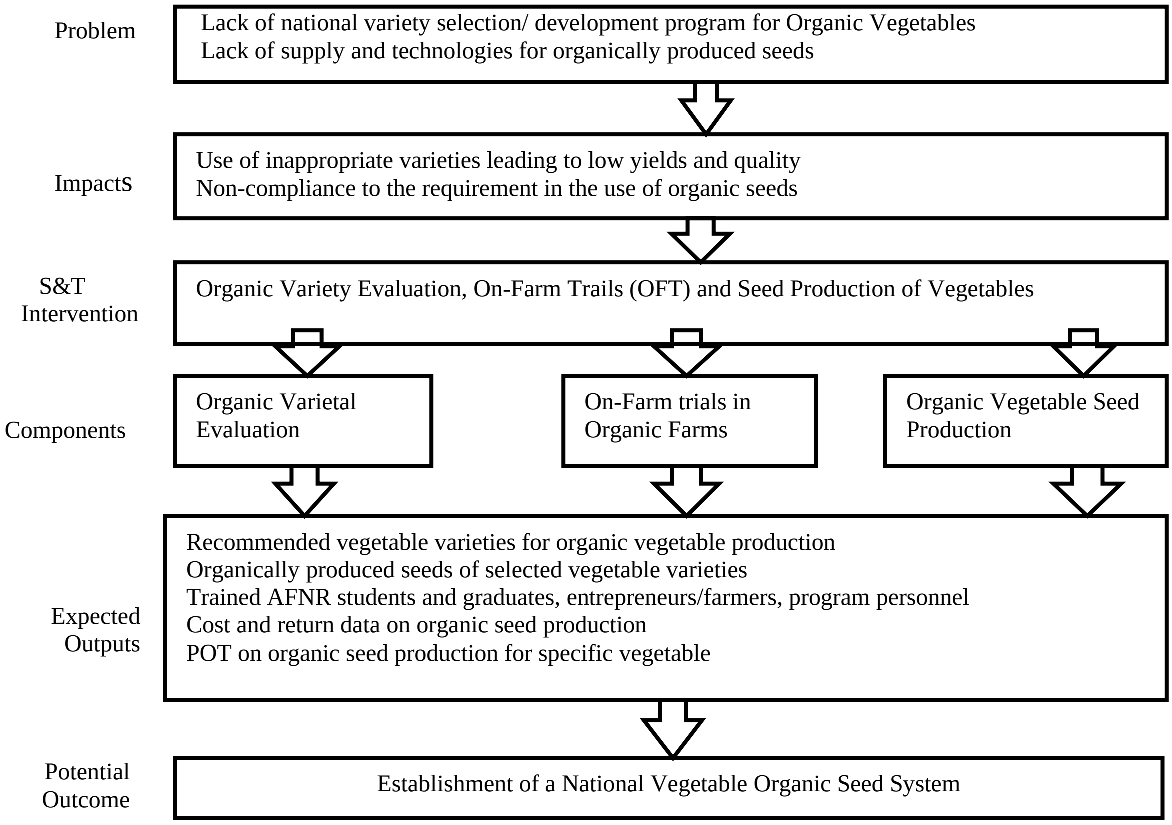
Objectives

The general objective of this project was to enhance the organic vegetable production and develop it as an entry point for livelihood enterprise for the employability of Agriculture and Fishery Natural Resources (AFNR) graduates through technology and entrepreneurial capability development. It also aimed to increase organic vegetable production through selection of varieties for organic gardens and organically produced seeds, and develop a package of technology (POT) and cost and return data on organic seed production for specific vegetables.

METHODS

The program consisted of three components, namely: evaluation of varieties under organic conditions, on-farm trials in commercial organic gardens, and production of organically grown seeds of selected vegetable varieties. In all these components/stages, the AFNR students, graduates, farmers, and entrepreneurs were given the opportunity to work with the researchers/implementers in the program activities. There were lectures, demonstration, and hands-on sessions that aimed to better understand and appreciate the techniques in variety selection and evaluation and production of organically grown vegetable seeds. These activities enabled cooperators to be immersed in the day-to-day activities and management of an organic farm. These farms considered are Science & Technology model farms that showcased the latest organic vegetable farming technologies and inputs, which may also influenced other farmers, AFNR students and graduates to start their own organic farm and input business.

Conceptual framework



Evaluation of varieties under organic conditions

Open-pollinated varieties (OPV) were evaluated for at least two seasons under organic conditions (based on the PNS for Organic Agriculture). Entries were collected from IPB-UPLB (re: selections under organic conditions), farmers, and other breeding institutions. There were at least five varieties per crop. The area used for the trial has been dedicated to organic trials and production. There were minimal interventions in terms of pest management to determine the difference in resistance to pests and diseases among the entries. Meetings and workshops were held before the actual start of the project for leveling-off and synchronization of procedures.

The following crops were considered for Region III for evaluation under different locations: melon, onion, pechay, yard-long bean, squash, okra, eggplant, tomato and bitter gourd.

CROP	Agency		
	CLSU	PAC	BASC
Bitter gourd	X	X	X
Eggplant	X	X	X
Okra	X	X	X
Onion	X		
Pechay	X	X	X
Yard-long bean	X	X	X
Squash	X	X	X
Tomato	X	X	X
Melon	X	X	X

X = priority assignment

Cultural management for each crops such as irrigation, weeding, and pest and disease control were employed in the way of organic farming.

Fertilization

Basal application of organic fertilizer was done per hole or hill for eggplant, tomato, squash, muskmelon and bitter gourd. For pechay, onion and yard-long bean, the organic fertilizer was broadcast in beds or in furrows before planting. Application rate of organic fertilizer for all crops was 5 t/ha. Compost tea, manure tea, and fermented plant juices from *Gliricidia sepium*, *Ipomoea aquatica*, and *Leucaena leucocephala* were applied to provide the nutrient requirement of the crops.

Irrigation

The crops were irrigated using a shallow tube well and deep well delivered through earth. The experimental site was set up very near the source of water and away from conventionally tilled crops to avoid contamination.

Weeding

Weeding was done only using manual or animal-drawn equipment. No chemical weed control was employed.

Pest and disease control

Pest and disease control was done through the use of all available plants reported to have pesticidal and fungicidal properties. Other pest management such as intercropping, farmscaping, pest repellent crops, trapping, and use of barriers were also employed. Each crop was planted in a plot measuring 2 × 5 m with three replications for each entry. Basal application of organic fertilizer was employed. Liquid foliar fertilizer made from fermented fruit juices, fish amino acid, and others materials were employed to supplement the nutrient requirement of the crops for maximum growth and development. Evaluation period was done during two seasons (wet and dry).

Data on yield performance, horticultural characters, and reaction to pest and diseases was gathered. A portion of the plot was allotted for seed production for the next trial. For cross-pollinated vegetables (squash, bitter gourd) and often-crossed (eggplant, pepper) plants, selfing was done to ensure variety purity.

Selection of environment

The trial area followed most of the requirements of PNS. Nutrient management was through the use of organic fertilizers produced from available raw materials in the area. Pest management was mainly through cultural and physical means (intercropping, farmscaping, pest repellant crops, trap crops, barriers). Use of organic sprays was minimal to be able to select lines with field resistance.

Selection criteria

Selection criteria depended on the requirements of the market. In general, the selected lines should have resistance to pests and diseases, vigorous, good yield and quality, and long shelf life. Participatory varietal selection per site was done by inviting farmers, traders and consumers of organically produced vegetables in a field day held during peak harvesting season.

RESULTS AND DISCUSSION

Year 1 Accomplishments

Agro-climatic description of Nueva Ecija

Nueva Ecija is situated in the eastern rim of the broad Central Luzon Plains (Fig. 1 and 2) lying between 120’36’28’ to 121’21’45’ east longitude and 15’09’30’ to 16’09’30’ north latitude. The province of Nueva Ecija has Type II prevailing type of climate with distinct dry and wet seasons. In 2011 rainfall started as early as May and ended in December, with peak months from July to October; strongest rain was recorded in October, with 47 mm. Relative humidity ranges from 60% to 75%, with an average of 67%. The prevailing temperature ranges from 25.0 to 38.0 C^{o} with mean of 31.5 C^{o} (Fig. 3). The terrain of the province is comprised of low lying alluvial plains and rolling uplands. Generally, Nueva Ecija has clay to clay loam or sandy loam Maligaya type of soil. Vast and untapped deposits of metallic and non-metallic soils can be found in the mountain and forest areas. (wikepedia.org/wiki/Munoz Nueva Ecija).

Collection and selection of crop entries

Of the nine vegetable crops assigned to Pampanga Agricultural College (PAC), Central Luzon State University (CLSU) and Bulacan Agricultural State College (BASC), there were about 69 selections across nine crops with high potential as organic vegetable varieties for Region 3 (Fig. 4). Said selections are distributed among three experimental stations. It is worthy to mention, CLSU solely worked on onion, melon and pechay with three selections for each crop.

Coordination and promotion

To fast-track promotion of organic crop production systems, in particular organic vegetable production, to date there have been about 89 individuals who have benefited from the project through hands-on training, small group discussions and seminars (Fig. 5). Participants were asked to evaluate the crops’ acceptability using a simple survey questionnaire while conducting the evaluation. Results were used as guide in the selection and development of vegetable varieties.

2010-2011 (YEAR 1)

1. Varieties/lines of priority crops were developed through active breeding.
2. Organically produced seeds of squash, yard-long bean, tomato, eggplant, okra and melon, pechay, onion were priority outputs.
3. Trained AFNR students and graduates, entrepreneurs/farmers and program personnel in organic production methods.
4. Information from the study project noted as best practices:
   - Selfing in melon, squash, okra and eggplant in the low elevation is best done using aluminum foil or cotton, while for pechay, enclosing in a net cage is best.
   - Seed production in cucurbits is best done by sibbing with selfing. Sibbed seeds will be used as breeder or foundation seeds. The selfed seeds will just be remnant seeds to reconstitute the variety in case of genetic mixtures. Best plants and/or fruits are selected as stock seeds for the next round of seed production.
   - Seed treatment to prevent weevil in beans is to treat the seeds with wood ash three times at one-week intervals to ensure adult weevils and eggs will be killed.

2011-2012 (YEAR 2)

1. Project convergence was set-up at Gatiawin, Arayat, Pampanga wherein the best two performers among varieties/selections were used.
2. Replicated yield trials on melon, onion, pechay, yard-long bean, eggplant, tomato, squash and okra was conducted at on site.

3. Top 2-3 varieties/lines were selected to be used in on-farm trials.
4. Seeds of the selected lines were produced.
5. Technology and production protocols were also established.
6. New and improved lines/varieties were produced from the selection process and yield trials done at CLSU. These lines/varieties were initially used for on-farm trials in different locations around Region III.

2012-2013 (YEAR 3)

1. Seeds of various selections of different crop lines produced in stations.
2. Individual plant selections from existing selections in on-farm trials in Guimba and Science City of Munoz, Nueva Ecija
3. Seeds from these selections in OFT sites were also collected.
4. Production of breeder's seeds of the three priority crops and other selections.
5. Recommended onion improved varieties.
6. Seeds produced were kept in an ambient room temperature and cold storage.
7. On-going or continuing seed production trials and seed increase in pechay, melon tomato, eggplant, okra, and yard-long bean.
8. Analysis cost and returns of organic seed production of the priority vegetable crops.

CROP CHARACTERISTICS AND YIELD PERFORMANCE

Melon

From nine entries of melon, three selections were identified and exhibited the best performance. Entry Me-CLS10-8-1 registered a highest average yield of 19.28 kg/plot and computed yield of 9.64 t/ ha. Results also showed that three selections were out-yielded the checked variety. Lowest yield was obtained in Me-CLS10-1-1 of 7.68 t/ha. All selections performed uniform maturity with 85 days from sowing to harvest and were resistant to moderately resistant to common melon pests and diseases. All selections were characterized with roundish fruit and deep yellow flesh. The top three melon selections were set in the field for replicated seed trial. Seed yields obtained ranges from 54 to 103 kg/ha.

Onion

Out of the five selections, On-CLSTan 2-2-selection out-yielded the checked variety, while yields of two were found statistically at par with the check variety. These two are landraces from a farmer in San Jose City, Nueva Ecija and one from Nueva Ecija Fruits and Vegetable Seed Center (NEFVSC). The lowest yield was recorded in selections came from La Union, which was the Batanes varieties of only 10.15 and 9.75 t/ha respectively. All selections were resistant to moderately resistant to onion pests and diseases.

Three promising entries of onion were identified and set in the field for bulb production performance. No significant difference on yield per hectare was obtained among three selections with yield ranges from 13 to 15 t/ha, respectively. The information gathered was used to prepare a seed/bulb production guide and crop profile.

Pechay

Seven out of 15 entries for pechay were evaluated in a replicated yield trial. The highest yield was obtained in entry Pe-CLS10-1-5-1with 9.90 t/ha, while lowest yield was recorded in Pe-CLS10-1-4-1of 9.35 t/ha. The longest days to harvest was recorded in check variety (Black Behi; 44 days) while the other selections were harvested 42 days after sowing. Most of the entries were moderately resistant to pest and diseases while the entry from Benguet State University (BSU) was found susceptible to pest and diseases particularly to aphids and sooty mold disease. Top three fresh yield performers were also set in the field for replicated seed trial. Seed yield obtained ranges from 118 to 129 kg/ha.

Squash

Five out of six entries for squash were evaluated for replicated yield trial. The highest yield was obtained in entry Sq-CLS12-2-2 with 18.37 t/ha, and also with biggest fruit diameter of 322.30 mm, heaviest weight per fruit of 2.15 kg, thickest rid of 32.33 mm, and least number of days to harvest of only 95 days. Most of the entries, especially the low yielders, showed moderately resistance to pest and diseases. Squash beetle and powdery mildew was observed to be the most common pest and disease of squash during this season. Top three fresh yield performers were also set in the field for replicated seed trial. Seed yield obtained ranges from 63 to 80 kg/ha.

Yard-long bean

Out of the eight selections, four entries out-yielded the check variety. The highest yielder was noted on entry Ps-CLS07-10-2-1 with 11.08 t/ha, while the lowest yield was obtained in two Chinese selections Ps-CLSCh-11-1-1 and Ps-CLSCh-11-1-2 with 7.96 and 7.14 t/ha respectively. Statistically, yields of eight selections were found at par with the check variety. The shortest length of fruit was noted on entry Ps-CLSCh-11-1-1 with only 37.35 cm. The longest days to harvest was obtained in Ps-Ck-variety and earliest was noted in Ps-CLS78-10-1-1 of only 50.76 days. All varieties were resistant to moderately resistant to pests and diseases.

Three selections of yard-long bean were identified and set in the field for seed production. Entry Ps-CLSMTG-10-1-2 from CLSU produced 2.41 t/ha of seed, which is a little higher from two other selections obtained from IPB-UPLB with 2.04 and 2.0 t/ha of seeds respectively.

Okra

From eight entries of okra, only five selections were identified and exhibited the best performance. Yield performance of okra for replicated yield trial showed that entry Ok-CLS10-2-2-1 gave the highest yield per plot and computed yield of 8.65 t/ha. Lowest yield was obtained in Ok-PAC11-1 and Ok-PAC11-2 entries acquired from Pampanga with 6.23 and 6.68 t/ha respectively and also recorded the longest days to harvest of 55 days. All selections from smooth green entries were found resistant to common pests and diseases except for another variety having short fruit with ridges, which showed moderate resistance. The top three okra selections were set in the field for replicated seed trial. Seed yields obtained ranges from 1.06 to 1.12 t/ha.

Eggplant

Results of replicated yield trial on eggplant revealed significant differences on average weight/fruit and yield/ha. Eg-CLSDLP (check) gave the heaviest weight per fruit of 152.67grams followed by entry Eg-CLS10-1-1-1 long purple with 149.00 grams/fruit. Yield per hectare disclosed that entry Eg-CLS10-1-1-1 out yielded all entries with 15.90 tons/ha followed closely by checked variety Eg-CLSDLP with 14.25 tons/ha. Israel variety Eg-CLSIs-11-2-1entry with round purple fruit gave comparable yield with the locally acquired entries. Moreover, Eg-CLSIs-11-4-1selection recorded the shortest days from sowing to harvest of only 55 days.

Majority of the entries exhibited resistance to moderately resistance to pest and diseases. Top three fresh yield performers were also set in the field for replicated seed trial. Seed yield obtained ranges from 69.73 to 73.33 kg seeds per hectare.

Tomato

All tomato entries were characterized by having roundish to oblate shape of fruits with deep red to red orange color and medium size fruits. Entry To-CLS11-53-1 registered the highest yield per plot of 32.68 kg/20 m^2 plot or 16.34 t/ha, followed closely by To-CLS11-53-2 entry with 31.32 kg per plot and computed yield per hectare of 15.66 t/ha. Moreover, check variety was found comparable to other selections in terms of average yield per plot and yield per hectare. No significant difference among entries was recorded on the number of days to harvest. Most of the entries were resistant to moderately resistant to pest and diseases, except for entryTo-CLS10-4-3-1, which was found susceptible to fruit rot and early blight disease. Top three fresh yield performers were also set in the field for replicated seed trial. Seed yield obtained ranges from 66.50 to 73.33 kg of seeds per hectare.

Bitter gourd

The top three selections of bitter gourd were evaluated with the check variety. Am-CLS-2 selection performed significantly bitter with the other entries with 10.50 t/ha followed closely by Am-CLS-4 entry with the average yield of 9.78 t/ha. The other Chinese variety showed significantly lower computed yields of only 5.25 t/ha. All bitter gourd selections have the same number of days to harvest of 55 days.

Only two entries were set in the field for seed production. The seed yield obtained from Am-CLS-2 and Am-CLS-4 was computed at 104.16 and 88.33 t/ha respectively. The Chinese variety had only 70 kg/ha. Such differences in the obtained computed yield per hectare could be attributed to the length of the fruit.

SUMMARY

The project started in May 2010 with Pampanga Agricultural College (PAC) as the lead agency while Central Luzon State University (CLSU) and Bulacan Agricultural State College (BASC) as cooperating agencies. There were nine vegetable crops/varieties identified for development and evaluation: melon, onion, pechay, squash, yard-long bean, okra, eggplant, tomato, and bitter gourd. Each crop started with five entries, from which selections identified and used for yield trial. At CLSU various trainings were conducted, attended by farmers (17), BS Agriculture students (48), agricultural technicians (3) and researchers/research assistants (24). Of the nine vegetable crops across three project sites with 69 varieties/entries, about 24 selections were set in the field for yield trials. Twelve related research projects were conducted by seven undergraduates, three graduates and two faculty researchers. To ensure high degree of acceptability of these varieties among target end-users, a simple survey on fruit appearance quality was undertaken with organic vegetable growers, traders and consumers. Such information is being used to guide the crop varieties being developed.

The initial evaluation trial of the crop varieties was done in relatively small plot sizes of 10 m^2. Crops were exposed to environmental stresses, with minimal application of cultural management methods and farm inputs, including less irrigation. The selections were taken from those crops that performed well under these conditions of stress.

There were at least three entries or selections per crop that were developed further in the project. These varieties are now ready for seed production and eventually for utilization in organic farms and gardens in Central Luzon. Technology guides, cost and return analysis both for fresh and seed productions were also developed to ensure a high degree of success in encouraging farmers to engage in organic vegetable enterprises.

CONCLUSION

Varieties developed from OPVs selections were found competitive with their commercial counterparts; some even out-yielded those commercial check varieties or hybrids when planted and provided with organic inputs including solid and foliar fertilizers and botanical pesticides in organic gardens or farms. These varieties were selected under optimum fertilization, irrigation, zero weeds, and maximum pest control.

The farmer-cooperators and other project participants trained on how to develop varieties from the crop stands can become excellent plant breeders when given the resources and knowledge. By linking public breeders with organic growers and organic seed companies and doing collaborative on-farm breeding, new organic varieties will be developed that meet farmers' needs.

Senior agriculture students who were immersed from the project activities and trained about organic vegetable production and processing techniques have started their own enterprises, while others have landed jobs in related fields.

RECOMMENDATIONS

1. To ensure the availability and accessibility of quality organic vegetable seeds to end-users, PPP (public-private partnership) initiatives and farmers organization-based should be encouraged in the production of organic vegetable seeds.
2. Technical assistance (TA) about organic production systems and processing techniques among interested individuals should be provided by various government research and academic institutions.
3. The government should provide assistance, technically and logistically, for the certification of organic farms and gardens.
4. To legislate the provision of a free stall or space that is equipped with cold storage for organic products in every public market. At least one per municipality to increase market share, thus creating market demands for organic products.

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Figure 1. Map of the Philippines

Figure 2. Map of Region III

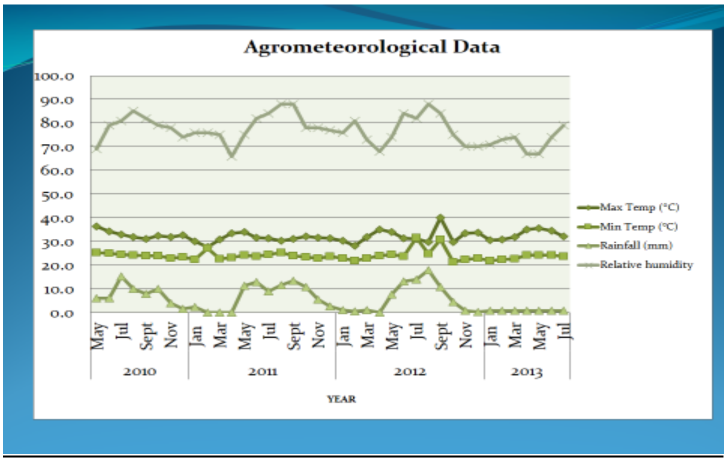

Figure 3. Agro-climatic data at Nueva Ecija from May 2010 to April 2013

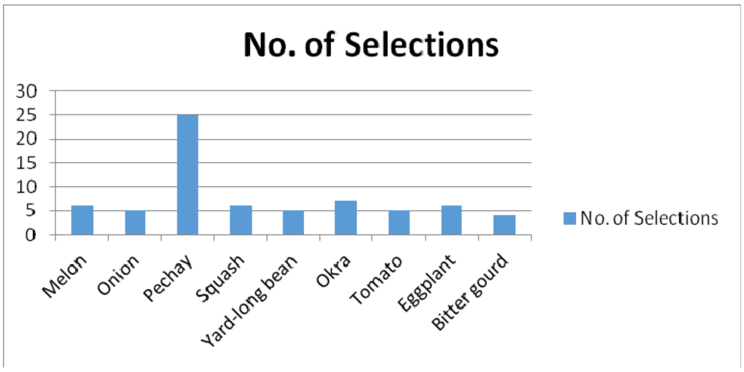

Figure 4. Total number of crops/varieties selected on the first year of the project

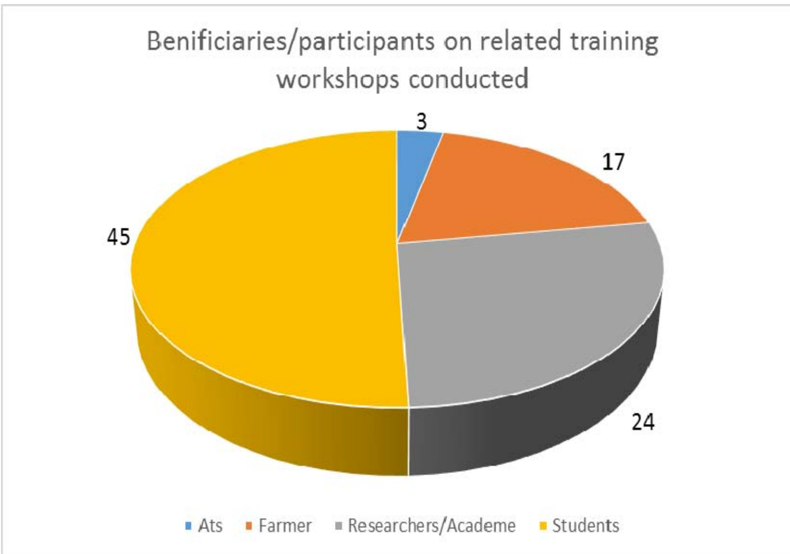

Figure 5. Number of beneficiaries'/participants on related training workshops conducted

Table 1. Summary table of selections evaluated in on-field trial and seed production trials

Crop	Selections	Status	Remarks
Melon	CLS-8-1, CLS-1-2, CLS-3-1	Breeder seed production, Replicated Seed Yield Trial (RSYT), OFT, Production Guide and Crop Profile	Plans for paper
Onion	CLSTan-2, CLSTan-1, CLSNE-1	Breeder seed production, Production Guide and Crop Profile	
Pechay	CLS10-5, CLS10-2, CLS10-1	Breeder seed production, RSYT, Production Guide and Crop Profile	
Squash	CLS10-12-1, CLS-12-2, CLS10-10-1	Breeder seed production RSYT, Crop Profile	Plans for paper
Yard-long bean	CLSMTG-1, CLS09-1, CLS07-1	Breeder seed production RSYT, Crop Profile	Plans for paper
Okra	CLS10-2-1, CLS10-2-2, CLS10-3-1	Breeder seed production, RSYT, Crop Profile	
Tomato	CLS11-53-1, CLS11-53-2, CLS11-40-1	RSYT, OFT, Crop Profile	
Eggplant	Long Purple- CLS10-1, CLS10-3 Round Purple-CLS10-2	Breeder seed production, RSYT, OFT, Crop Profile	Plans for paper
Bitter gourd	CLS2N-1, CLS-4-1	Seed increase on site, Crop Profile	On going for seed increase

Preliminary evaluation of resistance to powdery mildew (*Podosphaera xanthii*) in AVRDC collections of bitter gourd (*Momordica charantia* L.)

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ABSTRACT

Bitter gourd (*Momordica charantia* L.) is an important market vegetable in Asia, where it is also used in folk medicine to manage type 2 diabetes. Cucurbit powdery mildew (CPM) caused by *Podosphaera xanthii* is a serious fungal disease of bitter gourd and yield losses of up to 50% have been reported. After observing the initial field reaction of 150 global collections of bitter gourd to *P. xanthii* (Px), seven CPM-resistant lines (THMC 113, THMC 143, THMC 144, THMC 153, THMC 167, THMC 170, THMC 177) were further evaluated in field and greenhouse tests at AVRDC in Nakhon Pathom, Thailand and Taiwan, and USDA, ARS laboratories in Charleston, South Carolina and Salinas, California. Five lines (THMC 113, THMC 143, THMC 153, THMC 167, THMC 177) were resistant to an undefined race of Px in a field in Thailand. Four lines (THMC 143, THMC 153, THMC 167, THMC 177) were resistant to an undefined race of Px in a field in Taiwan. All seven lines were resistant to Px melon (*Cucumis melo* L.) race SD in a greenhouse in Salinas and to Px melon race 1 in a greenhouse in Charleston. When tested in a petri-plate assay at Charleston against Px melon race 1 collected from wild balsam apple (*Momordica charantia*) plants in Florida, THMC 113 and THMC 170 were susceptible. These tests

revealed potentially unique CPM pathotypes and races on bitter gourd, and sources of resistance for breeding CPM resistant cultivars.

Keywords
Host plant resistance, *Momordica charantia*, *Podosphaera xanthii,* Bitter gourd

INTRODUCTION

Bitter gourd (*Momordica charantia* L.) is an important cucurbitaceous market vegetable in Asia where nearly 34,000 ha of bitter gourd are planted annually by small-scale farmers (Arvind Kapur, Rassi Seeds, India, personal communication). It is also used as a folk remedy to manage type 2 diabetes which affects presently 347 million people worldwide (WHO 2012). Bitter gourd fruits are rich source of β-carotene, vitamin C, folic acid, magnesium and potassium (Yuwai et al. 1991).

Powdery mildew caused by *Podosphaera xanthii* (Castagne) Braun & Shishkoff [formerly *Sphaerotheca fuliginea*] is a serious fungal disease of bitter gourd and yield losses of up to 50% have been reported (Parag Agarwal, VNR Seeds, India, personal communication). The disease can be controlled with fungicides but use of genetic host plant resistance offers a more economical and environmentally-safe approach. But until today, no information has been available on genetic resistance of bitter gourd to powdery mildew. The objective of this study was to identify sources of resistance to CPM in bitter gourd through evaluation of the AVRDC global bitter gourd germplasm collection.

MATERIALS AND METHODS

After observing the initial field reaction of 150 global collection of bitter gourd to *P. xanthii*, five plants of seven lines (S_3 generation) THMC 113, THMC 143, THMC 144, THMC 153, THMC 167, THMC 170, THMC 177 were evaluated for powdery mildew resistance, in a non-replicated field test, in November 2011 at AVRDC-The World Vegetable Center, Kasetsart University, Kamphaeng Saen campus in Nakhon Pathom province of Thailand. Disease reactions were recorded on individual plants of each entry following a two-part rating scale where (S) indicated both sides of the leaves were covered with mildew mycelia and spores, and (R) indicated no visible CPM.

The seven lines (S_4 generation) were evaluated for resistance to *P. xanthii* in the Mycology Unit of AVRDC-The World Vegetable Center, in Shanhua, Taiwan in spring of 2012. Ten plants of each accession were evaluated in a non-replicated field test. Disease severity was rated on individual plants using 0-11 visual scale (Horsfall and Barratt, 1945): 0 = no symptoms, 1 = 1-3%, 2 = 4-6%, 3 = 7-12%, 4 = 13-25%, 5 = 26-50%, 6 = 51-75%, 7 = 76-88%, 8 = 89-94%, 9 = 95-97%, 10 = 98-99%, and 11 = 100%. Plant ratings 0-2 were considered resistant.

The seven lines (S_6 generation) were evaluated against a locally prevalent Px melon race 1 (race classification based on CPM melon differentials) in Charleston, South Carolina, U.S.A. in a greenhouse test in summer 2012. Each line was replicated four times with four plants per replication. Disease reactions in the greenhouse were assessed using the resistant (R) or susceptible (S) scale as described above. Melon CPM differentials and susceptible squash were also planted and rated as a part of this trial as resistant or susceptible. The seven lines were then evaluated in a replicated petri dish assay inoculated with a Px race 1 isolate collected from wild balsam apple (*Momordica charantia*) plants in Florida, U.S.A. The petri dish assay was evaluated as (S), visible infection and sporulation, or (R), no visible infection.

The seven lines (S_6 generation) were evaluated against Px melon race SD in a replicated greenhouse in Salinas, California, U.S.A. in Summer 2013, using a visual scale: 0 = no visible infection, 1 = 1-10%; 2 = 11-25%; 3 = 26-50%; 4 = 51-75% and 5 = >75%. Plant ratings 0-1 were considered resistant.

RESULTS AND DISCUSSION

THMC 143, THMC 153, THMC 167, and THMC 177 were highly resistant to the local races of *P. xanthii* in Thailand and Taiwan (Table 1). THMC 133 exhibited resistant and susceptible reactions in Thailand and Taiwan, respectively, which indicated the presence of different Px races in these two locations. The seven accessions were resistant to melon Px races 1 and SD in Charleston (east coast of U.S.A) and Salinas (west coast of U.S.A), respectively. THMC 113 and THMC 170 were, however, highly susceptible to the wild balsam apple (Florida) isolate (Px race 1). This discrepancy indicates possible pathotype variation within Px melon race 1 (Lebeda et al. 2011).

Powdery mildew affects plant canopy, fruit yield and quality of cucurbits worldwide. Insensitivity of Px to the recommended CPM fungicides is well known in the U.S.A. (McGrath et al. 1996). Host plant resistance is a cost-effective and safe method to control CPM, but it too is subject to failure. Indeed, 45 races of *Px* have been reported on melon based on sets of CPM race differentials that range in number from as few as two to as many as 28 (McCreight et al. 2012,). Accessions resistant to CPM have been identified in melons (reviewed in Dhillon et al. 2012), watermelon (Tetteh et al. 2010), cucumber (Morishita et al. 2003) and bottle gourd (Kousik et al. 2008). These sources of resistance originated from the primary centers of diversity of these cucurbit species. All the bitter gourd lines used in this study with the exception of THMC 113 originated in India, the primary center of diversity of bitter gourd. The lines THMC 143, THMC 167, and THMC 177 were resistant across multiple locations and may have the potential to be sources of broad spectrum resistance. These lines can be used by breeders to develop CPM-resistant bitter gourd varieties.

The differential reactions of the seven lines used in these tests clearly demonstrated genetic variation (i.e., pathotypes and physiological races) among Px isolates for their ability to infect and sporulate on bitter gourd. Future research should aim to assess a wide array of bitter gourd germplasm for resistance to CPM using isolates collected from bitter gourd fields in various parts of Asia in order to establish a set of differentials for identifying pathogenically distinct Px races of bitter gourd.

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Table 1. Reactions of seven bitter gourds to CPM in Thailand and Taiwan (undefined races), and Charleston (race 1), Florida (race 1), and Salinas (race SD) in the U.S.A.

Line	Origin	Test location				
		Thailand	Taiwan	Charleston	Florida	Salinas
THMC 113	Belize	R	S	R	S	R
THMC 143	India	R	R	R	R	R
THMC 144	India	S	S	R	R	R
THMC 153	India	R	R	R	R	R
THMC 167	India	R	R	R	R	R
THMC 170	India	S	S	R	S	R
THMC 177	India	R	R	R	R	R

Induction of powdery mildew resistance in garden pea (*Pisum sativum* L.) using mutagenesis

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ABSTRACT

Physical and chemical mutagens were used to widen the genetic variability of pea (*Pisum sativum* L.) via experimental mutagenesis. A set of 5000 seeds of cultivar ‘Azad P-1’ and ‘Lincoln’ was irradiated with gamma rays at 30, 40, 50 and 60 Gy. Simultaneously, another set of 2500 pre-soaked seeds of each cultivar was treated with 0.3% and 0.4% ethyl methane sulfonate (EMS) solution for 8 h at 30 ± 1 ^{0}C with intermittent shaking in a gyratory shaker. The M_1 generation of both irradiated and EMS treated seeds was raised in the field during November 2011 at Palampur (mid-hill humid temperate zone). All the survived plants were harvested individually to obtain M_2 generation. Plant-to-row progenies of individual M_1 plants (M_2 generation) were sown in May 2012 at High Hill Agricultural Research and Extension Centre, Kukumseri (high hill dry temperate zone) to select desirable powdery mildew resistant mutants. From the M_2 generation, two putative mutant plants from mutagenized population of Lincoln, treated with 50 Gy gamma ray (L-50-1113-1) and 0.4% EMS (L-0.4-43-1), were selected showing resistance reactions of powdery mildew, while mild symptoms were only observed on leaves, but not on pods and stem at the end of vegetative maturity. The individual harvested M_3 plants were evaluated inside poly houses at Palampur during winter 2012-13. All 19 plants of mutant progeny L-50-1113-1 showed similar resistant reactions as those observed at Kukumseri. The induction of mutation conferring powdery mildew resistance constitutes a new development in the study of resistance to powdery mildew in garden pea.

Keywords
Pisum sativum, mutagenesis, powdery mildew, resistance

INTRODUCTION

Garden pea (*Pisum sativum* L.) is a leading vegetable crop in the north-western Himalayan region of India comprising the states of Himachal Pradesh, Jammu and Kashmir, and Uttrakhand. Owing to diverse agro climatic conditions in Himachal Pradesh, the crop is grown year round, yielding lucrative returns to the growers. In the high altitude areas of Himachal Pradesh, pea is grown as an off-season cash crop during summer whereas in winter, it is cultivated in low and mid-hills. Pea is vulnerable to a number of diseases, *viz.*, powdery mildew, fusarium wilt, achochyta blight, bacterial blight, white rot and rust. Of these, powdery mildew caused by *Erysiphie pisi* Syd is the most important disease affecting fresh pea production in Himachal Pradesh and other states of India and several other countries around the world (Warkentin et al. 1996). In addition to reduction in fresh pod yield, the disease also reduces the quality of the marketable harvest significantly. All the popular commercial cultivars (most preferred Azad P-1) are highly susceptible to powdery mildew. On the other hand, the resistant varieties were not preferred amongst farmers on account of light-green and medium sized pods. Under Indian conditions, consumers prefer sweet, long and dark green pods. Therefore, it is pertinent to develop suitable varieties possessing these horticultural traits coupled with high yield and resistance to powdery mildew disease.

Natural sources of resistance to powdery mildew in pea have been identified in germplasm from all over the world and regardless of their origins all sources of resistance have shown monogenic recessive inheritance. These resistant sources from lines ‘Mexique 4’ and ‘S143’ (er_1) and ‘JI2480’ (er_2) have been utilized for transferring resistance in garden pea. Agronomically, all these lines belong to the pulse type, having tall growth habit, small and yellowish green pods with high starch content. Conventional breeding approaches of hybridization followed by selection involving commercial susceptible variety and resistant donor parent have resulted in the development of powdery mildew resistant varieties with light, yellowish green and medium sized pods. Hence, these varieties are not preferred and could not replace the existing susceptible cultivars like ‘Azad P-1’.

Therefore, there is a necessity to develop new resistant sources/varieties against powdery mildew disease in the garden pea gene pool. Induced mutation usually creates variability not available in the gene pool or to correct specific deficiencies of an otherwise outstanding genotype (Bhat et al. 2001). In the absence of useful resistant donors to powdery mildew in the garden pea gene pool, induced mutagenesis appear to be the most appropriate technique for breeding powdery mildew resistant cultivars with long and dark green pods having high yield. The present investigation envisages induced mutagenesis of two commercial cultivars ‘Lincoln’ and ‘Azad P-1’ through gamma rays and ethyl methane sulphonate (EMS) to obtain desirable mutants.

MATERIALS AND METHODS

The present investigation was carried out at two geographically distinct locations, Department of Vegetable Science and Floriculture, Himachal Pradesh Agricultural University, Palampur (32°8′ N latitude and 76°3′ E longitude at an elevation of 1290.8 m above sea level, characterized as humid sub-temperate climate with high rainfall of 2500 mm and clay loam with pH 5.6) and High Land Agricultural Research and Extension Centre, Kukumseri (situated at an elevation of 2,672 m above sea level with 31^{o} 44′ N latitude and 76^{o} 41′ E longitude in Lahaul and Spiti represents high hill and dry temperate zone of Himachal Pradesh with an annual rainfall of about 125 mm and sandy-loam with pH of 6.7, gently sloping mountains and a growing season from April to October) in Himachal Pradesh, India.

The experimental material comprised two prominent garden pea cultivars, 'Lincoln' and 'Azad P-1.' A set of 5000 seeds of both cultivars was irradiated with gamma rays at 30, 40, 50 and 60 Gy at NRL, IARI, New Delhi. Simultaneously, another set of 2500 pre-soaked seeds of each cultivar was treated with 0.3% and 0.4% ethyl methane sulfonate (EMS) solution for 8 h at 30 ± 1 °C with intermittent shaking in a gyratory shaker. The treated seeds were thoroughly washed in running water for 8 h to leach out excess EMS. The M_1 generation (both irradiated and EMS treated seeds) was raised in the field on 23 November 2011 at Palampur. All the survived plants were harvested individually to obtain M_2 generation. Plant-to-row progenies of individual M_1 plants, i.e. M_2 generation, were sown in the last week of May 2012 at Kukumseri to select desirable powdery mildew resistant mutants.

The border rows of the experimental plot were planted with powdery mildew susceptible cultivar 'Azad P-1' and 'Lincoln' for attracting and spreading the pathogen inoculums. Artificial inoculation was also done with *in vitro* multiplied culture of virulent isolates of *Erysiphe pisi* to avoid disease escape for making selection more effective in isolating powdery mildew resistant mutants**.** The resistant M_2 plants were harvested individually to get M_3 seeds. The M_3 plants were evaluated at Palampur during winter 2012.

RESULTS AND DISCUSSION

Selection for powdery mildew resistant mutant progenies in the M_2 generations: Selections were made in the M_2 generations derived from 'Lincoln' and 'Azad P-1' for resistance to powdery mildew at Highland Agricultural Research and Extension Centre, Kukumseri (Lahaul & Spiti) during summer 2012. A total of 13,868 M_2 progenies comprising of a total M_2 population of 34,845 plants were evaluated. Two putative mutant plants derived from 'Lincoln', L-50-1113-1 and L-0.4-43-1, were obtained showing resistant reactions (Table 1). Mild symptoms of powdery mildew were only observed on leaves at the end of the vegetation growth while pods and stem remained free from powdery growth (Fig. 1).

Raising M_3 progenies for further screening against powdery mildew under polyhouse conditions: The M_3 progenies of two mutant plants, L-50-1113-1 and L-0.4-43-1, were grown inside the polyhouse with standard check 'Lincoln' and 'Azad P-1' at Palampur during winter 2012. All 19 plants of progeny L-50-1113-1 showed similar resistant reaction as at Kukumseri (Fig. 2). The mutant L-50-1113-1 is phenotypically very much similar to the original cultivar 'Lincoln.' On the other hand, progeny L-0.4-43-1 showed segregation for waxy leaves. Thses progenies were further evaluated for powdery mildew reaction at Kukumseri during summer 2013 and showed resistance to powdery mildew.

Pereira and Leitao (2010) reported successful generation of the resistant mutant similar to the variety 'Frilene' from which it was derived. The resistant plants showing some patches of symptoms on the leaves at the end of the vegetation period, suggests quantitative genetic control of the resistance. Pereira and Leitao (2010) reported that this kind of quantitative expression is illusory and but a simple and attentive analysis of each plant will allow its qualitative classification in one of two clearly distinguishable classes namely, resistant versus susceptible. A much more obvious qualitative expression of the resistance can be observed at the end of the vegetation period, heavily contaminated pods (susceptible reaction) comparing with healthy pods (resistant reaction). In other words, powdery mildew resistance evaluations performed during vegetation on the basis of leaf contamination can be confirmed at harvest on the basis of overall plant appearance and pods infection. Sharma (2003), based on multiple experiments on powdery mildew resistance, also concluded that resistant and susceptible plants can be qualitatively distinguished on the basis of infection on the stem, peduncles and pods, while ignoring the fungal growth on the foliage, whatever its intensity. In conclusion, the induction of mutations conferring powdery mildew resistance in garden pea was confirmed to be an effective method.

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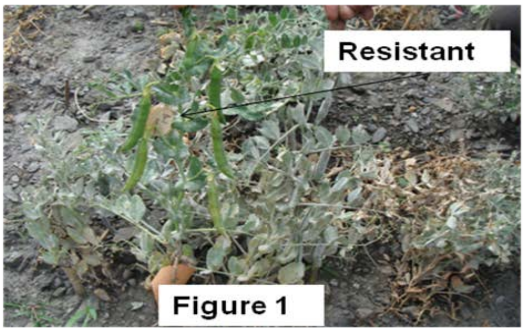
Table 1: Powdery mildew resistant progenies selected in different mutagenized generations during 2011 and 2012 at High Land Agricultural Research and Extension Centre, Kukumseri

Variety	Mutagen and dose	M_2 generation at Kukumseri (Summer 2012)			
		Number of M_2 progenies raised	Total number of M_2 plants	Powdery mildew resistant progenies obtained*	Selected M_2 progeny
Lincoln	30 Gy	1131	3619	-	-
	40 Gy	1039	2389	-	-
	50 Gy	1433	3875	1*	L-50-1113-1
	60 Gy	1250	3439	-	-
	0.3 % EMS	1146	2642	-	-
	0.4 % EMS	777	1631	1*	L-0.4-43-1
	Sub-total	**6776**	**17595**	**2***	
Azad P-1	30 Gy	1419	4402	-	-
	40 Gy	1477	4189	-	-
	50 Gy	1351	1553	-	-
	60 Gy	1323	3406	-	-
	0.3 % EMS	776	1862	-	-
	0.4 % EMS	746	1838	-	-
	Sub-total	**7092**	**17250**	**0**	**-**
Grand total		**13868**	**34845**	**2***	

***** Powdery mildew symptoms appeared only on leaves whereas stem and pod remained free from symptoms.



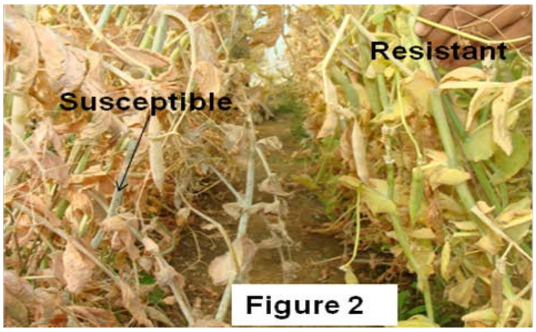


Figure 1: Powdery mildew resistant M_2 progeny (L-50-1113-1), Kukumseri (Summer 2012)

Figure 2: Comparative disease reaction at maturity stage of M_3 plants of L-50-1113-1 in polyhouse condition at Palampur (winter, 2012)

Seeds and insecurity: reducing Malaysia's dependence on seed importation

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ABSTRACT

Under the current list of National Key Economic Areas for Agriculture, Malaysia has maintained its commitment to increasing land area for food production. In this programme much focus has been given to rice self-sufficiency and the improvement of rice varieties. Meanwhile Malaysia remains a net importer of fresh vegetables and seed due to weak internal production. Difficulties in production are related to the restrictions Malaysia's climate places on some vegetables, limited superior local varieties and high production costs. Dependence on importation undermines the nutritional security of Malaysia's population as market fluctuations may leave some without access to fresh vegetables. In line with Malaysia's current agricultural commitments, more effort must be given to securing internal seed production as a foundation of self-sufficient vegetable production. Most seed is sourced from Thailand. Imported seeds are generally F1 cross-breeds adapted for tropical conditions. Malaysia has yet to formalise mandatory a Seed Certification Schemes to protect plant breeder rights. This will likely be established with the planned Malaysian Seed Act. This paper considers whether the reduction of dependence on seed importation should be given greater priority in Malaysia, suggesting that the development of a seed system capable of making the country more self-reliant, and protecting the rights of smallholders can only be achieved by adopting measures linking the interests of the seed industry and smallholders. This will include intellectual property legislation, the preservation of seed sharing traditions and investments to support the creation of large scale seed system. Developing the same model of government, industry and academic cooperation employed in the development of commodity crops may help to develop a system capable of developing and promoting new local, varieties of vegetables.

Keywords

Seed Supply, Intellectual Property, Brassicas, Biological Patenting, Adapted Varieties

INTRODUCTION

Despite Malaysia's rich biodiversity the country's agricultural priorities have been in the main focused on the promotion of monocultures, in particular rice and oil palm. This focus persists; in its most recent list of National Key Economic Area Economic Priority Projects (EPP's) for agriculture, the Malaysian Government redoubled its commitment to increasing land area available for food production (NKEA PEMANDU 2010, pp. 513-550). Once again, rice is targeted as the principle driver for food security with Pemandu stating that "…a game changing measure needs to be made to increase local rice production towards establishing long-term food security for Malaysia." (PEMANDU 2011 p. 193). The Malaysian government can rightly point to the efficacy of this approach: the country maintains a leading position in global palm oil production and year on year increases in rice production and productivity have been, and indeed continue to be reported (Najim et al. 2007). However outside of rice and palm oil production this situation has left Malaysia highly dependent on seed and fresh produce importation for a wide range of agricultural products. The additional costs and negative nutritional impacts of limited home production of vegetables in Malaysia are known and have been well rehearsed (See, for example, Mubarak 2000). In the late part of 2012, Crops for The Future Research Centre (CFFRC) proposed research to address this issue, focusing in particular on the potential of additional production of locally adapted and underutilised brassicas to meet domestic demand. During this research, a key question emerged concerning the capacity of the Malaysian seed supply system to support the introduction and/or expansion in supplies of new local varieties and if it is not meeting these requirements, what needs to be done to address this issue.

In this paper these questions are addressed through a preliminary examination of the seed industry in Malaysia and the inhibitory factors restraining its growth. The policy implications of possible improvements to local varieties are then rehearsed. The paper then concludes by considering whether Malaysia's success in developing the seed supply system for oil palm provides a possible model for a seed supply system that can protect small producers from the negative impacts of adjustments in seed supply seen in other countries.

Global Seed Industry

Since the 1980s the global seed industry has massively increased in terms of output (Fig. 1). Structurally the industry has been transformed, company mergers have created large multinationals transforming what had been an industry dominated by national entities into one dominated by a handful of global players. The International Seed Federation estimates the market to be worth 45 billion dollars. Large domestic seed markets include the USA, China and France, at 12, 9.95 and 2.8 billion dollars, respectively. In Southeast Asia, the Philippines is highlighted as having the most productive internal market ($18 million) while Thailand is the largest exporter at 4,370 tons annually generating $73 million. Indonesia exports larger amounts of seed (7,771) tons, but reaps only $11 million for its efforts.

Status of Seed Industry in Malaysia

Malaysia is a relatively small player in terms of seed production and consumption. However the structure of Malaysian seed supply is interesting. Outside of rice, oil and rubber cultivation, Malaysia remains 90% dependent on imports for all fruit and vegetable seed (Table 1). An interesting case of Malaysia's seed dependency is in watermelon production. Malaysia is the largest international exporter of fresh watermelon but the industry is 100% dependent on seed importation.

Efforts to drive seed production and improvement have been directed by the Malaysian Agricultural Research and Development Institute (MARDI). MARDI has been responsible for producing a number of new rice and fruit varieties and distributing them to private and public propagation organisations for eventual widespread adoption (Fong et al. 2006). MARDI's efforts have seen seed self-sufficiency established for rice but the seed supply for most other crop cultivation industries remains heavily import-dependent.

The main thrust of public policy in relation to agricultural development retains a focus on rice. The most recent iteration of Malaysia's National Key Economic Areas (NKEA, 2011) highlights Entry Point Projects (EPP's) the government wants to see implemented via public-private co-operation to address specific priorities in the development of different economic sectors. In relation to agriculture five EPP's aimed at plant based edible food production have been identified (Table 2).While three of the EPP's are specific to rice production only EPP7 (Premium Fruits and Vegetables), specifically targets improving output for non-rice produce. However, the primary aim of this measure is to deliver the fruits and vegetables to export markets. EPP14specifically aims improve seed production tonnage, the last NKEA Annual Update (2012), stated that the goal of 600 tons had been met by 407% (2,444 tons). While this is an impressive achievement, significant shortfalls still exist in relation to seed supply for fruit and vegetables (See Table 1). In short, not only is Malaysia's seed supply system limited, but in relation to certain types of crops appears likely to remain so.

Implications of the Current Seed System

From the above it is possible to conclude two things. Firstly, with the exception of certain priority species, Malaysia's seed supply is heavily dependent on imports, and secondly, this situation is unlikely to change in the foreseeable future. This in turn raises the further question of whether this is a situation that requires a policy response. In this section we consider this question by examining how the current seed supply system impacts vegetable production in Malaysia. Baseline work undertaken in relation to brassica production undertaken by CFFRC in conjunction with the University of Southern Cross, Australia provides some important insights into this question.

Brassicas are a nutritionally valuable and diverse and are the most widely consumed vegetable group in Malaysia (Izzah et al. 2012). The initial purpose of the study was to provide evidence concerning current patterns of production in Malaysia with a view to exploring the feasibility of developing improved varieties of local brassica. An analysis of brassica production statistics was undertaken in order to establish which species are being cultivated, where and by whom. This study showed that the bulk of brassica cultivation occurs in Pahang. Pahang is a large, agriculturally productive state of Malaysia accounting for greater than 50% of vegetable production. Over half of Pahang's recorded land area for agricultural production, 16,233.20 ha, is used to grow brassica species and almost 100% of this can be attributed to two highland districts; Bentong and the Cameron Highlands (DOA 2011, Fig. 2).

Sixty percent of the land given over to brassicas in these highland districts accommodate European brassica varieties, particularly cabbage, broccoli and cauliflower. These varieties generate 70% of the production value. Meanwhile, the remainder of the brassica industry that does not have access to highlands grows other species including *Brassica rapa*, *Brassica juncea* and *Brassica chinensis*, commonly: the mustards, Chinese cabbage and kale. Indeed the more sought after and higher value European species; cabbage, broccoli and cauliflower can only be found growing in three states of Malaysia in quantities greater than 1 ton, these are Pahang, Kelantan and Sabah (West Malaysia). Whereas historically, Asian varieties are recorded as growing in all states of Malaysia due to better climate adaptation (Dixon 2007).

The brassica industry is be divided between larger scale commercial growers in certain highland areas using limited space to produce high value, foreign, improved crops and everyone else making do with locally adapted species (Table 3). Comparing these two arms of the industry we find that the superior foreign varieties that have enjoyed a longer period of agricultural breeding and selection attention in Europe use only 5,799 ha to produce 183,095 tons of vegetables while the local varieties use almost twice the land area and yield less product. However the European varieties are restricted by climatic and agronomic factors to specialise, input intensive farming units based in a limited number of are as to produce a relatively expensive product. By contrast, local often unimproved varieties can be grown much more extensively at lower input cost making them more accessible at a lower price.

RAMIFICATIONS AND IMPACT

The current status of the brassica industry illustrates some of the implications of the current seed supply system for vegetable production and markets in Malaysia. These include susceptibility to market fluctuations, changes in the structure of seed markets, concerns over the capacity of agriculture in Malaysia to adapt to external shocks, and direct threats to food and nutritional security.

Hans Lofgren (2012), in “World Food Prices and Human Development”, describes how countries heavily dependent on importation, are susceptible to shocks in the market. Malaysia is a prime example of a country that is reliant on importation. FAO statistics record Malaysian vegetable output at 938,610 tons, while population demand is 2,296,572 tons, meaning the country is dependent on imports for 60% of its vegetables. In this context Malaysia has adopted policies to boost food self-sufficiency. However this has primarily focused on rice, leaving the country prone to significant fluctuations in vegetable prices. One way of addressing this problem is to increase domestic production. While the price of seed is not in itself a determining factor in limiting increased production the lack of sufficient seed of improved local varieties is. This situation is not likely to be addressed via the Malaysian seed supply system as currently structured.

Conventional wisdom suggests that the relatively low costs of seed means price increases have little impact on production practices. However an increasing body of evidence raises concerns over the impact that current development in the seed market pose on small producers (see for example Boudreaux and Aft 2008). Increased protection for large seed producers is not only making seed more expensive for smallholders seeking to improve their status through investing in more productive seed, but also imposes restrictions on what and how farmers can save and exchange seed potentially leading to fundamental alterations in the way farming is undertaken.

Rice is, for better or worse, promoted as the answer to food security throughout Asia but without accompanying dietary diversification nutritional insecurity will persist through nutrient deficiencies. The danger for Malaysia is that its current dependence on imported sources of these micronutrients leaves it vulnerable to fluctuations in market price and reduces their availability for low income consumers.

In summary while the current status of highland regions in Malaysia illustrates that some Malaysian farmers can benefit from the current structure of the seed supply system, the status of brassicas in the country also highlights the weaknesses of that system. While highland regions accommodate European vegetable varieties and succeed in generating significant income in these areas. Vegetable production that relies on highland climatic conditions is unlikely to ever deliver levels of production sufficient to address this deficiency. Simultaneously, a seed supply system dominated by imports fails to develop improved varieties of local brassicas suitable for extensive cultivation across Malaysia and threatens to impose additional costs and constraints on small holders.

Seed Industry Inhibitors

Leaving aside the cost of seed as a factor the development of an improved seed supply system may have an important role to play in enabling agriculture in the country to address these issues. In order to do so, however, a number of measures will be needed to address the constraints facing the industry. During the brassica study discussed above, five key issues which contribute to Malaysia's weak seed industry were identified; climate, lack of improved local varieties, fractured industry and public efforts, lack of industry bio-technical skill base and no private sector incentive

Climate

The average temperature for lowland Malaysia is 32 °C during the day and 22 °C at night, and humidity remains high between 85 to 95%. Highland regions, on the other hand, enjoy temperature as low as 15 °C. Across both highlands and lowlands rainfall is heavy for most of the year averaging 2,000 − 2,500 mm. In summary, Malaysia is consistently hot and wet year round. These climatic conditions are not optimal for seed production. Storage can be problematic requiring significant infrastructural commitments to control humidity and temperature

Lack of improved local varieties

Biotechnology uptake has been comparatively slow in Malaysia compared to other countries. Though great progress has been made in rice and oil palm this experience is only gradually diffusing to other edible produce and those that it is reaching are a mere eight species identified in the Third National Agriculture Policy (1998-2010), namely: papaya, pineapple, melon, starfruit, citrus, mango, jackfruit and guavas. Also, the only NKEA EPP to move beyond rice, EPP7: Premium Fruits and Vegetables, has highlighted a new list of target species (Table 4) for increased production, However this focus is not necessarily for breeding and biotechnology improvement, though the two lists bear a lot of overlap. Outside of certain key areas unstructured interviews undertaken during the course of this research confirm that farmers interested in alternative varieties have little choice but to source seed from foreign sources or, in the case of lowland producers, settle for local, unimproved species.

Fractured industry and public efforts

A preliminary survey of seed suppliers undertaken as part of this research found that the industry is fractured and lacks overall coherence. There is also no centralised body collating seed improvement and trade data. This leaves large question marks regarding the true state of seed supply in Malaysia. MARDI successfully supports a limited range of (primarily export) crops and certain crops such as oil palm and rice have effective seed supply systems. However outside of these sectors the industry consists of a number of disparate small scale for profit organisations. Often, these companies are focused on ornamental plant production. Outside of MARDI and the rice and oil palm sectors, there is little in the way of coherent improvement programmes or evidence of transfer of knowledge and experience between seed supply enterprises.

Lack of industry biotechnical skill base

MARDI and the University Putra Malaysia (UPM) have made efforts to co-ordinate undergraduate and PhD courses and seed workshops to boost the seed-oriented skill base from which research and private organisations can recruit. However limited job prospects and a general preference for urban employment amongst young Malaysians means that there is little interested in agriculture amongst young people. Without industry and government capital and research momentum the technical skills among graduates will remain insufficient to address future seed demand and will perpetuate the countries reliance on importation.

No private sector incentive

As mentioned above most private players in the seed industry are for-profit organisations which lack the resources to invest in enhancing local supply. Seed importation offers the most reliable and least risky way for such companies to generate income. A number of independent companies, such as Sin Seng Huat Seed S/B, Soon Huat Seed Corporation, Leckat Corporation S/B and Known-You Seed Company, offer imported seed from a variety of destinations, though the majority of externally sourced seed originates in Thailand (Fong et al. 2006).

Seed Protection Policy

Creating a coherent local seed supply system and reducing dependence on imports offers relatively limited, but nevertheless significant direct economic gains in the form of import substitution. However more importantly, by supporting the development of a local infrastructure it may increase the availability of improved varieties of locally adapted species. This would in turn open up the tantalising possibility of allowing Malaysia to capitalize on its available genetic diversity. Its recognition as one of the world’s biodiversity hotspots places Malaysia in a position to improve varieties beyond the norm, particularly among those species utilised by smallholders. Also, as an equatorial country, the diversity residing in Malaysia is heat tolerant meaning the country possesses a massive resource with which to discover transferable heat tolerance genes or novel, high yield varieties for market introduction. Efficient and sustainable exploitation of this resource could set Malaysia as an industry leader in heat tolerant variety development securing the country’s nutritional future and generating important research on heat tolerance for use by countries set to be worst hit, or currently suffering from climate change, such as those in sub-Saharan Africa.

In order to do so, Malaysian policy must create an infrastructure and an environment that is supportive of breeders. One key issue this policy will need to address is the question of how to protect new seed varieties and the intellectual property rights of producers. Such legislation is viewed as a necessary prerequisite to the development of seed supply system, allowing breeders to secure an adequate return on their investment in improving technologies. However, critics argue that the market protection conferred may mean that seed prices will rise and smallholders will find their input costs higher. Furthermore they will no longer possess the right to share seeds with neighbours. However, there is evidence that policies that protect the rights of private companies that produce improved varieties can enhance the livelihoods of smallholders. For example in the often-cited case of Bt (*Bacillus thuringiensis*) cotton, a strain capable of resisting pest insect species, while the price of seeds for this variety are higher, these are significantly offset by saving generated through reduced pesticide requirements, and, by extension, labour costs (Gouse et al. 2013) (Table 5). For Malaysia, this seems to suggest that policy needs to achieve a range of simultaneous objectives to create an environment that is supportive of plant breeders while protecting smallholders from the adverse impacts of run-away variety protection.

At the time of writing, the extent of policy covering plant breeder rights and crop improvement companies is limited to voluntary seed certification in accordance with the Trade Related Intellectual Property Scheme (TRIPS). To date, voluntary seed certification in Malaysia has seen a total of 145 applications for plant breeder rights, but, of these applications, only 25 have been granted plant breeder rights; 119 remain pending and 1 withdrawn (http://pvpbkkt.doa.gov.my/), and 45% of all applications are for ornamental varieties (reflecting trends trend seen in other of regions with active PVP such as the European Union).

Recently moves have been initiated to address this issue. Malaysia introduced the Plant Variety Protection Act (PVPA) in 2004, and a National Seed Council was established in 2010. Most recently the NKEA for Agriculture highlighted the need for seed industry development. As a consequence the Centre for Marker Discovery and Validation (CMDV) was established at MARDI to use Marker Assisted Selection techniques to better drive breeding efforts (PEMANDU 2012). In addition Malaysia is developing legislation to move towards a biological patenting model to protect the intellectual property rights of breeders. Already drafted, but not yet published, Malaysia's proposed National Seed Act proposes a mandatory certification scheme. All plant breeders who wish to sell their new varieties will be required to apply for approval and have their varieties scrutinised by experts to verify the claim. Under the new act, plant breeders will enjoy a public claim to novelty and ownership of their variety enabling a higher selling value, the breeder will also be able to claim royalties from whoever sells their seed and pursue legal action when the seed is traded without recompense.

DISCUSSION

The facts presented above confirm that vegetable seed and produce output are currently insufficient to meet demand in Malaysia. However a range of push and pull factors suggest that an improved seed supply system could result in substantial improvements in the country's capacity to produce vegetables, capitalising on its genetic diversity and allowing for the wider cultivation of vegetables rich in micronutrients. To achieve this, policy needs to focus on the development of a suitable enabling environment for such a system. While the Malaysian Government has been taking steps to strengthen the protection available for seed breeders, this will not in itself be sufficient to address all of the factors currently inhibiting the Malaysian seed supply system and at the same time balance the interests of seed producers and farmers.

Such an enabling climate must:

- Support investment in physical, knowledge and human resource infrastructure.

- Provide guarantees for plant breeder rights but also protect smallholder seed sharing traditions.
- Support the strategic coordination of the industry around established policy goals.
- Incentivise the private sector to invest in breeding and biotechnology.
- Recognise and protect the potential of local genetic diversity.

Within Malaysia a precedent for such a coordinated policy approach exists in the development of the Malaysian palm oil industry. Consistent government input and guidance saw the oil palm industry come to fruition, establish itself as a world leader, become financially self-sufficient and eventually independent. Malaysia's success with oil palm could be attributed to how it managed to harmonise efforts between industry, academic and government bodies. To achieve this, Malaysia tailored policy and financial incentives to stimulate industry and academic interest. Financial, tax, capital and trade incentives were released or changed to encourage home-grown sales and production. Academic institutions were offered research funding to promote palm oil related work, which drove skill and knowledge capacity regarding extraction, propagation and genetics. Careful monitoring and management throughout the oil palm industry's growth ensured efforts remained focused and did not lose momentum. Aspects of this approach may be applicable to the seed supply system, helping to build capacity, reduce Malaysia's large import dependency and producing varieties which are adapted to local farming conditions.

Similar tax and cash incentives together with a careful balance of public intervention and private enterprise are likely to be required to develop a more effective seed supply system in Malaysia, whilst also ensuring smaller farmers do not experience greater hardship. Such a system could combine public good investment in strategic infrastructure, additional finance and tax incentives for companies attempting variety improvement, research funding for academic institutions and monitoring of the systems development. In addition, however, mandatory plant variety protection/certification will help to develop a level playing field and offer security to crop improvement firms, and the outputs of publicly funded efforts. Again, however, consideration must be given to the possible impacts of such development on smaller farmers so that they also benefit through access to better varieties and do not suffer through price hikes and patent abuse. Contemporary solutions to this challenge may include novel intellectual property arrangements such as open sourcing. A critical issue in the development of such a system is the question of co-ordination and governance. While MARDI co-ordinates work on rice and the Malaysian Palm Oil Board is involved in the co-ordination of development in the oil palm sector no such coordinating body exists for the seed sector. While the National Seed Council has been established to drive seed policy there is a need for a mechanism to bring together all information regarding seed in Malaysia or co-ordinate strategy within the seed sector.

CONCLUSION

Given the relatively small size of the sector Malaysia's almost total dependence on imported seed for fruit and vegetable production may initially be regarded as being of limited significance. In this context the need to develop the local seed system has not been a major policy priority. The absence of such an effort means that outside of certain key species there are only limited incentives for seed production and improvement and a lack of coordination in the system. This has resulted in a fragmented seed supply system that largely focuses on supplying foreign varieties to the limited number of large scale farmers who can produce them commercially. This leaves smallholders using unimproved, but adapted, local varieties for their own and local market consumption. This situation limits local vegetable production contributing to shortages in the supply of micronutrient rich vegetables such as brassicas. In addition it keeps prices high and limits the extent to which the industry can expand. Ironically for a country renowned for its rich biodiversity and food heritage, Malaysia's capacity to capitalize on its locally adapted genetic diversity is limited.

The experience of the palm oil industry illustrates that a concerted effort to support the improvement of specific crops in Malaysia is possible and can yield significant rewards. However this experience also suggests that doing so requires a mix of private and public investment to deliver commercial rewards to the private sector, national development goals and improvements to local varieties important to smallholders and isolated markets.

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Table 1: Malaysian seed industry demand, production and shortfall (tons)

	Small-scale farmer	Large-scale farmer	Large-scale farmer
	Dryland (USD/ha)	Dryland (USD/ha)	Irrigation (USD/ha)
Yield Benefits per hectare @ $0.30/kg	47.20	30.30	167.90
Reduced pesticides benefit	3.10	11.00	28.30
Increased seed and technology fee detriment	15.70	22.60	55.00
Income advantage / disadvantage	35.40	18.70	141.10

Source: Gouse et al. 2013

Category	Demand	Local Production	Shortfall
Vegetables	650	13	-637
Fruits	626	3	-623
Cover Crops	500	150	-350
Cash Crops	130	30	-100
Total	1906	196	-1710

Source: Othman 2013

Table 2: NKEA Entry Point Projects relevant to crop and seed production

Entry Point Project	EPP Title
7	Premium Fruit and Vegetables
9	Fragrant Rice Varieties in Non-Irrigated Areas
10	Strengthening Productivity of Pady Farming in MADA*
11	Strengthening Productivity of Paddy Farming in Other Granaries
14	Seed Industry Development

Table 3: Foreign and local brassica species

Variety	Land Area (ha)	Production (t)	Value (USD)	# States grown
Foreign	5,799	183,095	122,984,000	3
Local	10,433	161,667	137,696,000	14

Table 4. Premium fruit and vegetables targeted for increased production

Fruits	Vegetables
Rock Melon	Lettuce
Starfruit	Tomato
Papaya	Capsicum
Banana	
Pineapple	
Jackfruit	

Table 5. South African small- and large-scale farmer income after adoption of *Bt* cotton

	Small-scale farmer	Large-scale farmer	Large-scale farmer
	Dryland (USD/ha)	Dryland (USD/ha)	Irrigation (USD/ha)
Yield Benefits per hectare @ $0.30/kg	47.20	30.30	167.90
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Source: Gouse et al. 2013

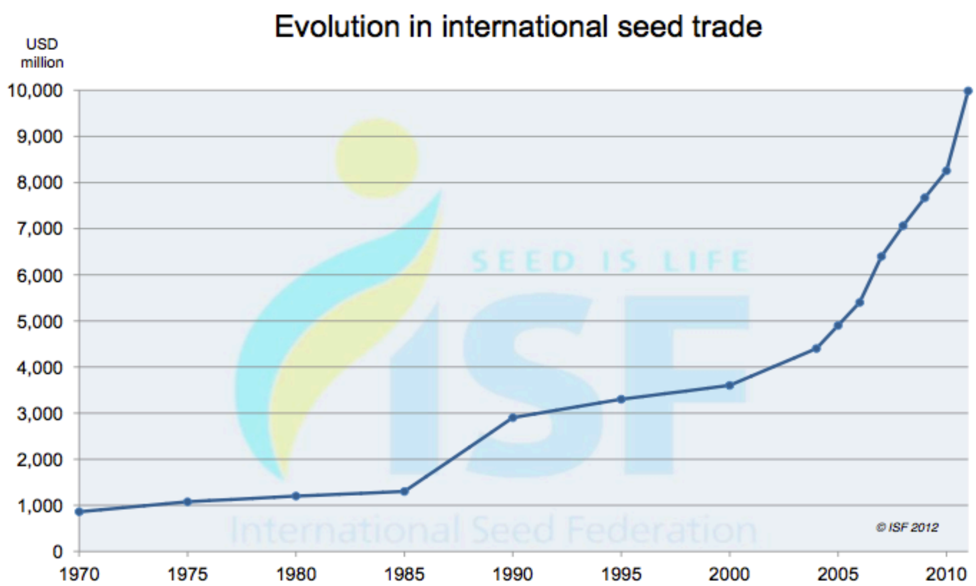

Figure 1: Seed industry growth from 1970-2010
(Source: ISF 2012)

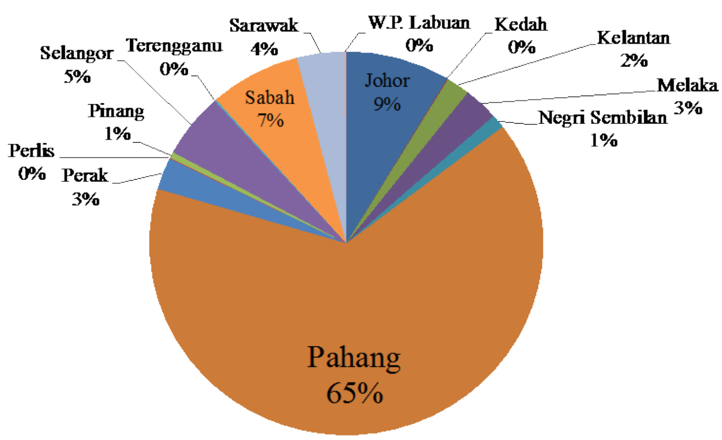

Figure 2: Status of brassica production in different states
(Source: DOA 2011)

Developing methods to screen for heat tolerance in sweet pepper *(Capsicum annuum L.)*

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ABSTRACT

Heat stress is an important abiotic factor that adversely affects the growth of sweet pepper *(Capsicum annuum* L.). Field trials in summer (March-August 2010) and fall (September 2010 -February 2011) were conducted in Taiwan to screen 16 sweet pepper accessions under high and normal temperatures (28.4° C and 22.5° C in 24 hr mean, respectively). Summer yields showed higher variance (σg) and broad-sense heritability (Hb) than fall yields, which indicates the potential for better selection during summer. In vitro pollen germination and tube growth were tested under wide temperature regimes (27–40° C). Pollen germination and tube growth were significantly reduced at 36° C–40° C, and pollen germination and pollen tube elongation at 36° C showed the highest variance and broad-sense heritability. It is thus suggested that 36° C is the critical temperature to differentiate heat-tolerant and heat-susceptible lines. Eight of 16 lines showed consistency in comparison of pollen viability at 36-40° C with percentage of yield in summer verse fall, which indicates pollen viability at high temperatures could be used as a screening method for heat tolerance.

Keywords

Capsicum, heat tolerance, pollen viability, sweet pepper

INTRODUCTION

Sweet pepper *(Capsicum annuum* L.) is an important cash and vegetable crop worldwide. Sweet pepper is rich in some micronutrients but production in the tropics is limited to cool, dry periods or highland production areas. Improved heat tolerance would extend the production period and production areas and increase sweet pepper supply as production is adversely affected by high temperature, humidity and low light intensity (Wien et al. 1990). Under heat stress conditions, sweet pepper root and shoot growth are seriously affected (Aloni and Karni 1992), leading to flower abscission and reduced pollen viability, fruit set and finally total marketable yield. The optimum growing conditions for sweet pepper are day / night amplitude of 7-9° C and 24 h mean temperature of 21-23° C (Bakker 1988). Daytime temperatures of 26-30° C and nighttime temperatures of 16-20° C are optimum for sweet pepper production.

Breeding for heat tolerance in sweet pepper is an important strategy. Several methods to screen heat tolerant sweet pepper lines have been developed, such as in vitro pollen germination and pollen tube length (Reddy et al. 2007); correlation between root temperature of seedlings, photosynthetic rate, stomata aperture and intercellular CO2 (Feng and Jiang 2000); ethphon spray under non-stress conditions and by measuring the electrolyte leakage on leaf disks (Anderson 1990). However, reports on heat tolerant germplasm of sweet pepper and inheritance of heat tolerance is completely lacking. The objectives of this study were (i) to evaluate performances of selected (based on previous characterization data) sweet pepper germplasm in summer and fall (winter) seasons to understand heat tolerance levels and (ii) to evaluate and develop screening methods for heat tolerance in sweet pepper lines using pollen viability.

MATERIALS AND METHODS

Plant materials

Fifteen sweet pepper lines were selected for screening along with a heat tolerant hot pepper check (AVPP9905). Among the sweet peppers, AVPP9823 and AVPP0910 were heat tolerant and heat susceptible checks, respectively (Table 1).

Methods

Heat tolerance screening trials

All 16 entries were evaluated in summer (2010 March-September) and fall (2010-11; September-March).Seedlings were transplanted in single row beds with 0.4 meter distance in a randomized complete block design with 4 replications having 9 plants in each plot. For summer, sowing was done on 24 March and seedlings were transplanted on 26 April. Fruits were harvested three times on 19, 27 July and 9 August. For fall (2010-11), sowing was done on 8 September and seedlings were transplanted on 19 October 2010. Fruit was harvested four times on 18 and 28 January, 9 February and 1 March 2011. Five randomly selected healthy fruits from the first or second harvest were taken to record data.

Data and analysis

Total number of fruit set, fruit yield per plant, and average fruit weight were measured from seven plants in each plot. First grade (better fruit in first harvest) fruit length-width-weight was measured using the average from five fruits harvested from a plot. Summer and fall fruit yield were compared as the % of summer versus fall to define the heat tolerance level of each line. Broad sense heredity (Hb) for all traits was estimated by analysis of variance using the SAS program (Statistical Analysis System) (Gorden 1972).

Pollen measurement

Pollen from 16 lines grown in a screenhouse were collected during the months of March (from plants grown in winter) and July (from plants grown in summer). The pollen was examined for viability using a compound microscope. Five to six open anthers per sample were placed into a Eppendorf tube containing 1 ml growing medium [10 ppm boric acid (H3BO3) and 10% sucrose (C12H22O11)] and a protocol developed by the authors was followed (Shieh 2013). In this protocol, pollen grains collected in fall and summer season were treated at different temperature regimes in incubator. Pollen germination percentage was determined by dividing the number of germinated pollen grains by the total number of pollen in a microscope field. A pollen grain was considered to have germinated when the pollen tube length was greater than the pollen grain diameter (Kakani et al. 2002). Measurements of pollen tube length were recorded from the average length of five pollen tubes in the observed microscopic field and converted into micrometers (µm). Pollen viability at different temperatures was compared to set the optimum critical temperature to evaluate the heat tolerant genotype (Reddy 2007).

RESULTS AND DISCUSSION

Yield, horticultural performance and heritability estimation for heat tolerance

Field performance of the 16 entries in summer 2010 and fall (2010-11) are given in Table 2 & 3. The average yield was 27% in summer compared with fall. Two heat tolerant checks, AVPP9823 and AVPP9905, achieved 57% and 78% comparative yield in summer over fall season, which were higher among all the entries .The performance of AVPP9807 was similar to the heat tolerant check with 46% yield in summer over fall season. High variation in yield and yield related traits (number of fruit/plant and weight/fruit) among 16 entries during two contrasting seasons resulted in great genetic variance (σ2g). This led to higher broad sense (Hb) heritability estimates for yield in summer (78.9%) and fall (47.7%).

In the tropics, sweet peppers are better adapted to winter (optimum temperature 22-28° C) than summer. Practically, breeders defined heat tolerant pepper by comparing the yield in summer as a percentage of yield in winter (fall) season (Table 4). If the percentage of yield of a particular line is higher than 50% (AVRDC 2002; 2003), such line is considered heat tolerant. In this study two lines, AVPP9823 and AVPP9905, with a yield difference of more than 50%, were classified as heat tolerant. Lines PBC266, AVPP0503, F1COA674, AVPP0091, TARI-SP4, AVPP0701, F1Andalus and AVPP9807 showed 20-49% yield in summer vs. fall, and are regarded as moderately heat tolerant lines. The lines AVPP0418, AVPP0407, AVPP0419, F1 Sunny and AVPP0408 showed only a 10-20% comparative yield in summer over fall, and thus can be regarded as heat susceptible lines. Comparison of fruit dimension of first grade fruits during both the season is given in Table 3. Summer trials showed higher broad sense inheritance than in fall, which suggests that summer has higher selection effectiveness. Two parental lines (AVPP9823 as heat tolerant and AVPP0418 as heat susceptible) were selected to study inheritance of heat tolerance in sweet pepper.

POLLEN STUDIES

Screening of germplasm

In general, results revealed that pollen viability decreased with the increase of temperature in both seasons (all data not shown; Table 5). In summer 2010, the testing temperatures in incubators ranged from 27° C to 36° C. Four lines (AVPP0407, AVPP0503, COA674R, F1Andalus) had no pollen viability at 36° C. In fall (2010-2011), all lines had pollen germination at 36° C, one line (AVPP0503) had no pollen germination at 38° C, and five lines (AVPP0418, AVPP0407, AVPP0503, COA674R and AVPP0910) had no pollen germination at 40° C. In the heat tolerant check (AVPP9823), pollen viability was highest at 36° C in summer (12.3% germination and 8.9 x 102 µm tube length). This check also performed best with reference to pollen viability at 40° C in fall (3.5% germination and tube length 1.4 x 102µm). Lines PBC266, AVPP0419, F1Sunny, AVPP0408, AVPP0019, AVPP0701, AVPP9807 and AVPP9905also responded in a manner similar to the heat tolerant check, and pollen germinated at maximum incubator temperatures in both seasons. For susceptible check AVPP0910, the pollen showed low germination at 36° C in summer

2010, and was not viable at 40° C in fall. Lines AVPP0418 (0.5%), AVPP0407 (0%), AVPP0503 (0%), COA674R (0%), TARI-SP4 (0%) and F1Andalus (0%) performed similar to the susceptible check and were classified as susceptible lines. For average entries, the variance (σ2g) of pollen viability was higher at 36° C in summer and resulted in higher broad sense heritability (Hb=38.1%).

Classification of germplasm

Table 5 summarizes the association between pollen viability at high temperatures and yield performance. Pollen viability at high temperatures was classified into three categories (high, medium, and low). Yield performance was also classified into three categories (high, medium, and low) by comparing the percentage of yield in summer versus fall. The consistency levels were judged as good, fair, or poor in terms of predicted (based on pollen viability test) and actual performance (yield % summer vs. fall). Pollen viability at 36° C could clearly differentiate between heat tolerant and heat susceptible lines. Thus, 36° C is critical temperature for pollen viability testing in sweet pepper. The results showed that nine lines were ranked highly consistent, and seven lines were ranked fair; this suggests that it would be valid to develop a good screening method by testing pollen viability at high temperatures.

CONCLUSION

All the entries gave higher fruit yield in fall season compared to yield in summer season (ranged from 6% to 78%; Table 4). In general, heat tolerance checks and hybrids showed higher percentage yield in summer as compared to inbred lines used in this study. Further in summer season, fruit size was reduced in all the entries and number of fruits decreased in most the entries except heat tolerant check genotypes (AVPP9823 and AVPP9905) showed higher fruit setting in summer than fall season and showed higher pollen germination at higher temperature (Table 4 & 5). This is also true for many chili pepper lines. Hence increased fruit setting in summer season can be used as in vivo method and pollen germination at higher temperature as in vitro method to screen heat tolerant sweet pepper genotypes. We intend to advance the segregating generations and make selection of heat tolerant plants under heat stress and it is expected that many of the heat tolerant sweet pepper lines will be made available to the international cooperators through international sweet pepper nursery (ISPN) in coming future.

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Table 1. Name, fruit type and pedigree of 16 pepper lines used in field trials to evaluate heat tolerance and pollen viability in summer (March-August 2010) and fall (September 2010-February 2011), Taiwan

Entry	Name	Fruit type	Pedigree	Remark
01	PBC266	Squash	ZolotoyUbiley	Inbred
02	AVPP0418 (0436-6005)	Bell Sweet	F1PR300-7sel./Yellow Bell	Inbred
03	AVPP0407 (0436-6006)	Bell Sweet	F1PR300-7sel./Yellow Bell	Inbred
04	AVPP0503 (0537-7032)	Bell Sweet	Orange#1/Yellow#1	Inbred
05	F1 COA 674R	Bell Sweet	AVRDC Test Hybrid	Hybrid
06	AVPP0419 (0436-6055)	Bell Sweet	Ja - Yi Yellow#1	Inbred
07	F1 Sunny	Bell Sweet	Enza-Zaden Hybrid	Hybrid
08	AVPP0408(0437-7031)	Bell Sweet	White King seln/Milord	Inbred
09	AVPP0910 (9943-4384)	Bell Sweet	F1 Tequila-seln	Hybrid (HSC)
10	AVPP0019 (PBC 271)	Long Sweet	Milord	Inbred
11	TARI-SP4	Long Sweet	TARI sweet	Inbred
12	AVPP9823 (9848-4840)	Conical Sweet	SP2 BS-HR	Inbred (HTC)
13	AVPP0701(0737-7016)	Long Sweet	Midway/Peto Wonder	Inbred
14	F1 Andalus	Long Sweet	Syngenta Hybrid	Hybrid
15	AVPP9807(9852-131)	Long Sweet	HDA249/Milord	Inbred
16	AVPP9905 (9955-15)	Long Hot	Susan's Joy	Inbred (HTC)

HSC and HTC = heat susceptible and tolerant checks

Table 2. Fruit parameters of 16 entries in summer 2010 and fall 2010-2011

Entry	Code	Fruit Number (no./ pl.)		Fruit Yield (g/pl.)		Fruit Weight (g/fru.)	
		Summer	Fall	Summer	Fall	Summer	Fall
1	PBC 266	7.0±2.3	10.6±2.7	231.4±82.7	1032.5±237	33.2±6	98.1±7.4
2	AVPP0418	2.8±0.5	12.4±2.9	136.4±53.5	1335.6±293.2	48.3±14.8	107.8±4.8
3	AVPP0407	4.4±0.7	14.1±1.8	190.8±40.7	1271.1±96.8	44.2±8.8	90.3±5.6
4	AVPP0503	9.2±1.9	11.6±1.7	268±79.1	1104.3±125.7	29.9±10.8	96.4±12.6
5	COA 674R	7±1.2	10.6±2.2	334.7±54.3	1378.1±187.6	48.9±11.6	132.6±17.9
6	AVPP0419	4.9±2.2	11.7±3.1	178.7±90.9	1389.7±180.1	36.2±4.1	122.8±20.3
7	F1 Sunny	4.4±1.4	12.5±3.4	175.3±90.9	1522.6±221.4	40.5±19.3	125.3±19.3
8	AVPP0408	2.3±0.9	9.1±1.9	121.7±50.4	893.5±305	54.1±17.5	97.4±25.4
9	AVPP0910	3.5±0.9	13±1.2	100.3±25.5	1619.5±127.6	28.9±1.7	125.4±10.7
10	AVPP0019	8.1±0.7	12.9±2.5	285.6±90.2	1256±286.8	34.9±10	96.7±6.3
11	SP4	6.5±2.3	14.2±1.2	369.3±145.3	1764.7±97.8	56.1±5.4	125±9.4
12	AVPP9823	30.5±3.4	21.6±4.1	718±158.6	1267.5±294.8	23.5±4.3	58.2±3.5
13	AVPP0701	13.7±3.6	19±4.5	490.7±236.3	1619±559.8	34.4±6.7	83.1±11.2
14	F1 Andalus	14.8±3.1	16.6±4.7	637.8±56.4	1892.4±514.7	44.4±7.9	114.8±10.9
15	AVPP9807	25.6±5.8	38.1±2.2	597.3±198.5	1311.4±176	23.4±5	34.4±4.1
16	AVPP9905	62.6±20.8	59.7±25	685.7±245.1	883.1±372	11±2.4	14.7±3.4
	Avg.	13	18	345.1	1346.3	37	95.2
	C.V.	42.5	37.6	32	20.6	24.6	13.6
	σ2g	250	182	45583.8	70197.3	138	1171.4
	Hb	89.2	79.9	78.9	47.7	62.5	87.5

Table 3. Fruit parameters of 16 entries in summer 2010 and fall 2010-2011

Entry	Code	First grade fruit					
		Length (cm)		Width (cm)		Weight (g)	
		Summer	Fall	Summer	Fall	Summer	Fall
1	PBC 266	6.7	7.4	3.8	8.4	69.2	165.1
2	AVPP0418	4.8	8.2	8	9.3	84.9	231.8
3	AVPP0407	4.4	7.3	7.8	8.9	78.7	162.9
4	AVPP0503	5.3	8.3	6.7	8.3	67.4	178.4
5	COA 674R	5.6	9	7.8	8.8	104.3	227.9
6	AVPP0419	5.2	8.8	7	8.7	80.6	218.3
7	F1 Sunny	4.9	8.9	7.2	8.9	84.1	216.8
8	AVPP0408	4.9	9	7.1	7.9	71.9	174.5
9	AVPP0910	4.6	9.2	5.3	8.3	43.3	197.4
10	AVPP0019	6.9	10	6.6	7.3	70.3	150.9
11	SP4	8.6	11.7	6.7	8	81.8	204.9
12	AVPP9823	8	11.4	4.9	5.8	40.1	100.4
13	AVPP0701	11.8	15.5	4.9	6.4	65.5	154.1
14	F1 Andalus	14.3	17.1	5.9	6.9	103.4	212.9
15	AVPP9807	10.6	13.1	3.6	4.5	36.9	78.1
16	AVPP9905	15.9	17.2	2.1	2.6	24.7	42
	Avg.	7.6	10.7	5.9	7.4	69.2	169.8

z: The fruits were bulked from the four replications, ANOVA was not conducted.

Table 4. Comparison of fruit parameters in percentage: summer 2010 to fall 2010-11

Entry	Code	% Summer / Fall					
		All Fruit			First grade fruit		
		(No/plant)	Yield/plant(g)	Weight(g)	Length(cm)	Width(cm)	Weight(cm)
1	PBC 266	66	22	34	91	45	42
2	AVPP0418	22	10	45	59	86	37
3	AVPP0407	31	15	49	59	88	48
4	AVPP0503	79	24	31	64	80	38
5	COA 674R	66	24	37	63	89	46
6	AVPP0419	42	13	29	58	81	37
7	F1 Sunny	35	12	32	55	80	39
8	AVPP0408	26	14	55	54	90	41
9	AVPP0910	27	6	23	49	63	22
10	AVPP0019	63	23	36	69	91	47
11	SP4	46	21	45	73	83	40
12	AVPP9823	141	57	40	70	84	40
13	AVPP0701	72	30	41	76	75	43
14	F1 Andalus	89	34	39	84	84	49
15	AVPP9807	67	46	68	81	80	47
16	AVPP9905	105	78	75	92	80	59
	Avg.	61	27	42	69	80	42

Table 5. Pollen viability screening verses yield performance for heat tolerance

Index	Code	Pollen germination %				Pollen viability score	% Yield	Heat tolerant class	Consistency category
		Summer	Fall				Summer vs Fall		
		36° C	36° C	38° C	40° C				
1	PBC 266	0.2	3.9	2.1	1.9	Medium	22	Medium	Good
2	AVPP0418	0.5	1.4	1.2	0.0	Low	10	Low	Good
3	AVPP0407	0.0	2.8	1.1	0.0	Low	15	Low	Good
4	AVPP0503	0.0	3.7	0.0	0.0	Low	24	Medium	Fair
5	COA 674R	0.0	4.4	1.4	0.0	Low	24	Medium	Fair
6	AVPP0419	5.4	2.9	1.2	0.7	Medium	13	Low	Fair
7	F1 Sunny	6.4	7.3	2.4	2.9	High	12	Low	Bad
8	AVPP0408	0.6	4.2	2.1	0.2	Low	14	Low	Fair
9	AVPP0910	1.7	4.7	0.8	0.0	Low	6	Low	Good
10	AVPP0019	0.3	12.7	2.0	0.6	Medium	23	Medium	Good
11	SP4	0.0	1.8	2.2	0.2	Low	21	Medium	Fair
12	AVPP9823	12.3	2.7	4.6	3.5	High	57	High	Good
13	AVPP0701	3.7	3.7	1.6	0.9	Medium	30	Medium	Good
14	F1 Andalus	0.0	10.1	3.0	0.2	Low	34	Medium	Fair
15	AVPP9807	0.4	5.6	2.8	1.3	Medium	46	High	Fair
16	AVPP9905	0.3	8.7	2.6	1.9	High	78	High	Good
	Avg.	2.0	5.0	1.9	0.9	Medium	27	Medium	Good

a: good consistency is when pollen viability score versus heat tolerance class is in low versus low, medium versus medium and high versus high

Seed health: Innovations and best practices from the private sector

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ABSTRACT

Seed quality and seed health is becoming increasingly important in the global seed industry, especially in tackling seed-borne diseases. “Seed health” refers to the presence or absence of disease-causing organisms such as bacteria, fungi and viruses including insects and nematodes. In order to produce and supply pathogen-free seeds to local and high value global markets, private seed companies are recognizing the importance of and becoming ever more focused on seed health management. The establishment of a comprehensive seed health program in a private seed company is vital because 1) the diseases initially present on the seeds may give rise to progressive disease development in the field and consequently reduce commercial value of the crop affecting income and livelihood of the farmer and 2) importation of seed from other regions/countries may introduce diseases or pests in new regions/locations. East-West Seed, a market leader for tropical vegetable seeds, has successfully established and implemented a comprehensive Seed Health Management (SHM) program. The SHM program is applied from upstream (breeding and foundation seed production) to downstream (stock seed and commercial seed production) operations. It is designed to produce high quality and healthy seeds free from infection of serious seed-borne pathogens and pests. This is in compliance with international regulations to support the local and high value global seed markets. The SHM program consists of the following initiatives: field sanitation practices, field phytosanitary inspections, seed disinfection, detection of seed-borne pathogen, application of seed treatments, and comprehensive training to staff and seed producers. As part of the SHM program, East-West Seed has successfully implemented a comprehensive seed disinfection program in which most of the commercial seeds are disinfected before being delivered to the plant for further processing. The disinfected seed is then sent to the seed health lab for conducting detection tests to confirm the seed is free from seed borne pathogens. With the establishment and monitoring of a solid seed health management program and practices, private seed companies can provide good quality and healthy seeds to farmers which can further enhance farmers’ income and provide opportunities for sustainable growth in the vegetable sector.

Keywords

Seed health, seed quality, seed borne diseases, field sanitation, phytosanitary inspections, seed disinfection, seed treatment

INTRODUCTION

Seed quality and seed health is becoming more important in the global seed industry. Currently, seed-borne bacterial pathogens and tobamoviruses infecting Cucurbitaceous and Solanaceous crops are the main target pathogens. In order to produce and supply pathogen-free seeds to local and high value global markets, East-West Seed Company has established and implemented a comprehensive Seed Health Management (SHM) program. The SHM Program has been applied not only for upstream operation, such as breeding and foundation seed, but also to downstream operations, such as stock seed and commercial seeds. The seed health policy and initiatives of the company is designed to be in compliance with the regulations set by international seed health institutions, such as International Seed Federation (ISF), International Seed Health Initiatives – Vegetables (ISHI-Veg), and International Seed Testing Association (ISTA). The main objective is to establish and implement a comprehensive Seed Health Management Program and Policy in every functions/departments with the aim to produce high quality and healthy seeds free from infection of serious seed-borne pathogens which is in compliance with international regulations to support the local and high value global seed markets.

Components of Seed Health Management program

The key components of the Seed Health Management program are indicated in Figure 1. A brief description of each component is provided below:

Comprehensive field sanitation and cultural practices

- Implement field sanitation practices including:
    - Monitor and remove plants or weeds showing disease symptoms from the field
    - Establish and apply foot bath and hand sterilization before entering in the field
    - Implement mandatory practices for the control of tobamoviruses and other targeted seed-borne diseases in commercial seed production fields
- Establish and implement IPM program – Integrated Pest Management practices in commercial seed production fields
- Monitor and map disease infested fields based on previous history and field inspection reports
- Monitor effectiveness and compliance of IPM practices

Implementation of phytosanitary field Inspections

- Develop and implement field inspection criteria, procedure and data recording process for foundation, stock and commercial seed fields
- Conduct field inspections at least twice, one before or at flowering stage and the other one before harvesting
- Ensure thorough inspection of commercial seed fields for targeted crops and diseases and maintain good records of field inspections
- Analyze and interpret field inspection data into two categories either clean or infected

Wet seed disinfection

The objective is to completely remove seed-borne pathogens from seed coat:

- Implement protocols for wet seed extraction and seed disinfection on all seed lots
- Plan, develop and establish central seed disinfection stations with sufficient space, equipment and personnel for effective implementation
- Develop and implement guidelines and flow charts for wet seed extraction and seed disinfection

- Develop and implement comprehensive safety guidelines for proper handling of chemicals and disposal at each disinfection station
- Monitor effectiveness and compliance of seed disinfection practices and procedures

Detection of seed-borne diseases

- Implement detection of all targeted seed-borne pathogens after seed harvesting
- Apply seed detection protocols similar to standard protocols developed by ISHI–Veg, ISF, ISTA or NSHS
- Compare detection results obtained by the internal laboratory with external professional seed health laboratories for quality and compliance determinations
- Implement central quality module for recording all seed health test results
- Implement detection assay for BFB, GSB and other potential seed-borne pathogens

Seed treatment

- Application of dry heat treatment for CGMMV and other tobamoviruses
- Apply additional treatments following the quarantine regulations of importing countries
- Seed film coating with necessary fungicides and additives for enhancing seedling vigor and uniform germination
- Seed priming/encrusting/pelleting for enhancing uniform germination and vigor as a value addition trait
- Monitor compliance and effectiveness of overall seed treatment process

Comprehensive training

- Provide regular trainings related to seed health detection and management to production team as well as growers involved in seed production process
- Provide hands on training on comprehensive wet seed disinfection to production staff
- Organize meetings with farmers to receive feedback for further improvement
- Monitor effectiveness and compliance of comprehensive training program

CONCLUSION

In summary, the establishment of a comprehensive seed health management program is critical for any private seed company in producing good quality seeds free from seed-borne pathogens. This will enable farmers to produce high quality, healthy vegetable crops that will enhance their income level and provide new opportunities for further expansion in vegetable farming.

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Figure 1. Seed health management functions

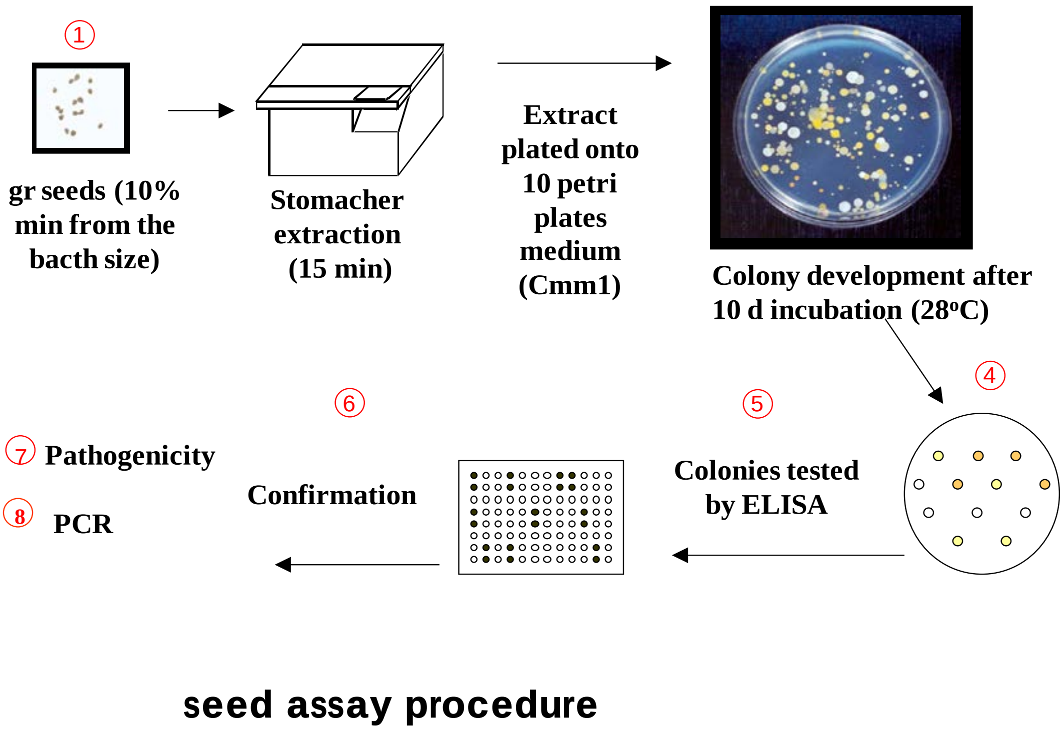

Figure 2. Seed health testing process

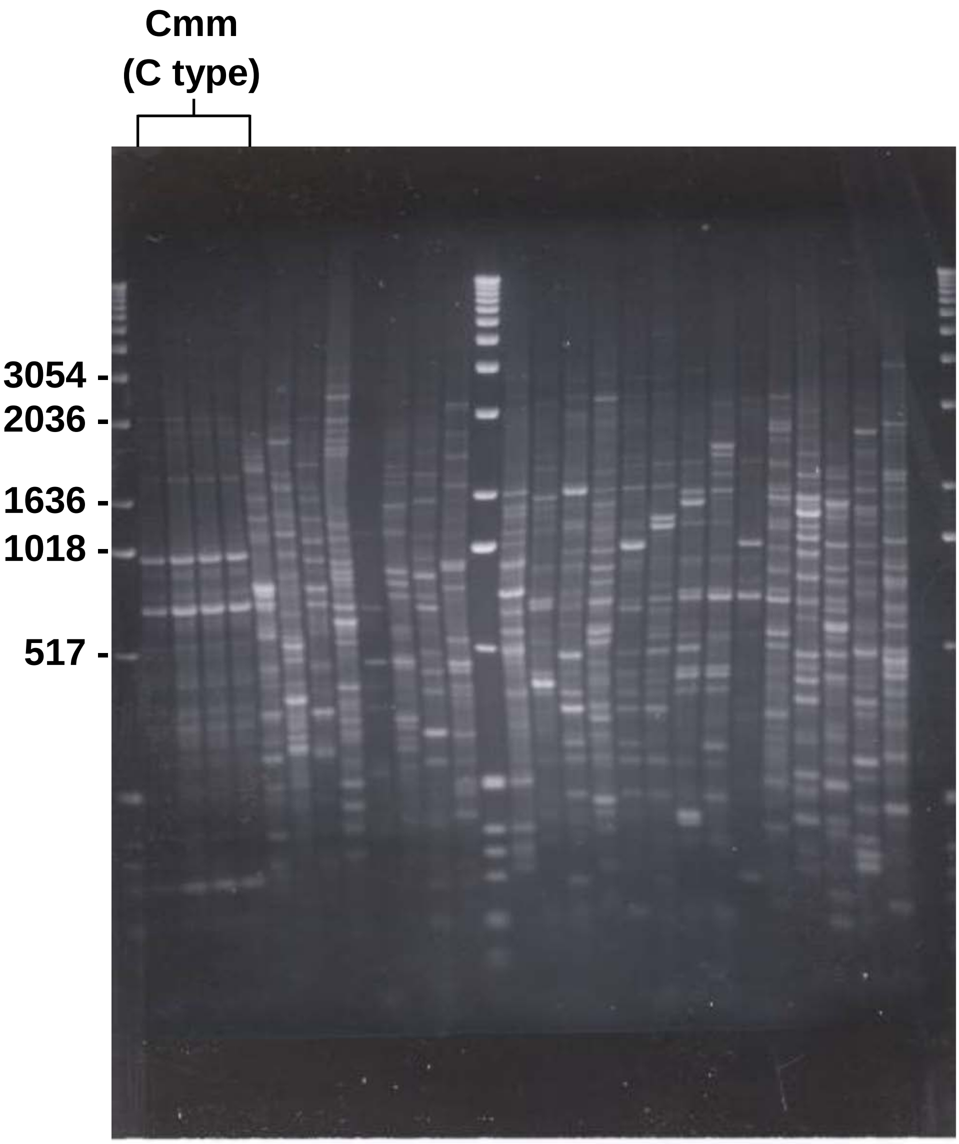

Figure 3. DNA based advanced methods of seed health detection

Spine gourd: The golden vegetable of the Western Ghats

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ABSTRACT

Spine gourd, popularly known as *mada hagala* in the Western Ghats of southern India, is the most popular, unexploited, dioecious perennial vegetable having tremendous nutritional, medicinal and economic values. It is a good medicine for cough and digestive problems. The roots of spine gourd are also being used for treatment of piles, urinary and bowl infections and believed to have growth stimulating substances that promote health, vitality and longevity of humans. Most of the crop comes to the market from wild collections by the native people and gets a premium price in the market due to its scarcity and for its medicinal values. This is also locally called *Malanada Honnu* (Golden Vegetable of the Western Ghats). However, this crop is not being given much importance as the yielding level is poor due to its dioecious nature. Artificial pollination could result in 90% fruit set, with each vine producing more than 60-70 fruits, instead of 12-18 fruits per vine with no assisted pollination.

INTRODUCTION

The Cucurbitaceae family has more than 125 genera and 960 species spread around the world. The family members are well-adapted to varied agroclimatic regions starting from temperate to tropical and from sea level to 3000 masl. Spine gourd/sweet gourd (*Momordica dioica* ssp. *sahyadrica* nom.) is widely grown in the Western Ghats (800-1800 masl) of southern India.

The classification of spine gourd is somewhat confusing. Some scientist classify this under *Momordica dioica* Roxb. while others classify under *Momordica cochinchinensis* Sreng. G. Don places it as *Momordica subangulata* ssp. *renigera*. A detailed study conducted by Joseph et al. (2007) classified this species under *Momordica dioica* ssp. *sahyadrica,* which grows at medium to higher altitudes where as *Momordica dioica* grows at lower altitudes.

The origin of *Momordica dioica* ssp. *sahyadrica* might be in the Western Ghats as many variations are found around this region in secondary forests at low and medium altitude receiving 1200 to 3500 mm rainfall annually and having RH >80% throughout the year (Joseph et al. 2007). In south India most of the crop comes to the market from wild collection by the native people and gets a premium price in the market (₹.250 to ₹.350/kg) due to its scarcity and for its medicinal properties. This is also locally called as *Malanada Honnu* (Golden Vegetable of the Western Ghats).

This perennial crop is the most popular unexploited vegetable crop owing to its nutritional and medicinal properties. The crop is most sought by the people due to its non-bitterness at immature stage and red lycopene and carotenoid contents at full mature stage. The roots of spine gourd are also being used for treatment of piles, urinary and bowl infections and believed to have growth- stimulating substances that promote health, vitality and longevity of humans (Burke et al. 2005).

Hitherto, spine gourd has been grown in a wild form and in backyards of farmers of the Western Ghats. Systematic studies have not been conducted to make the crop a commercial crop.

Hence, an attempt is being initiated at College of Horticulture, Sirsi, which is situated right in the centre of the Western Ghats, to study the following aspects:

- Exploration, collection, characterization and maintenance of germplasm
- Standardization of production technology (including pest and diseases)
- Standardization of propagation techniques
- Use of chemicals *viz.*, silver nitrate ($AgNo_3$) and growth regulators for altering the sex ratio
- Assisted pollination and dormancy related studies
- Medicinal properties and value addition
- Enhancing its status from unexploited to commercial status in south India
- Collaborative research with other institutes in India and abroad

The work

During June 2013, an exploration trip was undertaken in specific areas in the Western Ghats to collect elite germplasm of spine gourd. The tubers from both male and female plants were collected from forest habitats and home gardens. The collected germplasm was raised at College of Horticulture, Sirsi (619 masl). The data were recorded on various aspects of botany, growth and yield parameters.

Flowers are axillary with long pedicel, five petals and sepals and yellow in colour. Stamens are five in number with free filaments and united anthers. Stigma is divided. Fruit is pendulous, fusiform, ribbed with numerous tubercles. Anthesis is from 04:00 to 07:00. Anther dehiscence takes place in between 05:00 and 07:30. Stigma is receptive 24 hours before and after anthesis (Gopalakrishnan 2007).

It was observed that the fruit setting level was poor due to its dioecious nature and natural pollination is chiefly affected by bumble bees. Hence hand pollination was made artificially by collecting the pollen from male plants and pollination was done between 08:00 to 10:30. The result were encouraging and 75% fruit set was recorded as against 10-15% in the vines which were left as it is for open pollination.

The preliminary studies revealed that each spine gourd female plant bore 100-150 female flowers during a period of 100-120 days, and each plant produced 13-14 fruits at first harvest in assisted pollinated plants (Fig. 1). The fruits at maturity stage measured from 68-73 mm in length and 33-36 mm in diameter with average weight of 24 to 27 grams having 30-45 seeds per fruit and taking 22-26 days for maturity (Fig. 2).

CONCLUSION

The initial performance studies of spine gourd at the College of Horticulture, Sirsi shows that the crop can be successfully grown under open conditions, similar to other cucurbits. The best growth was noticed during the rainy season (June to October) and the crop responds well to scientific methods of cultivation. The yielding level of the crop could be enhanced by resuming artificial pollination. Hence there is ample scope for upgrading the status of spine gourd from unexploited to commercial status.

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Table: 1. Ancillary data of spine gourd (up to 90 DAP) recorded at COH, Sirsi.

Vine length (cm)		Days to flower	No. of branches/vine	Days to harvest	Avg. Fruits /vine (No's)	Avg. Yield /vine (kg)
60 DAP	90 DAP					
239.67	303.66	37.25	2	23.75	34.17	0.916

Table: 2. Fruit characters of sweet gourd (average of 5 replications)

Fruit length (cm)	Fruit width (cm)	Weight of fruit (g)	No of locules	Weight of 100 seeds (g)	Peel weight (g)	No of seeds/ fruit	Pericarp thickness (mm)	Mesocarp thickness (mm)
71.17	34.24	26.8	3.0	0.55	13.73	36.6	3.778	24.736

Figure 1: Spine gourd

Figure 2: Cross section of spine gourd fruit

Integrating biopesticides with chemical pesticides to manage legume pod borer (*Maruca vitrata*) on yard-long bean in Lao PDR and Vietnam

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ABSTRACT
A lack of studies on the effectiveness of biopesticides against legume pod borer (*Maruca vitrata*) on yard-long bean in Lao PDR and Vietnam has limited their use in integrated pest management (IPM) strategies. An earlier study confirmed the susceptibility of *M. vitrata* to selected biopesticides under laboratory conditions in Vietnam. A series of field trials were carried out to confirm the potential of biopesticide application in combination with chemical pesticides against *M. vitrata* on yard-long bean in Lao PDR and Vietnam. Four field trials were conducted in Hanoi, Vietnam during April – June 2012, and two field trials in Vientiane, Lao PDR during February – May 2012. The *Bacillus thuringiensis*-based treatments reduced pod damage by 50% in Vietnam, and yard-long bean yields were 17 to 50 times greater than the untreated check. Similarly, yard-long bean pod damage by *M. vitrata* in Lao PDR was reduced by 9-44%, with significant yield increases (63-68%) in *B. thuringiensis*-based treatments. Although the entomopathogenic fungi and neem-based treatments included few *B. thuringiensis* and chemical pesticide sprayings, they slightly reduced marketable pod yield losses. Based on these results, *B. thuringiensis* in combination with chemical pesticides and/or neem is a promising component for IPM strategies against *M. vitrata* on yard-long bean in Lao PDR and Vietnam.

Keywords
Maruca vitrata, *Bacillus thuringiensis*, entomopathogenic fungi, neem, yard-long bean

INTRODUCTION
Yard-long bean (*Vigna unguiculata sesquipedalis*) is the most popular vegetable legume in Southeast Asia (AVRDC 2001). It accounts for almost 7% of the total vegetable production area in the region (Ali et al. 2002), and is cultivated on more than 70,000 ha across Cambodia, Lao PDR and Vietnam (Chinh et al. 2000; Ali, 2002; DOA, 2011). Although a small number of farmers grow the crop year-round, mostly yard-long bean is grown during a specific season; November – March in Lao PDR (Genova et al. 2006), and February – July in Vietnam. Yard-long bean does not only play an important role in providing dietary protein, but also it is a high value, repeat-cycle crop that could lift small-scale farmers out of poverty. For instance, the average value of yard-long bean sales was US$ 4,400/ha per cropping cycle in Lao PDR (Genova et al. 2006). However, the productivity of yard-long bean is severely limited by various production constraints. Legume pod borer, *Maruca vitrata* Fabricius

(Lepidoptera: Pyralidae), is one of the major biotic constraints of yard-long bean production in Southeast Asia including Lao PDR and Vietnam (Muniappan et al. 2012; Srinivasan et al. 2013). Its larvae attack plants in the reproductive stage and a recent survey by our team estimated yield losses of up to 30% in yard-long bean due to *M. vitrata* damage alone in Lao PDR and Vietnam, if the crop is left unprotected.

Farmers apply chemical insecticides indiscriminately to combat *M. vitrata*, but without satisfactory results. In a recent survey by our team in Hanoi’s peri-urban vegetable production area, it was found that the farmers on average sprayed pesticides on yard-long bean every week as a prophylactic measure, using a mixture of two to three pesticides. Although overall pesticide use is lower in Lao PDR, the pesticides used tend to be of the outdated broad-spectrum active ingredients and formulations, such as methyl-parathion, which is very toxic and banned in most developed countries. In Cambodia and Lao PDR, much of the pesticide sold comes from neighboring countries and only has foreign language labels (CEDAC 2004; Escalada et al. 2006; Chou Phanith 2011). Indiscriminate pesticide use increases the likelihood that insects will develop resistance to the pesticides. Although resistance of *M. vitrata* to commonly used pesticides has not yet been documented in Lao PDR and Vietnam, resistance has already been reported in other Southeast Asian countries (Ulrichs et al. 2001). In addition, it is common to find pesticide residue in yard-long bean and other food legumes. For instance, pesticides are often applied to vegetables until close to harvest in Vietnam (Hoi 2010), leaving a harvest interval too short for pesticide residues to reduce to safe levels. The risk of harmful effects on consumer health is likely to be high. Hence, sustainable management strategies for *M. vitrata* are needed to reduce pesticide misuse on yard-long bean in Lao PDR and Vietnam.

Bio-pesticides are an effective tool in managing the borer pests including *M. vitrata*. Several earlier studies have confirmed the susceptibility of *M. vitrata* to *Bacillus thuringiensis*, entomopathogenic fungi such as *Beauveria bassiana* and *Metarhizium anisopliae*, and neem oil either alone or in combinations with other bio-pesticides (Jackai and Oyediran 1991; AVRDC 1996 and 1997; Ekesi et al. 2002; Oparaeke et al. 2005; Srinivasan 2008; Srinivasan and Sridhar 2008; Sunitha et al. 2008; Sreekanth and Seshamahalakshmi 2012). A recent study in Thailand confirmed that *B. thuringiensis* formulations could become an important component in the integrated management of *M. vitrata* on yard-long bean (Yule and Srinivasan 2013). However, the bio-pesticides were applied alone in the study. It is important to incorporate bio-pesticides in an integrated pest management strategy to reduce the risk of *M. vitrata* developing resistance. Hence, the current study was conducted to validate an IPM strategy using chemical and bio-pesticides for the management of *M. vitrata* on yard-long bean under field conditions in Lao PDR and Vietnam, since there were no previous attempts on validating the effectiveness of different bio-pesticides targeting *M. vitrata* in these countries.

MATERIALS AND METHODS

Six field trials were conducted in Lao PDR and Vietnam to evaluate the efficiency of chemical and bio-pesticides against *M. vitrata* on yard-long bean. Four field trials, two at Gia Lam, and two at Song Phuong, Hanoi, Vietnam were conducted during April – June 2012, and two field trials were conducted at the Clean Agriculture Development Center, Vientiane, Lao PDR during February – May 2012. Seven treatments were used in the trials in Vietnam, whereas six treatments were used in the trials in Lao PDR. In each treatment, the spraying order was decided based on the initial population level of *M. vitrata*. Commercial products of bio-pesticides were used in the trials. They were Redcat® 36,000 IU/mg WG (*B. thuringiensis* subsp. *kurstaki*), Zitarback F.C.® 8,500 IU/mg SC (*B. thuringiensis* subsp. *aizawai*), Thai neem 111® 0.1% Azadiractin SN (neem), entomopathogenic fungi *B. bassiana* and *M. anisopliae* and the commonly used chemical pesticide abamectin (Lao PDR) and cypermethrin (Vietnam). The experiments were conducted in a randomized complete block design (RCBD) with three replications for each treatment. The individual plot size was 3 m x 4 m. Pest and disease incidences were monitored and the application of treatments was started when the pod damage exceeded 10%. The recommended dose of each chemical or bio-pesticide was applied weekly until the final harvest. Pod damage caused by *M. vitrata* and yield were recorded at every harvest and the pods were categorized as marketable or unmarketable. The data were analyzed using analysis of variance (ANOVA) with the Proc GLM procedure of SAS, version 9.1 (SAS Institute, Cary, NC, USA). When significant treatment differences were indicated, means were separated by Tukey's HSD Test (SAS). Percentages were *arc-sin* transformed and yield data were square-root transformed to make the data follow a normal distribution before performing the statistical analysis.

RESULTS AND DISCUSSION

Although there were significant differences in the mean pod damage among the treatments in trial 1 at Gia Lam, Vietnam (Table 1), it was surprisingly less in untreated control. Comparatively this trial suffered from poor pod setting, which led to lower yield than other trials. However, the yield of marketable pods was significantly more in the first two treatments that had frequent applications of *B. thuringiensis*-based bio-pesticides. Because of the high *M. vitrata* population in the trial 2 at Gia Lam, Vietnam (Table 2), the treatments were started with the spraying of chemical pesticide or neem. Hence, the pod damage by *M. vitrata* was significantly reduced in various treatments compared to the untreated check. The pod damage was significantly reduced in plots receiving neem, cypermethrin, *B. bassiana* and *B. thuringiensis* subsp. *aizawai*. Most of the other treatments also reduced the pod damage by 46.78% - 56.73% compared to the untreated check. However, the plots that received more *B. thuringiensis*-based bio-pesticides produced better quality pods, and the marketable pod yield was significantly higher in those plots. However, the two trials conducted at Song Phuong, Vietnam did not show any significant differences in the proportion of pod damage or marketable yield among the treatments (Tables 1 and 2). This is mainly due to the fact that as well as *M. vitrata*, other pod boring pests such as common armyworm (*Spodoptera litura*) and blue butterfly (*Euchrysops cnejus*) also occurred as major pests in these trials. Hence, the intended chemical or bio-pesticide treatments did not show any promise in reducing the pod damage. Although the results from the two trials at Song Phuong are inconclusive, the results from trials at Gia Lam showed that the treatments based on *B. thuringiensis* based bio-pesticides with two applications of cypermethrin could reduce the pod damage by *M. vitrata* with significant increases in marketable pod yield. But, it requires further validation over different seasons in Song Phuong.

The results of the trials at Vientiane, Lao PDR are given in Table 3. Abamectin treatment led to significantly lower pod damage by *M. vitrata*. However, among the treatments involving bio- and chemical pesticides, the treatment based on *B. thuringiensis* subsp. *aizawai* resulted in lower pod damage in trial 1. Although the mean pod damage was intermediate in other combination treatments compared to the untreated check, the pod yield was similar in *B. thuringiensis* treatments as to the abamectin treatment. The average yield increase was about 66.49% in *B. thuringiensis* and abamectin treatments, when compared with the untreated check. Although the pod damage was statistically similar in *B. bassiana* and *M. anisopliae*-based treatments with the untreated check, these treatments resulted in significant yield increases. In trial 2, there were no significant differences in mean pod damage among the treatments. However, yard-long bean yield was significantly different among the treatments, and it was greater in the abamectin treatment. In general, the marketable pod yield was much less in this trial because of the severe infestation of southern green stink bug (*Nezara viridula*). The bio-pesticides were unable to control *N. viridula* as effectively as abamectin, resulting in less marketable pod yield. However, these two trials in Lao PDR confirmed that *B. thuringiensis* and neem based bio-pesticides with a single spray of abamectin could reduce pod damage by *M. vitrata* with significant yield increases, as effectively as repeated applications of the chemical pesticide, abamectin.

In most of the field trials, treatments with *B. thuringiensis* significantly reduced yard-long bean pod damage by *M. vitrata*. There were no previous reports showing the effectiveness of different bio-pesticides in combination with chemical pesticides against *M. vitrata* from Lao PDR and Vietnam. However, it was found that plots treated with *B. thuringiensis* subsp. *aizawai* or *B. thuringiensis* subsp. *kurstaki* alone suffered significantly less pod damage by *M. vitrata* in earlier field trials at Kamphaeng Saen, Thailand during 2011 – 2012 (Yule and Srinivasan 2013). It was also confirmed by Yule and Srinivasan (2013) that the *M. vitrata* larvae were highly susceptible to both *B. thuringiensis* subsp. *aizawai* and *B. thuringiensis* subsp. *kurstaki* formulations (Zitarback F.C.®.and Redcat®, respectively) in Thailand. Hence it is possible that *B. thuringiensis* based bio-pesticides could effectively reduce the damage caused by *M. vitrata* on yard-long bean in Lao PDR and Vietnam. Other field studies in India have also confirmed the efficacy of *B. thuringiensis* bio-pesticides against *M. vitrata* in field conditions (Sunitha et al. 2008; Sreekanth and Seshamahalakshmi 2012). However, it has to be noted that using the same pesticide or bio-pesticide repeatedly might lead to the development of resistance (Ekesi 1999); for that reason, we chose a combination of sprays based on chemical and bio-pesticides for the current study. Because, exposing insect pests to chemical and/or botanical pesticides such as neem could induce stress in them, and that subsequent application of bio-pesticides on stressed pests could lead to increased mortality rates (Schuler and van Emden 1997; Khalique and Ahmed 2001). Such synergistic effects were observed in this study for *Bacillus thuringiensis* + cypermethrin and *Bacillus thuringiensis* + neem + cypermethrin treatments in Vietnam, and *Bacillus thuringiensis* + neem + abamectin treatments in Lao PDR. However, the treatments based on entomopathogenic fungi did not result in substantial reduction in *M. vitrata* pod damage, even when they were combined with neem and chemical pesticides, except those treatments containing *B. thuringiensis*. Our earlier study in Thailand also confirmed that *M. vitrata* was not infected by *B. bassiana* (Yule and Srinivasan 2013). Similar results have been reported from India. The study by Sreekanth and Seshamahalakshmi (2012) confirmed that only *B. bassiana* SC formulation at the highest dose (300 mg/l) slightly reduced pigeon pea pod damage by *M. vitrata*. In addition, neem is effective only at higher concentrations for most lepidopteran pests (Jayadevi and Kumar 2011). Thus, the combinations of neem and entomopathogenic fungi were unable to provide sufficient control of *M. vitrata* on yard-long bean in Lao PDR and Vietnam.

CONCLUSION

It can be concluded from this study that an integrated strategy based on *B. thuringiensis*, chemical pesticides and/or neem could effectively curtail yield losses caused by *M. vitrata* in yard-long bean in Lao PDR and Vietnam. The integrated strategy not only reduces the *M. vitrata* damage and thus resulting in substantial yield increases, but also reduces the amount of chemical pesticides used in yard-long bean production systems. Hence, the local research and extension system in these countries should formulate pest management recommendations based on bio-pesticides and chemical pesticides.

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Table 1. Efficacy of various chemical and bio-pesticide treatments on the pod damage caused by *Maruca vitrata* at Gia Lam (April – May 2012) and Song Phuong (April – June 2012), Hanoi, Vietnam

Treatment	Gia Lam Trial 1		Song Phuong Trial 1	
	Mean pod damage per plot* (%)	Marketable Yield (t/ha)	Mean pod damage per plot* (%)	Marketable Yield (t/ha) ‡
Bacillus thuringiensis subsp. *kurstaki* – *B. thuringiensis* subsp. *aizawai* - cypermethrin – cypermethrin – *B. thuringiensis* subsp. *aizawai* – *Bacillus thuringiensis* subsp. *kurstaki*	43.23 ab	4.83 a	13.27	12.56
Bacillus thuringiensis subsp. *aizawai* – *B. thuringiensis* subsp. *kurstaki* - cypermethrin – cypermethrin – *B. thuringiensis* subsp. *kurstaki* – *Bacillus thuringiensis* subsp. *aizawai*	44.86 ab	5.28 a	13.85	11.68
Beauveria bassiana - *B. thuringiensis* subsp. *kurstaki* –*B. bassiana* – cypermethrin – *Metarhizium anisopliae* – *B. thuringiensis* subsp. *aizawai*	31.80 b	1.61 b	10.81	11.69
B. thuringiensis subsp. *kurstaki* – *B. bassiana* – *B. bassiana* – cypermethrin – *M. anisopliae* – *B. thuringiensis* subsp. *kurstaki*	30.83 b	0.94 bc	9.79	11.39
M. anisopliae – *B. thuringiensis* subsp. *kurstaki* – *M. anisopliae* – cypermethrin – *B. bassiana* –*B. thuringiensis* subsp. *aizawai*	52.92 a	0.97 bc	11.26	12.10
B. thuringiensis subsp. *kurstaki* – *M. anisopliae* – *M. anisopliae* – cypermethrin – *B. bassiana* – *B. thuringiensis* subsp. *kurstaki*	8.65 c	1.37 b	11.23	11.19
Untreated control	7.36 c	0.28 c	22.72	9.81
F-value	7.33	30.38	1.77	0.97
P-value	0.001	<0.0001	0.18	0.50

In a column, means followed by same letter(s) are not significantly different by DMRT at 5% level

Table 2. Efficacy of various chemical and bio-pesticide treatments on the pod damage caused by *Maruca vitrata* at Gia Lam (April – May 2012) and Song Phuong (April – June 2012), Hanoi, Vietnam

Treatment	Gia Lam Trial 2		Song Phuong Trial 2	
	Mean pod damage per plot* (%)	Marketable Yield (t/ha)	Mean pod damage per plot* (%)	Marketable Yield (t/ha) ‡
Cypermethrin – *Bacillus thuringiensis* subsp. *aizawai* – *B. thuringiensis* subsp. *kurstaki* – cypermethrin – *B. thuringiensis* subsp. *aizawai* – *Bacillus thuringiensis* subsp. *kurstaki*	14.34 bcd	24.32 a	14.36	13.28
Neem – *Bacillus thuringiensis* subsp. *aizawai* – *B. thuringiensis* subsp. *kurstaki* - cypermethrin – *B. thuringiensis* subsp. *aizawai* – *Bacillus thuringiensis* subsp. *kurstaki*	14.35 bcd	20.50 b	20.00	10.61
Neem – *Bacillus thuringiensis* subsp. *aizawai* –*M. anisopliae* – cypermethrin – *M. anisopliae* – *B. thuringiensis* subsp. *aizawai*	15.99 bc	15.57 c	15.93	12.27
Neem – *Bacillus thuringiensis* subsp. *kurstaki* –*M. anisopliae* – cypermethrin – *M. anisopliae* – *B. thuringiensis* subsp. *kurstaki*	17.27 b	14.56 c	13.59	12.41
Neem – *B. thuringiensis* subsp. *aizawai* – *B. bassiana* – cypermethrin – *B. bassiana* –*B. thuringiensis* subsp. *aizawai*	12.91 d	16.37 c	12.85	13.85
Neem – *B. thuringiensis* subsp. *kurstaki* – *B. bassiana* – cypermethrin – *B. bassiana* –*B. thuringiensis* subsp. *kurstaki*	14.24 cd	16.92 c	15.62	12.79
Untreated control	30.44 a	0.45 d	20.06	12.63
F-value	28.85	58.60	0.33	1.04
P-value	<0.0001	<0.0001	0.94	0.46

In a column, means followed by same letter(s) are not significantly different by DMRT at 5% level

Table 3. Efficacy of various chemical and bio-pesticide treatments on the pod damage caused by *Maruca vitrata* at Clean Agriculture Development Center, Vientiane, Lao PDR

Treatment	Trial 1 (February – March 2012)		Trial 2 (April – May 2012)	
	Mean pod damage per plot (%)	Marketable Yield (t/ha)	Mean pod damage per plot (%)	Marketable Yield (t/ha)
Bacillus thuringiensis subsp. *aizawai* – neem – abamectin – *B. thuringiensis* subsp. *aizawai* – neem	12.84 ab	10.21 a	13.86	1.18 ab
Bacillus thuringiensis subsp. *kurstaki* – neem – abamectin – *B. thuringiensis* subsp. *kurstaki* – neem	19.63 a	10.09 a	13.68	1.68 ab
Neem – *M. anisopliae* – *M. anisopliae* – abamectin – neem	17.34 a	6.52 ab	17.72	1.06 b
Neem – *B. bassiana* – *B. bassiana* – abamectin – neem	19.35 a	7.12 ab	15.74	0.90 b
Abamectin	7.52 b	10.08 a	11.27	2.17 a
Untreated control	22.82 a	6.08 b	15.04	1.03 b
F-value	6.70	4.91	0.49	6.32
P-value	0.004	0.01	0.82	0.005

In a column, means followed by same letter(s) are not significantly different by DMRT at 5% level

Pilot experiences of area-wide promotion and adoption of fruit fly IPM-Farmers Field Schools (FFS) in Lower Mekong River Basin countries

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ABSTRACT

The Asian Fruit Fly Integrated Pest Management Project is a collaborative effort among various public sector partners (Asian Institute of Technology (AIT), the Food and Agriculture Organization and its Regional Integrated Pest Management Programme (FAO-IPM) and associated National IPM Programmes in the Greater Mekong Subregion) and the private sector (Bio-Control Research Laboratories, India and Pupuk Alam, Malaysia). The project aims to promote the adoption of area-wide IPM and educate farmers on the ecology and management of *Bactrocera* fruit flies through participation in Farmer Field Schools. Since the project inception in September 2010, various capacity building training and action research activities were conducted at regional and country levels. These activities have led to country-specific project interventions, strategic design of effective 1-2-3 IPM strategies (1 - Protein Bait; 2 - Sanitation; 3 - Lures for population monitoring). Project outputs also include innovative development of fruit fly IPM training curricula and materials (http://ipm.ait.asia). This paper outlines pilot experiences of area-wide fruit fly IPM promotion and adoption by farmers from five Greater Mekong Subregion project member countries (Cambodia, Lao PDR, Myanmar, Thailand and Vietnam).

Keywords: *Bactrocera* Fruit flies, IPM, Farmers Field Schools, Greater Mekong Subregion

INTRODUCTION

Asia (East, Southeast, and South) is among the top three regions worldwide in terms of annual exports and imports of fresh fruits and vegetables. The productivity and quality of many of the fruits and vegetable crops produced are seriously reduced by tephritid fruit flies (*Bactrocera dorsalis, Bactrocera cucurbitae*). Tephritid fruit flies can cause direct damage to fruits and vegetables leading to 90-100% yield losses depending on locality, variety and season; indirect loss occurs by reducing the trade potential due to strict quarantine regulations. Until recently, area-wide fruit fly IPM promotion efforts in Asia have focused largely on introduction of the sterile male technique, without attention to status of farmer's education and promotion of an integrated management approach. Adoption of fruit fly IPM among smallholder farmers has been negligible and impact on control of fruit fly populations is limited.

Improving productivity and quality of fruit and vegetables enhances food and nutritional security, employment and trade opportunities. Asia (East, Southeast, and South) is among the top three regions worldwide for both exporters and importers of fruit and vegetables. The Mekong river basin countries are important producers of a range of tropical and subtropical fruit and vegetables for domestic consumption and international trade. In 2004, Asian countries produced 178 million tons of tropical fruit, which amounted to 66% of the total global production and earned US $2.5 billion (Somsri et al. 2007).

Several factors, however, constrain fruit and vegetable production in the Mekong river basin. Tephritid fruit flies (FF) (*B. dorsalis*, *B. correcta* and *B. cucurbitae*) cause direct damage to fruit and vegetables (Clark et al. 2005), potentially leading to 90-100% losses depending on locality, variety and season. In addition to the direct losses, fruit fly infestation results in serious losses in trade value and opportunity due to strict quarantine regulations imposed by most importing countries.

The Asian Fruit Fly IPM Project (http://ipm.ait.asia) is a regional consortium of research and development institutions (Asian Institute of Technology, Bangkok), the FAO Regional IPM Programme, the private sector (Bio-Control Research Laboratories India), and national government IPM and extension programmes in Cambodia, Lao PDR, Thailand and Vietnam. In partnership, efforts are underway to improvise the existing Fruit Fly IPM technologies, innovate IPM strategies, and subsequently extend these locally adapted IPM strategies to farmers. The Farmers Field School (FFS) platform is used both for training farmers and conducting action research with communities to empower them to raise healthy and profitable fruit and vegetable crops.

Protein bait developed from beer production has been extensively tested and used in Vietnam and elsewhere in Southeast Asia with support from Australian Centre for International Agricultural Research (ACIAR) projects with good success (Drew and Roming 1997; Chinajariyawong et al. 2003; Shanmugam et al. 2005). Similarly, Methyl Eugenol and Cue-lures are being used extensively in many counties either for population monitoring or for mass trapping of fruit flies and melon flies respectively.

Small and fragmented production systems impose a challenge for developing and operating an area wide approach in most Southeast Asian countries, except possibly for large scale commercial orchards. To overcome that problem, an innovative idea of working with a group of 30 farmers, using the Farmer's Field School platform, to cover the major crop area in a village, was successfully piloted by the project.

This paper outlines activities and preliminary results obtained from the adoption of 1-2-3 IPM strategies (1 - Protein Bait; 2 - Sanitation; and 3 - Lures for population monitoring) by the farmers working on a range of fruit and vegetable crops. Results were obtained from work carried out on bitter gourd and guava crops from Cambodia, mango from Myanmar, and Barbados cherry from Vietnam. These crops were selected based on how important a cash crop these were for smallholder farmers and the severity of fruit fly problems experienced. The key results presented here include the FTDs (flies per trap per day) counts, changes in farmers' knowledge and perception, as well as economic analysis. The discussion focuses on the lingering need to forge productive partnerships among various public and private sector institutions to develop science- based, robust IPM programmes for fruit fly management.

MATERIALS AND METHODS

Background Preparation: A Regional Inception and Planning Workshop in 2010 set the tone for project implementation in the four countries (Cambodia, Lao PDR, Vietnam and Thailand). Later, with support of two FAO export-oriented value chain capacity building projects (GCP/RAS/217/IFA &MTF/RAS/242/CFC, from 2012 onwards), pilot work and training were also initiated in Southern Shan State (SSS), Myanmar. There, project efforts focused on export-oriented mango value chains. All project stakeholders, including scientists from Asia, Australia and Hawaii, participated in this workshop with to analyze results of previous fruit fly projects and develop work plans for the project. It was clear that limited efforts had been made in the region to develop locally suitable fruit fly IPM packages as well as to develop appropriate and need-based community and/or farmer education programmes. Most past projects focused primarily on collecting basic information, i.e. species taxonomy, with the exception of Australian Centre for International Agricultural Research (ACIAR)-funded efforts on using protein baits in Vietnam and in other countries.

Workshop outputs then led to development of Country Strategy Papers by each of the four countries and a subsequent Geographic Information System (GIS) map assisted area selection for project site interventions (http://ipm.ait.asia). A Regional Training on IPM for Fruit Flies was organized in Tien Giang, Vietnam in December 2010. This training was organized by FAO and AIT, in collaboration with the Southern Fruit Research Institute and the Vietnam Ministry of Agriculture and Rural Development Plant Protection Department. (http://ipm.ait.asia/?page_id=667). Upon return from the regional training, IPM trainers with farmers undertook baseline surveys (BS) and information collected on crops and fruit fly infestations was analysed for fine-tuning project intervention and training work plans. A short-duration (7-10 days) Training of Trainers (TOT) was organized in each of the participating countries to equip IPM trainers with basic information on fruit flies (life cycle, ecology, biology, management, monitoring, etc.). This was followed by the development of curricula for the FFS on selected crops (one fruit and one vegetable crop) in each country: bitter gourd and guava in Cambodia, jujube in Lao PDR and mango in Myanmar; and adaptation of field exercises and population monitoring guides in local languages. Most of these curricula also included other biotic and abiotic stress affecting crop health as fruit flies were not the only problems encountered by participating farmers.

Flies per trap per day data were collected weekly by the participating farmers and trainers. Dead flies were sorted to oriental fruit flies or to Guava fruit fly or to melon flies depending on the crop and major prevalent species. Cost-benefit data were recorded, summarizing fixed costs and variable costs for crops. Data on pre and post ballot box were collected based on the scores obtained by participating farmers in the beginning and towards the end of the training season.

For analysis, single factor analysis of variance (ANOVA) was used (SAS 9.2) followed by mean separation using appropriate method. Only selected data are presented in this paper.

Farmer Field Schools on Fruit Fly IPM: Upon completion of basic preparations in each country, FFS for a systematic community-wide IPM on fruit fly for chosen crops commenced in 2011. Two areas, 2-3 km apart, with similar bio-physical and economic status were chosen for establishing FFS and population monitoring using Methyl Eugenol (Bador©, BCRL, India) for *B. dorsalis* and *B. correcta* for fruit crops and Cue-lure (BaCue©, BCRL, India for *B. cucurbitae*). A group of 25-30 women and men farmers participated in these FFS on a weekly basis (in the case of vegetable crops) and weekly to fortnightly basis during critical fruit fly stages for fruit crops. Every FFS meeting constituted of an agro-ecosystem analysis and calculation of the Flies per Trap/Day (FTD). The group of trainers and farmers also serviced (cleaning, changing lures and changing bottles if soiled) the bottle traps at regular intervals. Apart from FTDs, towards the end of the season, economic analyses were carried out to assess the costs and benefits of the strategies that were introduced. Additional farmers from the communities were invited and results of the FFSs were shared with them during mid-season and end-season Field Days. Pre and post knowledge and skills tests were carried out to evaluate the increment in farmer knowledge and practices related to FF IPM.

RESULTS AND DISCUSSION

To best of our knowledge, this was a first attempt to modify the area-wide concept using FFS platform to achieve larger participation of community and area of a given crop for fruit fly management. Generally, the project implementation positively added to the management of the fruit flies on most crops and at all sites in the project implementation countries. The project was unique in linking action research on innovative management practices with field training of smallholder farmers. The Farmers Field Schools facilitated learning and experimentation to develop crop-specific management practices suitable for local adoption. Some variability (Fig. 4) was also observed, which was caused by two important reasons a) large acreage of several varieties of mango, b) lack of experiences in implementing IPM.

Farmers' participation: Farmers enthusiastically participated in these FFS and learned about the life cycle, ecology, biology and also practiced management strategies as part of the 1-2-3 management of Fruit Fly IPM (Fig. 1 & 2).

Population monitoring: Excellent management of the FF was evident when FTDs were calculated and presented during weekly meetings. Initially IPM area recorded higher FTDs over the non-IPM area (Fig. 3 & 4). The overall case study (Fig. 5) from Lao PDR is the most interesting one. The yield (t/ha) in IPM plot was 18.75 t/ha whereas yield was 9.375 t/ha in the conventional practices plot. The percentage damage (calculated on the basis of randomly counting 100 fruits by 5 groups of farmers per week) prior to IPM implementation was in the range of 80-100%, which was brought down to the level of 10-20% post IPM adoption.

Economic returns: The reduced losses from FF damage in IPM areas resulted in higher yields leading to higher total and net-returns (Fig. 6). Similar trends of higher net returns were obtained by Barbados cherry farmers in Tien Giang, Vietnam (Table 1).

The project, within a short period of time since its inception in mid-2010, was able to establish a systematic and solid foundation for area-wide FF IPM adoption and adaptation. For example, the jujube fruit fly IPM experiences in Laos helped fine-tune the use of lures, not just for population monitoring but also for population regulation early on in the production season when populations are high. These adaptation processes were possible by building the science-based systematic project interventions into existing strong IPM-FFS based training programmes. These pilot initiatives and results obtained clearly demonstrate the prospects of successful community adaption of scientifically sound and robust technologies by using proven extension vehicles like FFS. Further, under the auspices of the project, newer and better lures and traps are being developed to enhance the catches by cue-lures, new dry traps to reduce servicing time and cost, and substitution of Malathion (which is widely used in small quantities to kill trapped flies) with less toxic biological substitutes like entomopathogens (*Beauveria bassiana*). The project highlights the need for partnership between public and private organizations (BCRL India for making lures available and Pupuk Alam, Malaysia for protein baits) to achieve sustainable fruit fly management in this region and beyond.

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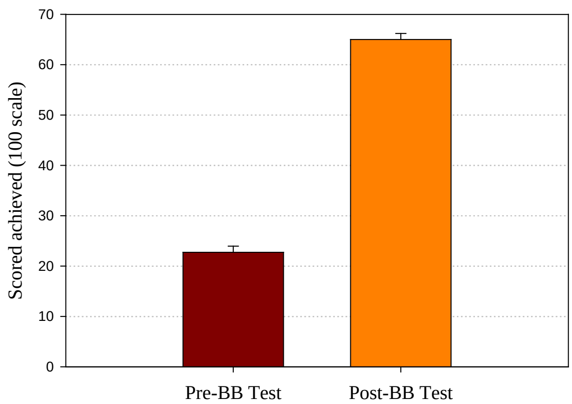

Figure 1. Knowledge and skill gains as expressed in pre and post ballot box scores achieved by FF-IPM trained farmers (Trang village, Ou Ta Ky commune, Thmor Koul district, Battambang province)

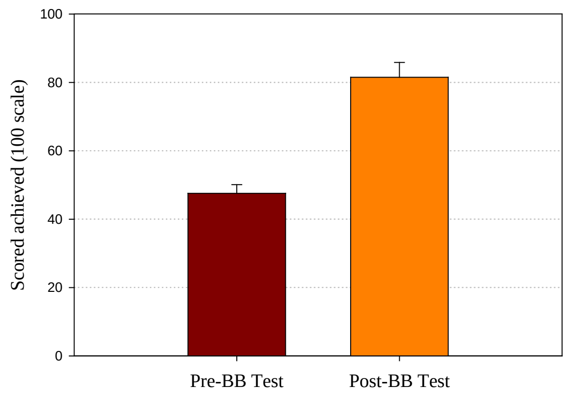

Figure 2. Knowledge and skill gains as expressed in pre and post Ballot Box score achieved by farmers (Sdao Kanlang village, Dey Ith commune, Kien Svay district, Kandal province)

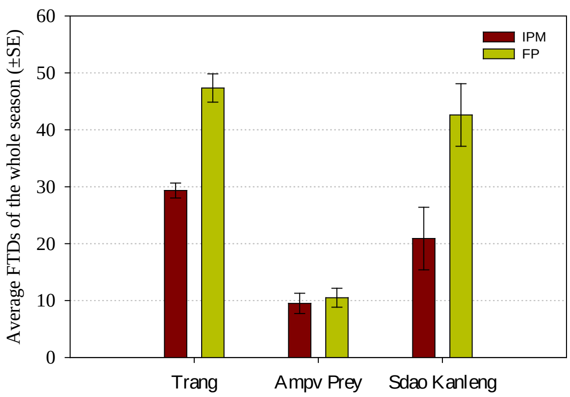

Figure 3. Average of FTDs (Flies per trap per day) from 3 FFS (season-long) conducted in Trang (6 sampling days, bitter gourd crop), Ampv Prey (7 sampling days, guava crop) and Sdao Kanleng (10 sampling days, guava crop) on bitter gourd and guava crops in Cambodia.

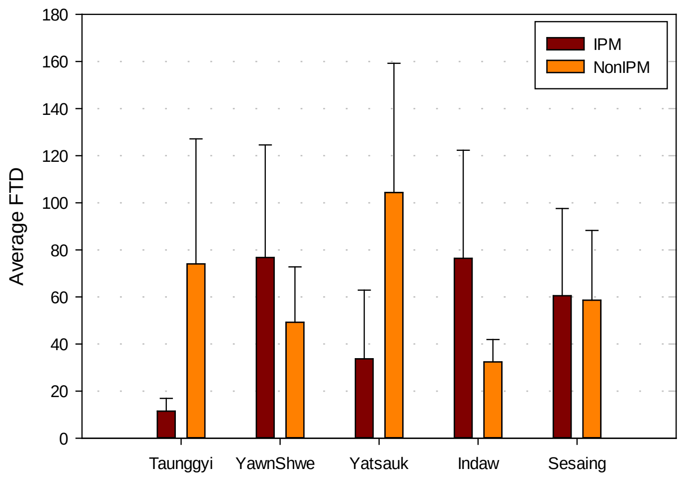

Figure 4. Average (FTD ± SE) of five months (April, May, June, July and August) collected by using IPM and Non-IPM methods of mango production in five zones: Taunggyi, Yawn Shwe, Yatsuk, Indaw and Sesaing, Southern Shan State, Myanmar (2013)

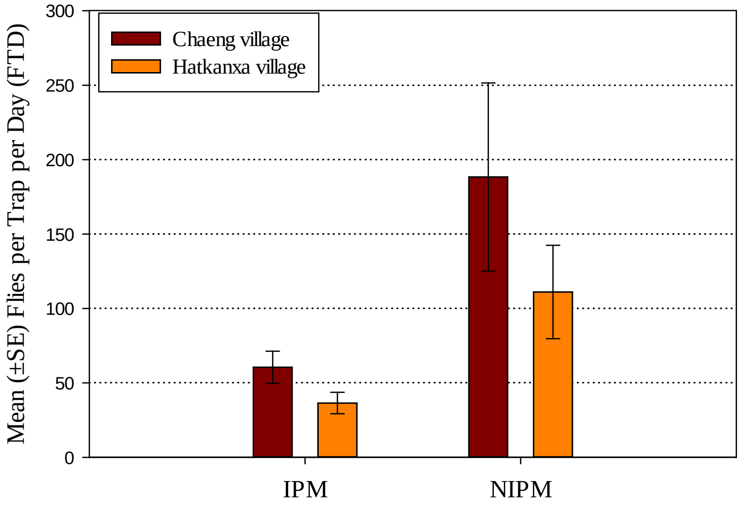

Figure 5. Average (FTD ± SE) of 4 months (starting mid-October 2013) collected by using IPM and Non-IPM methods in two villages (Chaeng, $F= 8.7$; $df= 1,2$; $P= 0.0064$ and Hatkanxa, $F= 3.98$; $df= 1,2$; $P = 0.05$;) on jujube crop in Lao PDR .

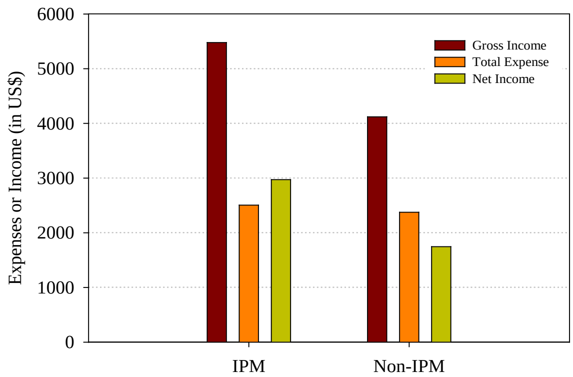

Figure 6. Gross income, total expense and net income achieved by bitter gourd IPM and non-IPM farmers (Trang village, Ou Ta Ky commune, Thmor Koul district, Battambang province). The IPM farmers harvested more healthy fruits with less cost (mainly on pesticides) leading to higher total and net-income.

Table 1: Gross income, total expense and net income achieved by Barbados Cherry IPM and non-IPM farmers (Tien Giang, Vietnam) per ha; in 000 Vietnamese Dong)

Indicators	IPM Field	FP Field
Total expenses	23,240	18,770
Material *(Varieties, Fertilizers, Pesticides, Protein bait)*	10,640	8,570
Labour (*Land preparation, take care, spray pesticides/protein bait, harvest…)*	12,600	10,200
Gross income	29,760	22,400
Net Profit	6,520	3,630

Effect of organic matter application, conservative tillage and reduced chemical fertilizer use on vegetable yield and soil organic carbon content on a volcanic ash soil in West Java, Indonesia

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ABSTRACT
To establish vegetable cropping systems that can reduce chemical fertilizer use and increase soil organic carbon, a field experiment was carried out from 2011 to 2013 on a volcanic ash soil in Lembang, West Java, Indonesia. Twelve treatments combining organic matter, chemical fertilizer and tillage were applied. Cabbage (*Brassica oleracea* L. var. *capitata*) and tomato (*Solanum lycopersicum*) were mix-cropped in the first cropping season (rainy season, starting in September). Bean (*Phaseolus vulgaris*) was planted in the second cropping season (transitional season, starting in January) and corn (*Zea mays*) was planted in the third cropping season (dry season, starting in April). The soil organic carbon content was determined before the experiment and after corn was harvested. In the first year the cabbage yield in some plots were significantly lower due to the outbreak of clubroot disease. In the second year the yield was not significantly different among all the treatments. Marketable tomato and bean yield was not significantly different among all the treatments both in the first and second year planting. 20 mt/ha organic matter application significantly increased corn yield in the first year. In the second year, corn yield with 20 mt/ha organic matter application was significantly higher than that of 0 mt/ha and 10 mt/ha organic matter application. Overall there was no significant yield reduction with reduced chemical fertilizer application and tillage practices. This suggests that chemical fertilizer application can be substituted with organic matter without reducing yield. Application of organic matter at the rates of 10 mt/ha resulted in larger Soil Organic Carbon (SOC) changes compared to no organic matter application. The minimum tillage (MT) treatment showed higher increase in SOC than the conventional tillage (CT) treatment. Results of the experiment can be recommended as a practical farm management system to increase soil organic carbon while reducing chemical fertilizer application and hence maintaining the vegetable yield and also increasing farmers' income.

Keywords
Cabbage, Tomato, Organic matter, Conservation tillage, Soil organic carbon

INTRODUCTION

Green House Gas (GHG) emissions from the agricultural sector forms 26% of the total GHG emission in developing regions (UNFCCC 2005). It should be noted that chemical fertilizer application indirectly contributes to GHG emission because it generates a considerable amount of GHG in the production process. Kongshaug (1998) estimated that fertilizer production is responsible for around 1.2% of total GHG emissions. More recently Zhang et al. (2013) reported nitrogen fertilizer-related emissions constitute about 7% of GHG emissions from the entire Chinese economy.

Organic matter application and conservation tillage are effective ways to increase soil fertility so that farmers can get improved and sustainable crop yields. Due to the growing concern about global warming, these practices are also being recognized as practical methods to decrease chemical fertilizer application and sequester carbon by increasing soil organic carbon (SOC). Japan International Research Center for Agricultural Sciences (JIRCAS), and Indonesian Agency for Agricultural Research and Development (IAARD) have carried out a long-term field experiment since 2006 in Indonesian Vegetable Research Institute, West Java Province, Indonesia. Sugino et al. (2013) reported that half to three-quarters of the conventional chemical fertilizer application for cabbage and lettuce can be replaced without any yield loss by applications of 20 mt/ha or 40 mt/ha of horse manure while there were no consistent changes over time in SOC due to the relatively low C/N ratio of horse manure and high SOC in the experimental fields.

In the present study, first, the effect of organic matter application and reduced chemical fertilizer application on the yield of various vegetables and corn was examined to determine the possibility of decreasing chemical fertilizer application for vegetables other than cabbage and lettuce. Second, the effect of organic matter application and conservation tillage on SOC was examined to determine the possibility of increasing SOC on farms with Andosol soils so that they can work as a carbon sink.

MATERIALS AND METHODS

A field experiment was carried out at the Indonesian Vegetable Research Institute, located in Lembang, Bandung, West Java (latitude: 6°48’S, longitude: 107°39’E, 1250 masl) with a mean annual temperature and precipitation of approximately 20° C and 1900 mm, respectively (Fauzi and Agus 2008). Lembang is located in the highland area of West Java, which is one of the vegetable production centers in Indonesia. A moderate climate in this area is suitable for temperate zone vegetables.

Andosol is developed from materials of volcanic origin such as volcanic ash and it is a typical soil in the highland area in West Java in Indonesia. It has a very large specific surface with aluminium hydroxide groups, which has a strong affinity for phosphate ions and consequently it is generally P-deficient (FAO 1993). It is also known that the decomposition rate of organic matter in Andosols is lower than that in other types of soil (Rural Culture Association 1999), which can benefit the accumulation of SOC.

The field examined (50 m x 10 m) had been used as an experimental field. The general properties of the original soil, as shown in Table 1, suggested that this soil was characterized by a high organic matter content (T-C content of the surface soil: 6.18%), high capacity to store nutrients (CEC: 23.77 cmol(+) x kg^{-1}), and very low bulk density (0.39 g/cc).

The crops were planted three times a year. The first cropping season (rainy season) starts in September, followed by the second (transitional season, starting in

January) and the third cropping season (dry season, starting in April). Cabbage (*Brassica oleracea* L. var. *capitata*) and tomato (*Solanum lycopersicum*) were mix-cropped in the first cropping season. Bean (*Phaseolus vulgaris*) was planted in the second cropping season and corn (*Zea mays*) was planted in the third cropping season (Table 2). Crop residues of cabbage and tomato were removed while those of bean and corn were incorporated into the soil in conventional tillage and left on the soil surface in minimum tillage after harvest. The soil surface was covered by plastic mulch after organic matter application and removed after bean harvest.

In the experiment to investigate the possibility of substituting chemical fertilizer with organic matter, and to elucidate the effect of organic matter application and conservation tillage on SOC, 12 treatments were set up with three replications and a randomized block design. The treatments were the combinations of three factors, namely, organic matter application (0 mt/ha, 10 mt/ha and 20 mt/ha), chemical fertilizer application (NPK1 and NPK1/2), and tillage practice (CT and MT) (Table 3). N, P2O5 and K2O were applied as urea, superphosphate and potassium chloride, respectively. The amount of chemical fertilizer application in NPK1 (113.0 kg N/ha, 96.0 kg P2O5/ha, 120.0 kg K2O/ha) is the standard dosage recommended by the Indonesian Vegetable Research Institute for vegetable farmers in Lembang. Chemical fertilizer application of NPK1/2 is a half of the standard dosage (56.5 kg N/ha, 48.0 kg P2O5 kg/ha, 60.0 kg K2O/ha). Fertilizer applications were selected to provide consistent amount of nutrients assuming that only a part of nutrients in manure would be released in a cropping season. Horse manure was selected as a typical organic fertilizer available in the study area. Horses are used as common means of transportation in Lembang and it was easy for the farmers to get the necessary amount of horse manure for their farms from the horse owners. Horse manure was stored for around one month with occasionally mixing so that it could be matured as compost before application. Fertilizer was applied manually. All the manure and superphosphate were applied as base fertilizer. Half of the urea and potassium chloride were applied as base fertilizer and a top dressing. The base fertilizer was applied in the planting hole and the top dressing was applied on the soil surface.

Tillage practices used were conventional tillage (CT) and minimum tillage (MT). In the MT treatment, minimum tillage was introduced. The soil was undisturbed except for making planting holes for cabbage and tomato seedlings. In the planting of corn, no fertilizer was applied. The crops were planted during September 2011 to July 2013 (6 cropping seasons). The area of each plot was 10.8 m^2 (3m x 3.6m) with a distance of 70 cm between the plots. In each plot, 6 rows were prepared at an interval of 60 cm and 6 plants (cabbage), 5 plants (tomato), 11 plants (beans) and 10 plants (corn) were grown in a row. During the experiment, irrigation was carried out when plants were subjected to water stress (irrigated every one to four days when the soil surface looked dry) and pesticides were applied as per conventional methods recommended by the Indonesian Vegetable Research Institute.

Plant samples (above ground) were collected from each of the 12 treatments at the end of each cropping season. The cabbage samples from the outer edge of the plot were abandoned and 16 plant samples were collected from each plot. After removing the outer part of the cabbage head, the weight of plant samples were measured to calculate the commercial crop yield. The tomato, beans and corn samples were collected from each plot and only marketable crops were recorded as harvest. Corn was harvested in early stages as baby corn. Soil samples were collected from each of the 12 treatments before the experiment and after the corn harvest. The organic carbon content was determined by the Kurmies method (Fauzi et al. 2005).

Analysis of variance (ANOVA) and Tukey's test was carried out for the dataset of plants from the 12 treatments to investigate the effects of fertilizer application and crop management.

RESULTS AND DISCUSSION

Crop yields under the 12 treatments are shown in Table 4-7. Since cabbage was planted in the previous season in the experimental field, the cabbage yield in some plots was significantly lower in the first year due to the outbreak of clubroot disease, which is caused by *Plasmodiophora brassicae*. However, no serious clubroot outbreak was observed in the second year. The observation was matched with the previous study (Sugino et al. 2005), reporting crop rotations excluding Cruciferae for two or three cropping seasons (8 to 12 months) can prevent outbreaks of the disease. In the second year the yield was not significantly different among the treatments. Marketable tomato and bean yields were not significantly different among the treatments both in the first and second year planting. 20 mt/ha organic matter application significantly increased corn yield compared to 0 mt/ha organic matter application in the first year. In the second year, corn yield in the 20 mt/ha organic matter application was significantly higher than that of 0 mt/ha and 10 mt/ha organic matter application. The results suggested chemical fertilizer application for vegetable and corn cultivation can be substituted by organic matter without yield loss.

Application of organic matter at the rates of 10 mt/ha resulted in larger SOC changes compared to no organic matter application (Table 8). The MT treatment showed an increase in SOC than the CT treatment. However, both differences were not statistically significant. Katamine et al. (2000) reported that 20 years of continuous organic matter application (1,340 kg/ha organic carbon per cropping season, two cropping season a year) in an Andosol upland field in Tochigi Prefecture in Japan (annual temperature and precipitation is 13.4° C and 1,418 mm, respectively) increased SOC content by 1%. This amount of organic carbon application is slightly higher than the HM20 treatment (applying 20 mt/ha horse manure). Considering the higher annual temperature and precipitation in the present experimental field, the possible increase of SOC by organic matter application would be lower. Antle et al. (2002) reported that after improving soil management, the increase of SOC in the first two to five years is relatively slow but increases more rapidly after five years. It is difficult to observe significant increase of SOC within a two-year experiment.

In spite of the limited effects on SOC increase, the results of the experiment can be recommended as a practical farm management system to reduce GHG emission from vegetable production through reduced chemical fertilizer application while maintaining vegetable yield. It can also increase farmers' income by reducing chemical fertilizer cost, which accounts for the majority of the vegetable production cost of the farmers in the study area.

CONCLUSION

Half of the conventional chemical fertilizer application for cabbage, tomato, bean and corn can be replaced without any yield loss by applications of 10 mt/ha or 20 mt/ha of horse manure. Sugino et al. (2008) reported that cost for farm inputs, including chemical fertilizers, formed more than half of cabbage production cost in the study area. According to the observation by the authors, most of the local farmers already applied more than 10 mt/ha organic matter in their vegetable fields, and they applied more chemical fertilizer than the standard dosage. This observation indicates that since farmers already apply organic matter and a sufficient amount of chemical fertilizer, the reduction of chemical fertilizer may not affect vegetable yield, while the production cost will be reduced by less chemical fertilizer application. Horse manure is a useful alternative to chemical fertilizer. Application of organic matter at the rates of 10 mt/ha resulted in larger SOC changes compared to no organic matter application. The MT treatment showed higher increase in SOC than the CT treatment. Results of the experiment can be recommended as a practical farm management system to increase soil organic carbon while reducing chemical fertilizer application and hence maintaining the vegetable yield and also increasing farmers' income. Further observations are necessary to determine the effect of these practices on SOC and to propose a practical farm management system to increase SOC while maintaining crop yields and farmers' incomes.

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Table 1. General properties of the soil (Fauzi and Agus 2008)

Horizon*1	Depth (cm)	pH (H2O)	T-C (%)	T-N (%)	C/N	CEC cmol(+)*kg −1	Bulk density (g/cc) *2
Ap	0-28	4.5	6.18	0.37	17	23.77	0.39
Ah	28-45	5.2	8.03	0.38	21	42.29	0.39
Bth1	45-63	5.3	7.60	0.31	25	44.84	0.39
Bth2	63-87	5.3	6.50	0.21	31	32.65	N.A.
Bw1	87-112	5.3	2.26	0.17	13	23.63	N.A.
Bw2	112-140	5.4	2.50	0.19	13	33.74	N.A.
Bw3	140-230	5.5	2.47	0.21	12	26.51	N.A.
2Ah	> 230	5.0	5.97	0.17	35	34.70	N.A.

*1 A: A layer, B: B layer, p: Ploughing or other human disturbance, h: Accumulation of organic matter, t: alluvial accumulation of silicate clay, w: Development of color or structure. Arabic numeral suffixes mean subdivisions in the respective layers. Arabic numeral prefixes indicate discontinuities (FAO 2006).
*2 20-60cm

Table 2. Cropping pattern in the experiment field

Year	2011	2012								2013		
Month	Sep.	Jan.	Jan.	Apr.	Apr.	Jul.	Sep.	Dec.	Dec.	Mar.	Apr.	Jul.
Season	1st		2nd		3rd		4th		5th		6th	
Crop	Cabbage+ Tomato		Bean		Corn		Cabbage+ Tomato		Bean		Corn	

Table 3. Treatments in the field experiment

Code of Treatment	I. Organic matter	II. Chemical fertilizer	III. Tillage
LT1	HM0 (HM0mt/ha)	NPK1	CT
LT2	HM0	NPK1	MT
LT3	HM0	NPK1/2	CT
LT4	HM0	NPK1/2	MT
LT5	HM10 (HM10mt/ha)	NPK1	CT
LT6	HM10	NPK1	MT
LT7	HM10	NPK1/2	CT
LT8	HM10	NPK1/2	MT
LT9	HM20 (HM20mt/ha)	NPK1	CT
LT10	HM20	NPK1	MT
LT11	HM20	NPK1/2	CT
LT12	HM20	NPK1/2	MT

Note:
HM = Horse manure
NPK1 = 113.0kg N/ha, 96.0kg P_2O_5/ha, 120.0kg K_2O/ha (standard dosage)
NPK1/2 = 56.5 kg N/ha, 48.0 kg P_2O_5 kg/ha, 60.0 kg K_2O /ha (half dosage)
CT = Conventional Tillage, MT = Minimum Tillage

Table 4. Cabbage yield

	Cabbage			
	1st season		4th season	
Code of Treatment	Yield (kg/m2)*1	*2	Yield (kg/m2) *1	*2
LT1	3.414 (0.570)	a	1.662 (0.279)	a
LT2	5.424 (0.405)	ab	1.507 (0.563)	a
LT3	5.230 (0.492)	ab	1.185 (0.419)	a
LT4	6.428 (0.157)	b	1.791 (0.167)	a
LT5	4.496 (0.667)	ab	1.765 (0.212)	a
LT6	5.874 (0.302)	b	2.035 (0.297)	a
LT7	4.496 (0.372)	ab	0.857 (0.741)	a
LT8	5.333 (0.548)	ab	2.486 (0.222)	a
LT9	4.058 (0.507)	ab	1.907 (0.363)	a
LT10	5.681 (0.507)	b	1.881 (0.591)	a
LT11	5.797 (0.183)	b	1.778 (0.569)	a
LT12	5.926 (0.229)	b	2.319 (0.241)	a

*1: Means (Standard error)
*2: The data with the same letter in the same column are not significantly different (Tukey, $p<0.05$)

Table 5. Tomato yield

Code of Treatment	Tomato			
	1st season		4th season	
	Yield (kg/m2)*1	*2	Yield (kg/m2) *1	*2
LT1	2.378 (0.560)	a	5.120 (0.175)	a
LT2	2.612 (0.553)	a	4.619 (0.169)	a
LT3	2.138 (0.355)	a	5.777 (0.824)	a
LT4	2.073 (0.223)	a	5.435 (0.297)	a
LT5	2.875 (0.175)	a	5.072 (0.067)	a
LT6	2.430 (0.372)	a	5.314 (0.214)	a
LT7	2.359 (0.387)	a	5.515 (0.547)	a
LT8	1.970 (0.117)	a	4.325 (0.209)	a
LT9	2.394 (0.265)	a	4.973 (0.196)	a
LT10	2.677 (0.112)	a	5.401 (0.590)	a
LT11	2.667 (0.321)	a	5.125 (0.584)	a
LT12	2.888 (0.160)	a	5.175 (0.348)	a

*1: Means (Standard error)
*2: The data with the same letter in the same column are not significantly different (Tukey, p<0.05)

Table 6. Bean yield

Code of Treatment	Bean			
	2nd season		5th season	
	Yield (kg/m2)*1	*2	Yield (kg/m2) *1	*2
LT1	1.909 (0.123)	a	1.377 (0.101)	a
LT2	1.851 (0.045)	a	1.397 (0.012)	a
LT3	1.956 (0.068)	a	1.342 (0.047)	a
LT4	1.830 (0.014)	a	1.249 (0.076)	a
LT5	1.784 (0.036)	a	1.198 (0.025)	a
LT6	1.959 (0.021)	a	1.302 (0.045)	a
LT7	1.906 (0.091)	a	1.344 (0.059)	a
LT8	1.981 (0.079)	a	1.263 (0.107)	a
LT9	1.933 (0.063)	a	1.362 (0.050)	a
LT10	1.931 (0.009)	a	1.300 (0.062)	a
LT11	1.968 (0.134)	a	1.282 (0.047)	a
LT12	1.856 (0.094)	a	1.254 (0.086)	a

*1: Means (Standard error)
*2: The data with the same letter in the same column are not significantly different (Tukey, p<0.05)

Table 7. Corn yield

Code of Treatment	Corn			
	3rd season		6th season	
	Yield (kg/m2)*1	*2	Yield (kg/m2) *1	*2
LT1	1.574 (0.155)	a	0.704 (0.102)	a
LT2	1.679 (0.054)	a	0.716 (0.081)	a
LT3	1.870 (0.232)	a	0.537 (0.095)	a
LT4	1.383 (0.123)	a	0.636 (0.054)	a
LT5	1.519 (0.121)	ab	0.827 (0.012)	a
LT6	1.895 (0.062)	ab	0.840 (0.068)	a
LT7	1.827 (0.027)	ab	0.728 (0.073)	a
LT8	1.772 (0.138)	ab	0.790 (0.064)	a
LT9	2.019 (0.037)	b	1.025 (0.103)	b
LT10	1.907 (0.096)	b	1.019 (0.085)	b
LT11	1.821 (0.114)	b	1.000 (0.160)	b
LT12	1.759 (0.037)	b	1.037 (0.075)	b

*1: Means (Standard error)
*2: The data with the same letter in the same column are not significantly different (Tukey, p<0.05)

Table 8. Soil organic carbon (SOC) in the experiment fields

Code of Treatment	SOC before experiment (%) (1)	SOC 3rd season (%) (2)	SOC 6th season (%) (3)	SOC change 1st year (%) (2) - (1)	SOC change 2nd year (%) (3) -(2)	SOC change whole period (%) (3) - (1)
LT1	5.17	5.66	5.90	0.48	0.25	0.73
LT2	5.34	5.31	5.30	-0.03	-0.01	-0.04
LT3	5.54	5.65	4.88	0.10	-0.76	-0.66
LT4	5.32	5.53	6.17	0.21	0.64	0.85
LT5	5.23	5.51	5.69	0.28	0.18	0.46
LT6	5.16	5.66	6.56	0.50	0.93	1.42
LT7	5.12	5.36	5.85	0.24	0.48	0.73
LT8	5.22	5.73	6.16	0.51	0.43	0.94
LT9	5.38	5.65	5.73	0.27	0.08	0.35
LT10	5.42	5.78	5.70	0.37	-0.08	0.29
LT11	5.20	5.66	5.71	0.47	0.04	0.51
LT12	5.64	6.11	5.81	0.47	-0.30	0.17

Production and utilization of organic inputs using beneficial microorganisms

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ABSTRACT

Microbial inoculum is a blend of a multitude of beneficial microbes. It was mixed with molasses and maintained at low pH under ambient conditions. Results showed the effectiveness of beneficial microbes in diversified activities such as composting, crop production and bioremediation. The study revealed that the organic compost fermented with beneficial microbes has a very high percentage of 57.1% organic matter, 3.0% nitrogen, 8.70% phosphorous, and 5.2% potassium. There was an increase in the growth and yield performance of rice and corn when applied with BM organic inputs. The result on the chemical analysis of *Dioscorea* species showed that the fermented plant extracts were effective in the control of golden snails.

Also the enhanced BM Inoculant through the use of a natural carrier acted synergistically to produce useful compounds for agricultural and bioremediation applications. Results showed that immobilized BM inoculant with natural zeolite as biological carriers are very effective in reducing the ammonium-N concentration when applied in pig manure. The composted pig manure was found to be highly enriched with nitrogen, phosphorus and potassium based on results of the analysis on the NPK components of manure treated anaerobically with immobilized BM inoculant.

INTRODUCTION

Today the rapid increase in population and demand for food has initiated the intensive use of insecticides and pesticides. These toxic chemicals continuously pollute the environment and contribute to farm infertility. Conventional farming practices, which use chemical methods to kill both useful and harmful life forms indiscriminately, results in the malfunctioning of the food chain and food web. Bio-control is the best method to cope with the losses caused by chemicals. Insects, pests and pathogens are removed using biological methods without harming the environment and other organisms.

Biopesticides, also known as biological pesticides, are derived from natural materials including animals, plants, bacteria, and certain minerals. Biopesticides are less toxic and also reduce pollution problems caused by conventional pesticides. Another recommended measures for improving the economic feasibility of organic farming is the use of microbial inoculants. These inoculants consist of naturally occurring mixed cultures of beneficial microorganisms. Research has shown that microbial inoculant can improve soil quality and the growth, yield, quality and protection of crops.

The study was conducted to mass-culture beneficial strains of microoorganisms, conduct formulation studies on organic inputs using beneficial microbes, and perform efficacy tests on organic inputs using beneficial microbes in crop production and bioremediation.

METHODS

Mass culture of beneficial microorganisms

The microorganisms were obtained from the Philippine National Collection of Microorganisms (PNCM) central repository of microbial strains of BIOTECH at Los Banos, Laguna. These microorganisms were obtained in their natural state and grown on natural media.

Processing of the microbial inoculants

The microbial inoculants consisted of various strains of beneficial microbes and subsequently were refined to include four types of organisms commonly found in all ecosystems: lactic acid bacteria, yeasts, actinomycetes, and photosynthetic bacteria. They were blended in molasses with medicinal plants and fruit extracts and maintained at a low pH under ambient conditions.

Total count and evaluation of the microflora of the microbial inoculants were conducted at the National Institute of Molecular Biology at University of the Philippines Los Banos. The inoculants were submitted to the National Animal Disease Diagnostic Laboratory of the Bureau of Animal Industry for toxicity tests.

Production of organic inputs

Organic compost

The organic matter used in preparing the compost consisted of agricultural and household wastes. Molasses was dissolved in water at a ratio of 1:10. All the ingredients were mixed thoroughly. The microbial inoculant was added into the prepared solution. This was poured on the organic substrates. The mixture was fermented for 7- 14 days either by aerobic or anaerobic methods.

Organic pesticide

This was prepared by using chopped fresh weeds and medicinal plants that were fermented with microbial inoculant. Various plants were used to increase the bioactive substance and microbial density.

Immobilization and stability assessment of BM Inoculant

Mixed culture of BM inoculants was coated onto zeolite. Samples of culture were immobilized with and onto zeolite and stored at ordinary room temperature in open and closed containers.

Efficacy test of the organic inputs

BM derived compost and organic pesticide were applied to crops to determine their growth and yield performance. The effects of enhanced BM inoculants as a bioremediation agent were tested in the degradation of ammonia-N in pig wastes.

RESULTS AND DISCUSSION

Total count and evaluation of microflora

A microbiological assay was conducted, which included bacterial and fungal counts of microbial isolates. Table 1 shows that the liquid inoculants contain large amounts of bacteria followed by fungi.

Chemical analysis of organic compost

The properties of the processed organic compost is shown in Table 2. Results revealed that the organic compost fermented with beneficial microbes has a good percentage of organic matter, C, N, P, K, and Mg, which can enhance plant growth and soil humus formation.

Pesticidal property of *Dioscorea* species fermented with beneficial microorganisms

The pesticidal properties of the *Dioscorea* species is shown in Table 3. The qualitative studies conducted revealed that all the plant species are positive for saponin and tannin. Also the two species, *Dioscorea hispida* and *Dioscorea alata,* were positive for alkaloids. It was reported that dioscorene was a toxic component of *Dioscorea hispida* while *Dioscorea alata* contained glucoside.

Efficacy test of fermented *Dioscorea e*xtracts

Table 4 shows that all the *Dioscorea* extracts fermented with microbial inoculant were effective in the control of golden snails. It was clearly revealed that *Dioscorea alata* (ubi) was the most effective in the control of golden snails with a percentage mortality rate of 68% three days after spraying; 72% four days after spraying and 81.33% five days after spraying. The toxic effects of the fermented extracts can be attributed to the presence of alkaloids and glucoside, which are further enhanced by the enzymatic activity of the beneficial microbes.

Growth and yield performance of crops using organic compost fermented with beneficial microorganisms

Table 5 shows the growth and yield performance of rice as affected by the applications of fertilizer. It is revealed that the application of 50% inorganic and 50% organic fertilizer showed high performance of rice and corn in terms of yield, grain weight and height. The application of 100% organic is comparable to 100% inorganic. Table 6 shows that corn applied with 50% inorganic and 50% organic performed well in terms of plant height, length and diameter of cob, weight and yield. The application of 50% inorganic is comparable to 50% organic.

Efficacy of microbial inoculant in the treatment of pig wastes

Table 7 shows the result of the ammonium-N concentrations on the pig manure treated with immobilized BM inoculant during a 1 to 2 week period of treatment. Untreated pig manure exhibited a very high ammonia-N concentration. The anaerobically processed immobilized BM inoculant recorded a very high ammonia-N degradation from 50.0 mg/kg to 6.0 mg/kg during the treatment period. The aerobic type immobilized BM inoculant also exhibited ammonia-N reduction of 66.33 mg/kg during the 1 week period of treatment. The untreated pig manure showed a very high ammonia-N concentration of 482.50 mg/kg compared to the other treatments. Results showed that immobilized BM inoculant with natural zeolite as biological carriers are very effective in reducing the ammonium-N concentration when applied in pig manure.

The most important property of zeolites is the removal of ammonia (NH3) and ammonium (NH4+). Zeolites remove ammonium ions by means of ion-exchange and, at higher concentration, adsorption. The ammonium ions present in pig manure are exchanged for sodium ions. The dynamic capacity of zeolites for ammonium is about 0.9 meq/g. If there are a number of different cations present in the wastewater, the adsorption capacity per ion will be lower as a consequence of competition between the different cations. The adsorption will depend on relative selectivity of zeolites for the different ions, the composition of water and the temperature. The relative selectivity is determined by the hydrated diameter, the charge and the mobility of the ions (Lefcourt and Moises-Meisinger 2001).

NPK and ammonia-N concentrations of immobilized BM inoculants (anaerobic) 2- week treatment

The composted pig manure was found to be highly enriched with nitrogen, phosphorus and potassium based on the result of the analysis on the NPK components of the pig manure treated anaerobically with immobilized BM inoculant. Also, there was a high ammonium degradation after 2 weeks of treatment. The synergistic effects of BM inoculant and zeolite was responsible for the degradation of ammonia. This result was confirmed based on the findings of Bernal et al. (1993) who composted anaerobically swine manure using zeolite within 3 days and significantly reduced airborne noxious odor. Also the compost qualified as organic fertilizer for use in crop production.

CONCLUSION

This study showed the effectiveness of beneficial microbes in diversified activities such as composting, processing of biopesticides, crop production and as bioremediation agents. The inoculant consists of bacteria as the major component, fungi and yeast. Other ingredients are molasses, medicinal and aromatic plants.

The compost prepared by beneficial microbes was three to six times faster than the traditional methods of composting and was found to have a good percentage of organic matter.The application of organic compost fermented with beneficial microbes improved the growth and yield performance of crops such as rice and corn, thereby increasing farm productivity. Microbial fermentation enhanced the bioactive components of the three species of *Dioscorea*, which can be used as an organic molluscide in the control of golden snails.

The immobilization of BM inoculants have been conducted to provide a dependable source of beneficial microorganisms that can survive in the soil and become available to the plant and also to provide an active biological agent in bioremediation.

The removal of ammonia in pig wastes applied with immobilized BM inoculants was remarkable considering the short period of treatment. The level of ammonia-N was greatly reduced from 50 mg/kg to 6 mg/kg. Further, the zeolite acts as a buffer for ammonium ions.

In case of a large ammonia production, part of the ammonia is adsorbed by zeolite and if the ammonia concentration is low, the bacteria metabolize part of the adsorbed ammonium. This was indeed a breakthrough in bioremediation.

It was clearly shown that the pig manure treated with immobilized BM inoculant with zeolite as carrier was found to be highly enriched with nitrogen, potassium and phosphorus.

The beneficial microbes can perform many functions that affect crop production, animal husbandry and environmental protection. This technology holds a promising future in the modern world, which is conscious of the environment, promotes eco-friendly and sustainable organic agriculture, and strives to achieve food security by preserving soil productivity and health.

RECOMMENDATIONS

More studies should be done on the formulation process, especially bacterial survival as affected by several variables: the culture medium used for bacterial cultivation, the physiological state of the bacteria when harvested from the medium, the process of cell encapsulation, the use of protective materials, the type of drying technology used, and the rate of dehydration. An on-farm demonstration should be conducted along with training and extension to showcase the technology and its effective action in the biodegradation of ammonia-N from poultry and pig manure. Application periods should be longer to totally eradicate the ammonium-N concentration. Further research should be undertaken on other possible applications of the formulated products.

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Table 1. Microbial Plate Count of Inoculant

Total Count	Mean	Rank
	CFU/ml	
Bacteria	5.40×10^8	1
Fungi	1.28×10^7	2
Yeast	<10	3
TOTAL COUNT	4.25×10^6	

Table 2. Chemical analysis of organic compost

Parameters (%)	Value
pH	7.2
Organic matter	57.1
Carbon	28.0
Nitrogen	3.0
Phosphorus	8.7
Potassium	5.2
Magnesium	0.3
C/N ratio	63.0

Table 3. Qualitative Analysis- presence of alkaloids in Dioscorea species

	***Dioscorea hispida* (nami)**	***Dioscorea fasciculata* (tugue)**	***Dioscorea alata* (ubi)**
Alkaloid	+ Dioscorene	**+**	**+** Glucoside
Isocyanide	_	_	_
Saponin	+	+	+
Tannin	+	+	+

Table 4. Summary of treatment means on the percentage mortality of golden snails

	Mortality rate (%) (Days of application of extracts)		
Treatments	3 days	4 days	5 days
T1= 250g ubi + 250 ml water	6.67	10.67	10.33
T2= 250g ubi + 250 ml alcohol	13.33	22.67	26.67
T3= 250g ubi + 250 ml fermented ubi	68.00a	72.00a	81.33a
T4= 250g tugue +250 ml water	17.33	30.67	36.00
T5= 250g tugue + 250 ml alcohol	30.67	47.67	69.33
T6= 250g tugue + 250 ml fermented tugue	42.67	40.00	74.67
T7= 250g nami + 250 ml water	38.67	36.00	42.67
T8= 250g nami + 250 ml alcohol	44.00	49.33	58.67
T9= 250g name + 250 ml fermented name	36.00	46.67	57.33

Table 5. Growth and yield performance of rice as affected by the application of fertilizers

Treatments	Height (cm)	1000 grain weight (g)	Yield (kg/h)
T1 – 100% Inorganic	78.90a	22.69b	5922b
T2 - 50% Inorganic + 50 Organic	73.30b	24.00a	6141a
T3 – 100% Organic	70.50c	23.83b	5756b

Table 6. Growth and yield performance of corn as affected by the application of fertilizers

Treatments	Plant height at maturity	Length cob (cm)	Diameter cob (cm)	Weight 1000 seeds/ treatment	Yield tons kg/ha
T1 – 100% Inorganic	198.00b	17.65b	5.48a	307b	7.12b
T2 - 50% Inorganic + 50% Organic	202.00a	19.72a	6.10a	417a	8.05a
T3 - 100% Organic	201.00a	19.33a	5.50a	400a	7.31b

Table 7. Ammonia- N concentrations (mg/kg) of untreated and treated pig manure after 1 week of application

Treatments	Mean
T0 - Control (untreated)	482.50
T1 – Treated with immobilized BM (anaerobic)	50.0
T2 – Treated with immobilized BM (aerobic)	66.33

Table 8. Results of analysis of immobilized BM inoculants (anaerobic) 2 weeks after treatment

UNITS (mg/kg)		MDLs
Total Nitrogen	1,440	140
Total Phosphorus	46,900	1250
Total Potassium	4,150	20
Ammonia-N	**247**	**6.0**

Adoption, yield and profitability of tomato grafting technique in Vietnam

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ABSTRACT
This paper assesses the impact of AVRDC's tomato grafting approach on yield and farm profitability in Lam Dong province and Red River Delta, Vietnam. Tomato grafting is advantageous to farmers suffering from soil-borne disease and abiotic stresses. However, there is scanty information on the extent of knowledge on adoption studies of tomato grafting technology in Vietnam. Based on a farm household survey conducted in August 2012, this paper provides detailed assessment of the adoption and profitability of introducing tomato grafting in the two study areas. Results indicate a 100% (n=225) adoption in Lam Dong province, and a 48% (n=36) adoption in the Red River Delta. The use of rootstock varieties differs in both locations to address location-specific agronomic challenges: tomato variety 'Vimina' (or HW7996) to address bacterial wilt (BW) problem, and eggplant EG203 variety in the Red River Delta to address both BW and waterlogging problem. Estimates from a Cobb-Douglas production function show that tomato grafting increases yield by 30% based. Marketable yield of grafted tomato was significantly larger (71.3 t/ha in Lam Dong Province and 75.0 t/ha in Red River Delta) than nongrafted (48.0 t/ha in Red River Delta). The benefit-cost ratio of grafted tomato production was higher compared to non-grafted due to increased yield and higher premium price. Nonetheless, further validation studies are required, considering the relatively small sample size in the Red River Delta and the high variability of some parameters.

Keywords
AVRDC, vegetable grafting, farm productivity, farm profitability, Cobb-Douglas production function, bacterial wilt, Vietnam,

INTRODUCTION OF TOMATO GRAFTING IN VIETNAM
Tomato (*Solanum lycopersicum*) is one of the important crops in Vietnam. However, during the hot-wet season, its yields are low due to poor fruit setting caused by high temperatures and high incidence and severity of disease , particularly bacterial wilt caused by *Ralstonia solanacearum* (Doan and Nguyen 2005; Nguyen and Ranamukhaarachchi 2010). Bacterial wilt (BW) has been reported in all eight administrative regions of Vietnam in varying degrees of severity. It is usually more

severe during the wet season (April-October) than during the drier months (November-March) (Tung 1985; Vinh and Ngo 2006), and can lead to 100% yield loss (Afari-Sefa 2012). Prior to the 1990s, the Red River and Mekong River deltas did not have problems with bacterial wilt in crop production during the drier months (Tung 1985). However, in the mid-1990s, Dung (1997) found that bacterial wilt had become prevalent all year-round especially in Hanoi and the adjacent areas. In Ho Chi Minh City, the rapid expansion of vegetable cultivation including tomato, eggplant and pepper, which are all highly susceptible to the disease, contributed to BW's vigorous proliferation. Farmers also have few options for managing BW once the soil is infested with the bacterium (Wang and Lin 2005). Disease-resistant varieties can be overcome by the pathogen due to its genetic diversity and complex genotype-environment interactions. Likewise, the usefulness of crop rotation becomes limited due to the pathogen's wide range of host plants (Nguyen and Ranamukhaarachchi 2010). Chemical control of soil-borne diseases is also costly and usually unsuccessful (Lin, Hsu, Tzeng and Wang, 2008).

Tomato grafting is an alternative crop management strategy to control BW, root-knot nematode (caused by *Meloidogyne incognita*) and tomato Fusarium wilt (caused by *Fusarium oxysporum* f.sp. *lycopersici*) when high-yielding resistant tomato varieties are unavailable (Wang and Lin, 2005). It combines a flood- and bacterial wilt-resistant rootstock with a high-yielding tomato scion (Aganon, Mateo, Cacho, Bala and Aganon 2002).

AVRDC – The World Vegetable Center started working on tomato grafting in 1992 and introduced the technique to Vietnamese scientists in September 1998 during a one-month training course at AVRDC headquarters in Taiwan. The technique uses the tube splice method, and is elaborately explained in the AVRDC International Cooperator's Guide "Grafting Tomatoes for Production in the Hot-Wet Season" (Black, Wu, Wang, Kalb, Abbass and Chen 2003). It recommends the use of AVRDC BW-resistant varieties *Solanum lycopersicum* 'Hawaii 7996' and *Solanum melongena* 'EG203', coupled with ideal sowing schedule, grafted seedlings and field management activities (e.g., raised beds and shelters, transplanting depth, sucker and adventitious root removal, staking and pruning, pest and water management). From 2002-2006, the technique was disseminated in Lam Dong province (southern Vietnam) in collaboration with the Potato, Vegetable and Flower Research Center (PVFC) under the Institute of Agricultural Sciences for Southern Vietnam (IAS), and to the Red River Delta (northern Vietnam)[1] in collaboration with the Fruit and Vegetable Research Institute (FAVRI) in Hanoi.

Objectives of the study

This paper summarizes some of the findings of a recent study[2] (Genova, Schreinemachers and Afari-Sefa, 2013) conducted by AVRDC which assessed the pattern of adoption, yield and profitability of tomato grafting ten years after its dissemination to Vietnamese farmers in 2002. As this study is based on a cross-sectional data, this paper will not analyze the dynamics of technology adoption nor the impact of tomato grafting on the well-being of farmers nor on the distributional effects. To the best of our knowledge, there are no previous studies on the adoption of

[1] These terms will be used interchangeable in the text: Lam Dong province refers to south or southern Vietnam, and Red River Delta, north or northern Vietnam.
[2] Copy of the full report (Genova et al. 2013) can be downloaded at http://203.64.245.61/fulltext_pdf/EB/2011-2015/eb0205.pdf

tomato grafting in Vietnam or on the dissemination of the proposed tomato grafting technique.

METHODS

The data used for the analysis in this study is based on a field survey conducted by AVRDC in collaboration with local partners, FAVRI and PVFC in August 2012.

The survey covered two major tomato growing regions: Lam Dong province in the south and Red River Delta in the north. These sites were selected by the national collaborators at FAVRI and PVFC. A total of 300 tomato growers were interviewed, 75 respondents (representing 25% of the total sample) from the north and 225 respondents (representing 75%) from the south. The sample size and regional distribution were pre-determined based on the estimated population of tomato farmers, relative importance of grafted tomato in each region, and time and resources available. The agricultural extension officers in Lam Dong province and FAVRI staff, assisted by the commune leaders, provided the main tomato-producing provinces, districts and communes, and the list of tomato farmers in each selected production area. Compiling the list of tomato farmers in both locations proved a daunting task given the time constraints and the challenges faced in identifying tomato farmers; it is therefore likely that the total 1,440 tomato farmers in both regions is an underrepresentation. A two-stage stratified random sampling was used to identify the sample units, i.e. farm households. Areas were stratified by district and by commune in Lam Dong province; and by province, district and commune in the Red River Delta. Tomato growers were allocated across the provinces/districts/communes so that the proportion of farmers sampled for each district/commune is identical to the proportion of farmers in each district/commune in the total population (Table 1).

Information on farmers' production practices, input and output regimes, costs and revenues, and other factors related to tomato cultivation from their most recent production cycle were collected using a semi-structured questionnaire. Detailed data on farm assets, rootstock and scion varieties used, inputs used (quantities, price per unit, family and hired labor), crop outputs and revenue (production distribution, market price per kilogram), changes in crop management practices following the adoption of grafting, pest and disease management, marketing information, training and extension needs, and household income and welfare indicators were gathered, as well as household's socioeconomic information, and their perceptions on the use of grafting in growing tomato.

Profitability analyses

Sources of material inputs, prices per unit, quantities/number of units purchased, and labor were collected for the 2011/2012 production season (farmer's immediate production cycle). In this paper, total operational cost is based on these two cost items. Material inputs consist of seed/seedling cost, animal manure/compost, inorganic fertilizers, fungicides, insecticides, agrochemicals, mulching materials, irrigation/watering costs, staking, harvesting/marketing costs, fuel (transport) and other costs (e.g. rent, etc.). The total cost per input was calculated by multiplying price per unit and quantity/number of units bought and aggregated to arrive at total input costs per respondent.

The following field activities comprise the labor component: land preparation, direct seeding/transplanting, mulching, weed control application, staking, chemical fertilizer application, manuring/composting, pesticide application, watering/irrigation, harvesting, packing/transportation, and other marketing activities. Total person-days of both family and hired labor were aggregated and multiplied with the daily wage rate for nongrafted and grafted tomato cultivation per respondent to arrive at total labor cost. In Lam Dong province, the average daily wage rate was based on the range of values provided by each respondent. Observations with missing values were replaced with the computed average daily wage rate by village, sub district, district or province. The 2011/2012 daily wage rate for an adult farm worker in the Red River Delta was around US$0.41-7.7 per person-day for nongrafted; US$4.3-7.2 per person-day for grafted; and US$2.9-7.2 per person-day for grafted tomato cultivation in Lam Dong province.

Gross income is equivalent to sales. It was calculated by multiplying the marketable crop yield and the produce's selling price. Gross margin was computed as gross income less total variable (i.e., operating costs including material and hired labour) for that reference season. Means, standard deviations and t-tests were computed using STATA version 11 Econometric software package. Extreme values and outliers were excluded in the multivariate regression estimates l using Cook's distance (D) conventional cutoff point of 4/306 (4/n where n is the number of observations).The Cook's D is one of the commonly used measures of test of outliers, wherein it measures the influence of individual cases by looking at the amount of change in the regression coefficients when a particular case is excluded from analysis (Norusis, 2003; Cousineau and Chartier, 2010). The farther it is from zero, which is the lowest value that it can assume, the more influential the point is. In total, 42 out of 321 observations were dropped (15 with missing data in one of the regressors and the rest recognized as influential).

Cobb-Douglas production function

A Cobb-Douglas production function was used to empirically assess the relative influence of grafting technique and other input variables on tomato yield (not marketable yield). The general expression of the Cobb-Douglass functional form is:

$$Y = AL^{\beta}K^{\alpha} \tag{1}$$

where Y is total production (endogenous or dependent variable); L is labor input; K is capital input (L and K are the exogenous or independent variables); A is the total factor productivity; and α and β are the output elasticities of capital and labor, respectively. The model can be linearized as:

$$lnY = \alpha + \sum_{j=1}^{n} \alpha_j \ln(X_{ij}) + e_i \tag{2}$$

where Y_i denotes the yield of the *i*th farmer, X_{ij} the vector of *j*th input used in the *i*th farm in the production process, α_i represents coefficients of inputs which are estimated from the model (α is a constant term), and $e_i$is the error term of the *i*th farm. The α_j is the set of parameters to be estimated that reflect the impact of change on yield given a change in the levels of each input, *ceteris paribus*. This implies an ideal division of yield due to each factor input of production (e.g., seed, fertilizer, labor).

Tomato yield (dependent variable) was assumed to be a function of seed, manure and inorganic fertilizer, fungicide, insecticide, mulching, irrigation, staking, other input costs, labor and three dummy variables (the use of grafting, regional difference, and pest/disease severity) as independent variables. A dummy variable for the use of grafting was included to evaluate the impact of tomato grafting. A location dummy was furthermore included to capture yield variation between the agro-climatic conditions in the two different locations. A pest/disease severity dummy variable was also included because previous studies have shown that insecticide/fungicide productivity is underestimated if pest/disease severity is not specified in the production function (Norwood and Marra 2003). The linearized model has been specified as:

$$lnYIELD = \beta_0 + \beta_1 lnseed + \beta_2 lnma\_fe + \beta_3 lnfung + \beta_4 lninse + \beta_5 lnmulc + \beta_6 lnirri + \beta_7 lnstak + \beta_8 lnag\_oth + \beta_9 lntomdha + \beta_{10} GT\_NGT + \beta_{11} loc\_n + \beta_{12} mode + e_i \quad (3)$$

where:

LNYIELD	Yield level of the *i*th farmer
LNSEED	Natural log of seed/seedling expenditures
LNMA_IFE	Natural log of manure and inorganic fertilizer expenditures
LNFUNG	Natural log of fungicide expenditure
LNINSE	Natural log of insecticide expenditure
LNMULC	Natural log of mulching expenditure
LNIRRI	Natural log of irrigation expenditure
LNSTAK	Natural log of staking expenditure
LNAG_OTH	Natural log of other expenditures
LNTOMDHA	Natural log of labor
GT_NGT	Dummy variable: =1 if grafted, =0 nongrafted
LOC_N	Dummy variable: =1 if Lam Dong province (south), =0 Red River Delta (north)
MODE	Binary pest severity variable: =1 if less severe, =0 otherwise

Three alternative models were estimated for both locations combined (Model 1), and separately for Lam Dong province (Model 2) and the Red River Delta (Model 3).

RESULTS

Adoption pattern and main varieties used

Adopter is defined as a user of the technique whether past or present. Genova, et.al. (2013) found a 100% adoption rate in Lam Dong province and 48% in the Red River Delta. Varieties used for the grafted transplants differ in each location (Table 2). In Lam Dong province, the common rootstock-scion combination was 'Vimina' and *S. lycopersicum* 'Anna F1' (a hybrid variety of Monsanto). The use of 'Vimina' resulted from IAS' testing for bacterial wilt resistance in 2002/2003 and was subsequently released after evaluation starting in 2004 (Ngo QuangVinh, personal communication, November 7, 2012). In the Red River Delta, challenges to rootstocks posed by waterlogging necessitated the use of *S. melongena* 'EG203' paired with *S. lycopersium* 'Savior' (a hybrid variety of Syngenta). These popular scion varieties were selected by farmers due to their high yield performance, good appearance, popularity among consumers, and higher number of fruits harvested.

Farmers purchased almost all seedlings for rootstocks and scions from specialized nursery operators in Lam Dong province. In the Red River Delta, about 61-67% of 'EG203' and 'Savior' came from FAVRI, with the rest sourced from farmer groups and specialized nurseries. It appears that specialized nurseries are not as common in the Red River Delta as in Lam Dong province. One reason could be the economies-of-scale advantage FAVRI has in the sale of rootstock and scion seedlings, which may have prevented the entry of more specialized nurseries in the delta. Also, grafting is a newly accepted farm production technique in the delta with only 48%

farmers using the technique. Setting up these specialized nurseries is knowledge- and capital-intensive and individuals will only invest if proven profitable and huge demand exists.

Yield and profitability of grafted tomato

The average marketable yield of grafted tomato was 71.3 t/ha in Lam Dong Province and 75.0 t/ha in Red River Delta (Table 3). Comparing the performance of grafted tomato in terms of average selling price, gross income and total operational costs in the two locations, all values were significantly higher (p<0.001) in the north. The average selling price in the north was twice than that in the south. Similarly, the total mean operational cost in the Red River Delta was significantly higher, mainly due to high seedling (p=0.008), staking (p=0.000) and labor costs (p=0.000). Seedling cost was also significantly more expensive (p<0.001) in the north at US$ 0.07 per plant versus US$ 0.03 per plant in the south. These results however should be interpreted with caution due to the small number of observations found in the Red River Delta and the high variability of some parameters.

Assessing the profitability performance of grafted versus nongrafted tomato was done only for the Red River Delta due to the 100% adoption in Lam Dong province. Results show significant differences among a number of parameters between grafted and nongrafted tomato in the north. For one, the mean yield and selling price of grafted tomato transplants were significantly higher (p=0.0025) by 56% and 64%, respectively, than nongrafted (Table 4). This resulted in a much larger gross income amounting to US$31,300 per ha for grafted tomato as compared to US$11,537 per ha for nongrafted (p=0.000). However, grafted tomatoes were also more costly to produce, requiring significant amounts of inputs such as seedlings (additional costs of the rootstock, p=0.000), mulching materials (nylon and rice straws, p=0.012) and labor (p=0.010), leading to a higher (p=0.0023) total operational costs. For instance, grafted seedling cost was higher (p=0.000) by US$0.05 per plant than nongrafted transplant.

Nevertheless, because of the significantly higher gross income, farmers using grafted tomato earned US$12,878 per ha more than nonadopters. Based on these results, the benefit-cost ratio was 2.23 for grafted tomato compared with 1.76 for nongrafted tomato, which means that adopters can expect US$2.23 for every US$1 in cost. Further research would be useful to generalize these results for the whole of the Red River Delta, given the small sample size of the nonadopter group. In general, the major cost items in grafting that comprised more than 50% of total operational costs were seedlings, labor, staking and manure and inorganic fertilizers.

Factors affecting tomato yield

Results from the regression analysis show that the coefficients for seedlings, fungicide, insecticide, mulching, labor (person day per hectare [MD/ha]) and grafting are highly significant (p<0.01) for Model 1. A 100% increase in input use would increase yield by 4% for fungicides, 2% for insecticides, 1% for mulching, 9% for labor and 30% for the use of grafting. Increasing seedling expenditures by 100% would result in a yield reduction of 1%. The model shows a decreasing returns to scale of 0.403 (p<0.01) as suggested by the sum of regression coefficients.

Although location was not significant in Model 1, differences between the two locations were observed by comparing Models 2 and 3. In Lam Dong province (Model 2), seed and insecticide costs were found to be highly significant (p<0.01). A 100% increase in seed expenditures corresponded to a 28% increase in yield of grafted tomato. The effect of insecticide use on yield was small at only 1.5% change for a 100% change in insecticide use. In the Red River Delta (Model 3), the impact of grafting on yield was highly significant, as was the expenditure on seedlings, fungicides, insecticide, mulching, and the use of labor. Controlling for all other factors, the use of grafted seedlings led to a 31% increase in yield ($p<0.01$). However, since grafting was relatively new in Red River Delta, a 100% change in seedling expenditures would lead to a 1.3% reduction in yield ($p<0.01$). This could be due to a number of reasons, including low grafted seedling survival rate due to laborers' lack of grafting experience; poor handling of grafted seedlings after purchase and prior to transplanting; and improper field management practices such as graft joints planted below the soil or farmers' failure to remove suckers, which defeat the purpose of grafting. A 100% increase in the use of other inputs in the specified model resulted in a significant ($p<0.05$) increase in yield of 4% for fungicides, 2% for insecticides, 1% for mulching and 6% for labor.

The results from Models 1 and 3 suggest that the use of grafting provides statistically significant yield improvement over the use of nongrafted seedlings. The estimates also suggest that the marginal effect of fungicides, insecticides, and mulching on tomato yields is lower for grafted than for nongrafted tomato. This is consistent with the idea that applying fungicide, insecticide and mulching is redundant when a technology that inherently controls for bacterial wilt, nematodes and other soil-borne diseases is already being used; grafting therefore substitutes for fungicide use as it controls Fusarium wilt.

CONCLUSION

This paper provides a baseline reference of farmers who adopted AVRDC's grafting technique, the case of Vietnam. It shows that in places where bacterial wilt and other soil-borne diseases affecting tomato are a problem, tomato grafting offers very significant monetary benefits to farmers. Mean marketable yield and selling price of grafted tomato transplants are significantly higher ($p=0.0025$) than nongrafted tomato. The Ministry of Agriculture and Rural Development, in partnership with FAVRI, should set up more field demonstration experiments in areas with high bacterial wilt infestation in the Red River delta to encourage more farmers to use the technique vis-à-vis the observable and tangible results from on-site demonstrations. This serves a dual purpose: a) it does not only increase farmers' yield due to the reduction of BW incidence, b) it also accelerates the entry of more specialized nurseries in the area that could potentially drive down the current grafted seedling price of US$ 0.07 per plant closer to the US$ 0.03 per plant in Lam Dong province. Nonetheless, further studies would be useful considering the relatively small sample size in the Red River Delta and the high variation observed for some of the variables. A full cost-benefit evaluation of grafting and non-grafting operations in the Red River Delta as well as an in-depth adoption study of grafting in Lam Dong province could be an ideal follow-up research project to validate the results of this paper now that we have seen the difference in the two locations.

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Table 1. Proportionate stratified sampling by location in Vietnam

Province/District/Commune	Population		Proportionate stratified sample	
	Frequency	*%*	*Frequency*	*%*
Number of tomato growers	**1,440**	**-**	**300**	**-**
Lam Dong province				
a. Communes in Don Duong district				
Da Ron	169	21.9	39	21.9
D'ran	96	12.4	22	12.4
Ka Do	131	17.0	30	17.0
P'ro	101	13.1	23	13.1
Tutra	63	8.2	15	8.2
Lac Xuân	212	27.5	49	27.5
Sub-total	**772**	**100.0**	**178**	**100.0**
b. Communes in DucTrong district				
Lien Nghia	36	17.8	8	17.8
HiepThạnh	14	6.9	3	6.9
GiaChanh	10	4.9	3	4.9
Phu Hoi	69	34.2	16	34.2
Tan Hoi	46	22.8	11	22.8
Tan Thanh	27	13.4	6	13.4
Sub-total	**202**	**100.0**	**47**	**100.0**
Red River Delta				
a. BacNinh province	18	3.9	3	3.9
b. Hai Duong province	97	20.8	16	20.8
c. Nam Dinh province	241	51.7	38	51.7
d. VinhPhuc province	100	21.5	16	21.5
e. Ha Noi province	10	2.1	2	2.1
Sub-total	**466**	**100.0**	**75**	**100.0**

Source: Survey conducted by AVRDC in collaboration with FAVRI and PVFC (2012), n=300.

Table 2. Main rootstock varieties used in each location

Variety	Description	Reason	Price (US$/seedling)	Source
Solanum lycopersicum 'Vimina' ('Hawaii 7996')	main rootstock variety used in Lam Dong province commonly paired with Monsanto hybrid *S. lycopersicum* 'Anna' F1 (scion)	to protect from soil-borne diseases (caused by fungi, bacteria, nematodes) and other diseases	0.03	private nurseries
Solanum melongena 'EG203'	main rootstock variety used in Red River Delta commonly paired with the Syngenta *S. lycopersicum* 'Savior 1' (scion)	to protect from soil-borne diseases and help control excess moisture (waterlogging)	0.07	FAVRI

Source: Survey conducted by AVRDC in collaboration with FAVRI and PVFC (2012), n=300.
Note: US$1=VND20,703.4.

Table 3. Sample means of marketable yield, material inputs and labor costs of grafted tomato production in Lam Dong province and Red River Delta, 2011/2012 (US$/ha)

Variable	*Lam Dong province (n=215 obs)*		*Red River Delta (n= 16 obs)*		*Total (n=231 obs)*		*P-value*
	Mean	*SD*	*Mean*	*SD*	*Mean*	*SD*	
Seedling cost (US$/plant)	0.03[c]	0.01	0.07[c]	0.01	0.03	0.02	0.0000
Marketable yield (t/ha)	71.27	16.96	74.99	29.37	71.52	18.03	0.6231
Ave. selling price (US$/kg)	0.19[c]	0.15	0.41[c]	0.12	0.20	0.16	0.0000
Gross income	**13,138.2[c]**	**10,902.9**	**31,300.5[c]**	**15,683.3**	**14,396.2**	**12,165.7**	**0.0003**
Material input:	5,881.1	10,761.6	8,499.7	4,314.8	6,062.5	10,460.1	0.0528
Seedling	956.4[b]	198.1	1,863.9[b]	1,184.3	1,019.2	425.8	0.0079
Manure and inorganic fertilizer	1,585.3	767.4	2,060.1	2,380.1	1,618.2	965.4	0.4389
Fungicide	707.8	392.0	748.9	925.2	710.6	446.0	0.8619
Insecticide	247.1	419.5	359.3	618.1	254.8	435.3	0.4853
Mulching	379.1	261.2	389.7	370.9	379.9	269.2	0.9121
Irrigation	157.7	513.2	251.6	1,006.3	164.2	558.3	0.7167
Staking	913.7[c]	553.0	2,325.8[c]	987.3	1,011.5	690.8	0.0000
Other inputs	934.0	10,668.0	500.4	1,746.6	904.0	10,300.5	0.6101
Labor cost:	1,853.2[c]	791.5	7,151.2[c]	3,795.6	2,220.1	1,827.5	0.0001
Labor (person-days/ha)	331.1[c]	138.4	1,314.2[c]	633.1	399.2	326.4	0.0000
Total operating costs	**7,734.3[c]**	**10,791.7**	**15,650.8[c]**	**7,003.9**	**8,282.6**	**10,752.5**	**0.0004**

Source: Survey conducted by AVRDC in collaboration with FAVRI and PVFC (2012), n=231 observations. Notes: Values are based on 2011/2012 prices; other inputs include agrochemicals; T-test uses Welch's approximation due to small sample size in one group; Level of significance is denoted by a) p<0.05, b) p<0.01, c) p<0.001; US$1=VND20,703.4.

Table 4. Sample means of inputs, outputs and prices of grafted and non-grafted tomato production in Red River Delta, 2011/2012 (US$/ha)

Variable	*Grafted (n= 16 obs)*		*Non-grafted (n= 48 obs)*		*P-value*
	Mean	*SD*	*Mean*	*SD*	
Seed/seedling cost (US$/plant)	0.07[c]	0.01	0.02[c]	0.02	0.0001
Marketable yield (t/ha)	74.99[b]	29.37	47.98[b]	17.68	0.0025
Average price (US$/kg)	0.41[c]	0.11	0.25[c]	0.09	0.0001
Gross income	**31,300.50[c]**	**15,683.34**	**11,536.93[c]**	**5,703.23**	**0.0001**
Material inputs:	8,499.65[b]	4,314.76	4,499.69[b]	6,680.49	0.0084
Seed/seedling cost	1,863.92[c]	1,184.34	216.17[c]	256.47	0.0001
Manure and inorganic fertilizer	2,060.11	2,380.09	1,378.93	3,413.08	0.3832
Fungicide	748.94	925.19	500.03	512.76	0.3192
Insecticide	359.27	618.05	106.47	127.47	0.1244
Mulching	389.71[a]	370.89	119.92[a]	216.76	0.0125
Irrigation	251.57	1,006.28	53.83	262.48	0.4485
Staking	2,325.76	987.3	2,064.29	5,471.63	0.7532
Other inputs	500.37	1,746.61	60.04	96.82	0.3294
Labor cost:	7,151.16[a]	3,795.55	4,265.66[a]	2,502.22	0.0100
Labor (person-days/ha)	1,314.20[a]	633.1	896.04[a]	519.65	0.0255
Total operating costs	**15,650.81[b]**	**7,003.89**	**8,765.35[b]**	**7,484.43**	**0.0023**
Gross margin	**15,649.70[c]**	**11,970.70**	**2,771.59[c]**	**9,604.52**	**0.0007**
Benefit-cost ratio	**2.23**	**1.41**	**1.76**	**1.11**	**0.2376**

Source: Survey conducted by AVRDC in collaboration with FAVRI and PVFC (2012), n=64 observations.
Notes: Values are based on 2011/2012 prices; other inputs include agrochemicals; T-test uses Welch's approximation due to small sample size in one group; Level of significance is denoted by a) p<0.05, b) p<0.01, c) p<0.001; US$1=VND20,703.4.

Table 5. Econometric estimation results of production inputs on yield
Dependent variable: LNYIELD

Variable	**Pooled (Model 1)**	**Lam Dong province (Model 2)**	**Red River Delta (Model 3)**
	Coef.	Coef.	Coef.
LNSEED	-0.011[b]	0.277[c]	-0.013[b]
LNMA_IFE	0.004	0.066	-0.005
LNFUNG	0.036[c]	0.013	0.037[a]
LNINSE	0.016[b]	0.015[b]	0.018[a]
LNMULC	0.009[b]	0.002	0.012[a]
LNIRRI	0.002	-4.360	-0.009
LNSTAK	0.000	0.001	-0.001
LNAG_OTH	0.004	0.004	0.001
LNTOMDHA	0.086[c]	0.048	0.060[a]
GT_NGT	0.301[c]		0.307[b]
LOC_N	-0.114		
MODE	0.070	0.104	0.025
_CONS	2.612[c]	-2.414[b]	2.972[c]
Number of cases	279	215	64
F-ratio	23.09	12.14	10.61
Prob> F	0.000	0.000	0.000
R-squared	0.433	0.270	0.692

Source: Survey conducted by AVRDC in collaboration with FAVRI and PVFC (2012), n=306 observations.
Note: Level of significance is denoted by a) p<0.05, b) p<0.01, c) p<0.001.

Managing soil borne and virus diseases in cucurbits through eco-friendly approaches

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ABSTRACT
Among the cucurbits, Watermelon (*Citrullus lantus* Thunb) Matsum and Nakai, is grown in all parts of India up to an elevation of 1528 masl. Major limiting factors for successful cultivation are its susceptibility to soil-borne diseases such as fusarium wilt and mixed incidence of *Watermelon bud necrosis virus* (WBNV) transmitted by thrips and *Zucchini yellow mosaic virus* (ZYMV) transmitted by aphids causing yield loss ranging from 60-100%. Grafted seedlings of watermelon (bottle gourd used as rootstock) in combination with Agril Net cover in the open field until flowering gave protection against fusarium wilt as well as mixed infection of WBNV and ZYMV leading to economically successful production of watermelon in India. The benefit cost ratio was 3.21 and additional return:additional cost ratio was 11.3.

Keywords: Watermelon, virus diseases, Fusarium wilt, grafting, mature leaf resistance

INTRODUCTION
Among the soil-borne diseases of cucurbits, fusarium wilt of watermelon (*Fusarium oxysporum* f.sp. *niveum*) is the most damaging disease causing yield loss of 75% (Taylor et al. 2008). The pathogen can survive in the soil for more than a decade. The spread of the pathogen is via wind, water, mechanical tools and seeds. There is no cost-effective remedy for the disease control. Among the virus diseases of cucurbits, *Watermelon bud necrosis virus* (WMBNV) of watermelon transmitted by thrips (*Thrips palmi*) and *Zucchini yellow mosaic virus* (ZYMV) transmitted by aphids (*Aphis gossypii* and *Mysus persicae*) are endemic in southern states of India, causing yield loss ranging from 60-100% (Singh and Krishna Reddy 1995; Pandey and Pandey 2001; Rajasekharam 2010). Natural infection of WBNV has also been reported on muskmelon, ridge gourd, bottle gourd, and bitter gourd (Rajasekharam 2010). Chemical control of virus diseases is ineffective. Developing varieties for multiple resistance to soil-borne fungi and virus diseases is time consuming and capital intensive. For immediate short-term approaches, an experiment was conducted at the experimental farm of Namdhari Seeds Pvt. Ltd., Bangalore India during January to March 2013 using fusarium wilt resistant bottle gourd as rootstock and susceptible watermelon varieties as scion followed by Agril Net (unwoven polypropylene) cover until flowering (up to 55 days after sowing) to counter losses due to the mixed infection of WBNV and ZYMV and taking advantage of age related induced resistance to virus complex.

MATERIAL AND METHODS

Grafting and curing techniques

Four inbred lines of watermelon PI 175(V1), PI 5(V2), PI 55(V3), PI 1-10 (V4) and one watermelon hybrid NS 295(V5) susceptible to fusarium wilt as well as WBNV and ZYMV were sown in 99 plug trays 3 days prior to the sowing of fusarium wilt resistant bottle gourd (*Lagenaria siceraria*) used as rootstock. Sowing was done in an insect proof protected nursery. Side grafting operation was done on 13th day of sowing by giving an upward slanting cut with the help of a sharp blade to the hypocotyls region of the bottle gourd seedling, thereby removing one cotyledon leaf and 1st true leaf of the rootstock. The second cotyledon leaf and the root system of the rootstock were kept intact. A downward cut was given to the hypocotyl region of the scion keeping the two cotyledons and first true leaf intact. The cut region of the scion and rootstock was held together using a plastic clip. The grafted seedlings were kept in a curing chamber for a period of 7 days, maintaining 100% relative humidity at 25-30° C. During the first three days the grafted seedlings were ventilated for a period of 10 min each during morning (09:00) and evening (16:00). On the 4th and 5th days, the seedlings were ventilated for 30 min each during morning (09:00) and evening (16:00). On the 6th day, the ventilation was done for 45 min in the morning (09:00) and evening (16:00). On the 7th day, one hour of ventilation was done each during the morning (09:00) and evening (16:00). Thereafter, the grafted seedlings were transferred to the insect-proof nursery for further hardening. The non-grafted seedlings were raised in 99 plug trays in the protected nursery to be used as control treatment.

Experimental design and statistical analysis

Yield data pertaining to 15 treatment combinations was analyzed in a 5 × 3 factorial RBD design: A total of 3 treatment combinations were given each to the 5 watermelon lines/varieties as follows:

Treatment 1 (T1): Grafted seedlings + Agril Net cover in the wilt sick open field till flowering (55 days of sowing)
Treatment 2 (T2): Grafted seedlings without Agril Net cover in the wilt sick open field.
Treatment 3 (T3): Non-grafted seedlings without Agril Net cover in the wilt sick open field.

Twenty-three-day-old grafted and non-grafted seedlings were transplanted in the wilt sick open field. Ten seedlings in each treatment combination were transplanted on raised bunds in a 5 x 3 factorial RBD with three replications in a wilt sick plot keeping row to row distance of 2.5 m and plant to plant distance of 0.7 m. Reflective plastic mulch was used to cover the raised bunds. Fertigation was done at the rate of 150 kg N+ 100 kg P2O5 and 75 kg K2O using water soluble fertilizers. Yield observations were recorded on 5 plants. Average yield (kg/plant) for each treatment combination was recorded replication wise. Once flowering commenced, the Agril Net cover was removed gradually from the seedlings to facilitate pollination by bees.

The Benefit Cost Ratio for each treatment combination was calculated by dividing the gross return by gross expenditure. Additional Return: Additional Cost ratio for T1 or T2 was calculated by subtracting the gross return of T3 from gross income of T1 or T2 and dividing the resultant by additional expenditure on T1 or T2.

Observations pertaining to fusarium wilt were recorded on 55, 75 and 90 days of sowing (Table 8, Fig. 3). Visual observations were confirmed by lab test. Infected samples were collected from freshly wilted plants rinsed under running water to remove the soil and debris. Stem section of 1 to 2 mm in length were surface infected in 1.2% of active sodium hypochlorite for 5 minutes followed by 1 to 2 rinses in sterile water. Sections were plated on to Kodama's medium, which is selective for fusarium oxysporum. Plates were incubated at room temperature under 12 hours of fluorescent lighting. Fusarium colonies that grow on Kodama's selective medium were identified as *Fusarium oxysporum* on the basis of morphological characteristics. Pathogencity test was conducted by preparing a suspension of *Fusarium oxysporum* microconidia using Esposito and Fletcher broth and adjusted to a concentration of 1 x 10^5 spores per ml. The root system of 10 replicated seedlings of susceptible watermelon variety Sugar Baby were dipped into the spore suspension and transplanted into the pots containing 4:1:1 sand: vermiculite: peat medium by volume maintaining soil temperature at 24-24° C. Replicated seedlings of Sugar Baby dipped in Esposito and Fletcher broth without fungus isolate when used as negative control plants, started wilting at onset of flowering.

Observations pertaining to WBNV and ZYMV were recorded on 5 plants randomly selected in each treatment combination replication wise on 75 and 95 days of sowing. For ELISA test young expanded leaves with typical symptoms of WBNV and ZYMV were collected from the terminal portion of secondary branches whereas mature leaves were collected towards the base of secondary branches (Fig. 4). Typical WBNV produced chlorotic and necrotic spots on leaves, necrosis, elongated dark brown streaks and die back of young growing shoots and buds (Fig. 1), whereas, that of ZYMV caused upward growth of the growing shoot tips, yellowing of the apical leaves, short internodes, and discrete mottled spots and discoloration of the leaves (Fig. 2). Visual symptoms of WBNV were confirmed by Direct Antibody Coating-Enzyme Linked Immuno assay (DAC-ELISA) procedure, as suggested by Rajasekaram (2010). The polyclonal antiserum directed against nucleocapsid (N) protein of PBNV purchased from ICRISAT, Hyderabad was used (Rajasekaram 2010). Double antibody sandwich ELISA using polyclonal antiserum virus (Bioreba AG Reinach Switzerland) was used for confirmation of ZYMV.

Total number of symptomatic and asymptomatic leaves were counted on 3 infected plants selected randomly from each variety in treatment #1 and #2 replication wise at an interval of 55, 65, 75, 85 & 95 days after sowing. In treatment #3 the leaf count could not be taken because of the onset of wilt during 65-75 days after sowing. The symptomatic and asymptomatic leaf count in treatment #1 and #2 for 5 varieties and 3 replications at different intervals were averaged separately (Table 5).

RESULTS AND DISCUSSION

Yield analysis in RBD factorial experiment

Yield data was analysed in 5 × 3 factorial design with 3 replications in RBD. Considering the 15 treatment combinations together in a randomized block design with 3 replications, the total variation between the plot yields was partitioned into the components for replications, treatments and experimental error (Table 1 & 2).

The F-test indicated that there were significant differences among the treatment combinations. For finding significant differences between the means, the CD @ 5% was calculated (Table 2).

The data indicated that there was a definite decreasing trend in varietal yield when treatment #1 was changed to treatment #2 and treatment #3. Treatment combination V5T1 was the best and it differed significantly from rest of the treatment combinations (Table 1). Further the significance of the variance for the main effect of varieties (V) and treatments (T) and the interaction (VT) was tested against the error variance by F-test. A table of complete analysis of variance pertaining to 5 x 3 factorial experiment was prepared (Table 3).

The F-test indicated that the main effects of variety (V) and treatment (T) were significant at 1% level of significance; however, the interaction (VT) was not significant at 5% level of significance (Table 3).

All the 3 treatments differed significantly from each other as indicated by CD @ 5%. The best treatment combination was V5T1 giving the highest yield of 74.4 mt/ha. The nonsignificance of interaction (VT) proved that different varieties did not alter the effect of a particular treatment. Irrespective of the varieties used, the treatment #1 (60.3 mt/ha) remained significantly superior (10.2 mt/ha, CD 5%) to treatment #2 (mean 24.6 mt/ha) and treatment #3 (mean 13.2 mt/ha) (Tables 2 & 3). Fifty-nine percent yield reduction was noticed when T1 was changed to T2 and 78% yield reduction was observed when T1 was changed to T3 (Table 4).

Benefit cost ratio was analyzed as 3.21 in T1, 1.51 in T2 and 0.90 in T3. Additional Return: Additional Cost ratio was analyzed as 11.3 in T1 and 6.84 in T2 indicating that for each additional expenditure of Rupee 1 there was an additional return of Rupees 11.3 in T1 and Rupees 6.84 in T2. In T3 for every one rupee of investment there was a loss and just a return of Rupee 0.905.

Grafting and quality parameters

In grafted plants the fruit harvesting was delayed for one week, the fruit texture was firm to medium crispy and the Total Soluble Solids (TSS) was comparable to fruits from non-grafted plants (Table 7).

Viral disease management during different stages of plant growth

The induction of resistance to disease during plant development is widespread in the plant kingdom. Resistance appears at different stages of host development and varies with the plant age or tissue maturity. Above the critical leaf stage and physiological maturity when the cells are not dividing, the disease symptoms do not develop in the infected leaves (Atkinson and Matthews 1970). In Treatment #1, where grafted seedlings were given a protection against virus infection for a period of 55 days, they produced on an average 46 asymptomatic leaves as compared to symptomatic leaf count which was zero; however, the ratio between asymptomatic and symptomatic leaf count gradually decreased from 29:1 to 4.8:1 during 65 to 95 days of sowing when the protection was taken off at 55 days of sowing (Table 5). At the time of harvest between 85 to 95 days the number of asymptomatic leaf count ranged from 335 to 367 per plant as compared to symptomatic leaf count which ranged from 38 to 69, yielding on an average 60.3 mt/ha in treatment #1.

In Treatment #2 where the protection to the grafted seedlings against virus infection was provided only up to 23 days in nursery and thereafter no protection was provided in the field after transplanting, the ratio of asymptomatic and symptomatic leaf count decreased from 3.1:1 to 1.7:1 during 55 to 65 days of sowing. Thereafter the asymptomatic to symptomatic leaf count ratio increased from 1:1.2 to 1:2.75 during 75 to 95 days of sowing (Table 5). Thus in Treatment #2 there was a reduction of 82% in mature asymptomatic leaf count as compared to Treatment #1. This might be the reason for 59% yield reduction in Treatment#2 as compared to Treatment #1.

ELISA Test

The ELISA test was used to confirm presence of both WBNV and ZYMV qualitatively in diseased plants (Table 6). Young expanded leaves with typical symptoms of WBNV collected during 75 days and 95 days of sowing showed positive reaction, whereas, mature asymtomatic or mild symtomatic leaves collected during 75 days of sowing showed negative reaction and at 95 days of sowing it showed positive reaction. This might be due to the rate of virus replication and or long distance transport of virus infectivity, which varies with physiological maturity of the leaves (Mathews 1995). Age related response in tobacco was assoicated with five-fold increase in endogenous salicylic acid known to have antiviral properties (Yalpani et al. 1993). In the case of ZYMV, the young expanded leaves collected with typical symptoms of ZYMV showed positive reaction during 75 and 95 days of sowing; however, in mature asymptomatic leaves or leaves with mild symptoms, it showed positive reaction at 75 days of sowing, whereas some of them showed negetive reaction at 95 days of sowing. This might be due to the strong interaction of plant age and environmental conditions with host genotype to produce the final response. Many metabolic changes occur as leaves mature. Variations in physiological maturity of leaves within the plant may give different response to the infection (Mathews 1995). Grafted watermelon seedlings using fusarium wilt resistant bottle gourd rootstock provided sure protection from fusarium wilt. Further protection of the grafted seedlings with Agril Net for a period of 55 days provided ample oppurtunity to develop 337 mature leaves with mild symptoms or no symptom of virus infection in Treatment #1, leading to the production of a healthy economic crop.

Occurance of mature tissue and mature plant resistance irrespective of the susceptible level of genotype of *Peanut bud necrosis virus* has been reported by Buiel and Parlevliet (1996). Bell and banana pepper also exhibited mature plant resistance to *Tomato spotted wilt virus* transmitted by Thrips (Beaudoin 2009). Overall, it can be concluded that grafted watermelon seedlings with Agril Net cover until flowering (55 days of sowing) gives suffcient protection against fusarium wilt and virus complex of WMBN and ZYMV, leading to the production of an economically sucessful crop.

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Table 1. Average yield (kg/plant) in RBD

Treatment combination	R-1	R-2	R-3	Total	Mean	mt/ha	Yield (mt/ha) descending order	
V1T1	8.8	9.5	10.3	28.6	9.5	63.5	**V5T1**	74.4
V2T1	7.0	8.5	6.5	22.0	7.3	48.9	**V1T1**	63.5
V3T1	8.5	9.5	10.3	28.3	9.4	62.9	**V3T1**	62.9
V4T1	6.0	9.1	8.1	23.2	7.7	51.6	**V4T1**	51.6
V5T1	10.0	11.0	12.5	33.5	11.2	74.4	**V2T1**	48.9
V1T2	5.0	3.5	2.7	11.2	3.7	24.9	**V5T2**	31.1
V2T2	4.5	2.5	3.4	10.4	3.5	23.1	**V1T2**	24.9
V3T2	3.5	2.2	3.0	8.7	2.9	19.3	**V4T2**	24.4
V4T2	4.0	3.0	4.0	11.0	3.7	24.4	**V5T3**	23.3
V5T2	5.0	3.5	5.5	14.0	4.7	31.1	**V2T2**	23.1
V1T3	2.0	1.0	1.5	4.5	1.5	10.0	**V3T2**	19.3
V2T3	2.0	1.5	2.5	6.0	2.0	13.3	**V2T3**	13.3
V3T3	1.0	2.0	1.3	4.3	1.4	9.6	**V1T3**	10.0
V4T3	2.0	1.4	1.0	4.4	1.5	9.8	**V4T3**	9.8
V5T3	4.0	3.5	3.0	10.5	3.5	23.3	**V3T3**	9.6

Table 2. RBD Analysis of Variance

SOV	df	SS	MSS	F	
Replication	2	0.51	0.26	0.304755791	NS
Treatment	14	449.90	32.14	38.22255367	**
Error	28	23.54	0.84		
Total	44	473.95			
CD 5%	1.533 kg/pl	10.2mt/ha			

Table 3. Factorial Analysis of Variance

Source of Variation	SS	df	MS	F	P-value	
Replication	0.51	2	0.26	0.305		NS
V (Columns)	29.31	4	7.33	9.140	**5.94E-05**	**
T (Rows)	407.07	2	203.54	253.856	**1.58E-19**	***
Interaction	13.51	8	1.69	2.106	**0.066832**	NS
Error	**23.54**	**28**	**0.84**			
Total	473.95	44				
CD 5% for Variety	0.885 kg/Pl	5.8 mt/ha				
CD 5% for Treatments	0.685 kg/Pl	4.5 mt/ha				

Table 4. Percent reduction in yield

	T1 Vs T2	T1 Vs T3	T2 Vs T3
V1	60.8	84.3	59.8
V2	52.7	72.7	42.4
V3	69.3	84.8	50.2
V4	52.6	81.0	59.8
V5	58.2	68.7	25.0
Mean	**59.0**	**78.0**	**47.5**

Table 5. Asymptomatic and symptomatic leaf count ratio during different developmental stages of plant growth

	Treatment 1			Treatment 2		
Days	**Asymptomatic : Leaves (no)**	**Symptomatic Leaves (no)**	**Ratio**	**Asymptomatic Leaves (no)**	**Symptomatic Leaves (no)**	**Ratio**
55	46	0	46:0	31	10	3.1:1
65	174	6	29:1	85	50	1.7:1
75	325	17	19:1	73	90	1:1.2
85	367	38	9.6:1	65	150	1:2.3
95	335	69	4.8:1	58	160	1:2.75

Table 6. WBNV and ZYMV ELISA test

Variety	Sample No.	WBNV		ZYMV	
		75 days Reaction	95 days Reaction	75 days Reaction	95 days Reaction
Pi 175	Sample 1	+	+	+	+
	Sample 2	-	+	+	-
NS 295	Sample 1	+	+	+	+
	Sample 2	-	+	+	+
Pi 5	Sample 1	+	+	+	+
	Sample 2	-	+	+	-
Pi 55	Sample 1	+	+	+	+
	Sample 2	-	+	+	-
Pi 1-10	Sample 1	+	+	+	+
	Sample 2	-	+	+	-

Samle 1: Young expanded leaves collected from terminal portion of growing secondary branches showing typical symptoms of WBNV and ZYMV. Sample 2: Mature leaves with mild symptoms or no symptoms collected from the base of infected secondary branches.

Table 7. Quality parameters

Treatment	Maturity (days)	TSS (%)	Texture
T1	85-95	10-12	Medium crisp
T2	85-95	10-12	Medium crisp
T3	78-90	10-12	Granular

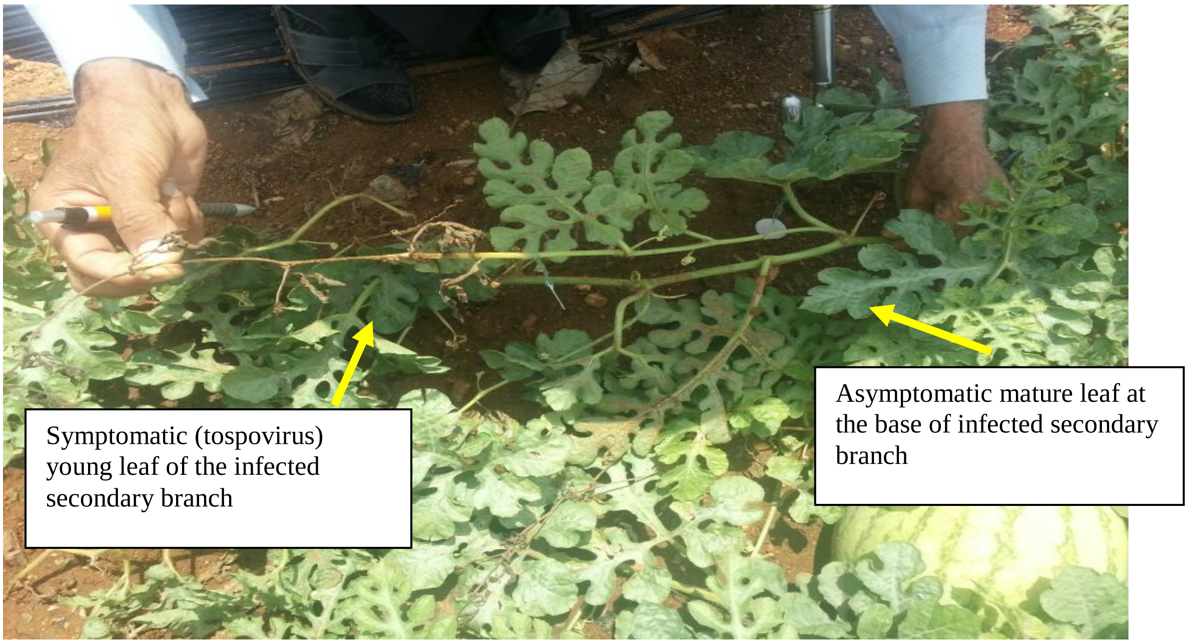
Table 8. Incidence of fusarium wilt (%) in different treatment combinations (average of 3 replications)

Treatment combination	Fusarium wilt (%)		
	55 days	75 days	90 days
V1T1	0	0	0
V2T1	0	0	0
V3T1	0	0	0
V4T1	0	0	0
V5T1	0	0	0
V1T2	0	0	0
V2T2	0	0	0
V3T2	0	0	0
V4T2	0	0	0
V5T2	0	0	0
V1T3	35	71.5	84.2
V2T3	28.5	53.2	72.6
V3T3	33	65.8	85
V4T3	36	68.7	86
V5T3	29.1	48.6	65.7

Figure 1. Watermelon bud necrosis

Figure 2. Zucchini yellow mosaic virus

Figure 3. Fusarium wilt in non- grafted watermelon



Plant factories

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ABSTRACT
There will be major constraints in the future for urban and peri-urban agriculture due to the lack of suitable land and of fresh water. As cities increase in size, the need to source food from further away will increase, posing not only transport problems but also postharvest difficulties.

Plant factories offer the potential to produce fresh vegetables close to the centres of population (cities) where they are to be consumed.

Plant factories are sometimes described as vertical farming, with exotic architectural pictures of people and crops in large, well-lit buildings. Nothing is further from the truth. The plant factory of the future is likely to be a utilitarian building (maybe even a skyscraper) filled with plants and managed by a minimum of operators.

Plant factories offer the potential to be very efficient in terms of land footprint (an important factor in mega-cities were land will be at a premium), to be water efficient, and to be able to produce crops on demand. Because plants are grown in a sealed container it will be possible to use high levels of carbon dioxide to speed up growth, and also much longer periods of photosynthetic lighting. Produce will be free from pesticides, and have a very low microorganism count, and so will be extremely safe, and not require washing or other treatment prior to consumption.

Studies undertaken using LED lighting, different carbon dioxide levels and different air temperatures will be presented for the growth of both lettuce and cabbage seedlings.

The need for such studies will be discussed, and the long term future of plant factories will be considered.

Keywords
Irradiance, temperature, carbon dioxide, controlled environment agriculture

INTRODUCTION
The origin of "plant factories"—the ultimate form of controlled environment agriculture (or protected cropping)—is to be found in the orangeries established by the rich in the 18th and 19th Century in Europe. An orangery in its simplest form comprised a stone building with windows and a heating stove, in which orange trees in large pots were transferred into to protect them from frost damage during the European winter. To call them greenhouses is probably an insult, as their main objective was to keep the plants warm, rather than provide them with light.

In 1850 there was the Great Exhibition in London, which included the Crystal Palace, a large glasshouse built by a prominent horticulturist of the day, Joseph Paxton. This showed that it was possible to build large glass-clad structures (greenhouses) in which to grow crops (rather than to overwinter frost sensitive plants), and was the beginning of the greenhouse industry as we know it today.

Over the years there has been a steady improvement in our ability to modify and control the environment within the greenhouse, but a major constraint has always been the variation of the outdoor environment, particularly that of radiation (light) due to latitude, time of year, time of day, and the amount of cloud cover. To a large extent it is possible to control temperature by means of heating and/or cooling systems, but light intensity is really dependent on the sun, over which we have no control.

Yield is a function of genotype and environment. The plant environment involves both the root and the above-ground part of the plant.

The root environment changes reasonably slowly, but the above-ground environment in the field (or the greenhouse) is capable of changing minute to minute—for example, the sun going behind a cloud will immediately change the quantity of light reaching the plant, and also to a lesser extent the light spectrum. It will also influence the temperature of the plant, which may influence development and photosynthesis, etc.

In any case, one factor is very clear: it is impossible to have more than 12 hours of sunlight daily anywhere in the world over a 12-month period. Of course at high latitudes the day length is much greater during the summer, but commensurately shorter in the winter, whereas near the equator the day length is approximately 12 hours per day every day of the year.

Of course under special circumstances it is possible to use artificial lights to extend the natural day-length, but until recently these have tended to be used only to influence the photoperiodic response of the plant. Using artificial lights to enhance photosynthesis has until now only been justified during the winter months at high latitudes, but in recent times LED's, and High Pressure Sodium lights have become a popular source of supplementary light in greenhouse operations in Europe (particularly in the Netherlands and Scandinavia). The importance of light as the driver of photosynthesis (and therefore yield) goes without saying. For example, the development of glass which scatters light rather than simply transmits it is said to enhance productivity by up to 10%.

Plant factories are one further advance on the control of the plant environment, in which the plants are completely insulated (and isolated) from the external environment. This is not a new concept, as growth rooms have been an important tool for many years in horticultural science (via plant physiology) to gain a better understanding of "what makes plant tick" in order to develop more efficient and effective growing systems.

The major problem has been that at this point in time, our understanding is that the major wavelengths for photosynthesis are to be found only in the blue and red part of the electromagnetic spectrum, although other parts of the spectrum can have a major influence on plant growth and development. For example the red/far red phytochrome complex, which controls many biological processes, such as flower initiation.

Nevertheless, until recently the ability to produce near monochromatic light of specific wavelengths did not exist. Most light sources produced spectra that were not ideal for plant growth. I recall in 1954 assisting in growing tomato seedlings in mid-winter in UK using supplementary light from Mercury Vapour lamps. Later these lamps were superseded by High Pressure Sodium lamps, but in all cases there was a considerable infrared component, which heated the plants rather than enhanced photosynthesis. Note: tungsten bulbs provide very little photosynthetic light, but can be valuable for extending day length.

The development of Light Emitting Diodes (LEDs) provided a solid state long life source of monochromatic light. Unfortunately they are expensive and are still significantly underpowered, but every year they halve in price, and double in power, so the future looks very promising. One potential of LEDs is that one no longer has to be concerned about radiant heat, although the system still produces considerable sensible heat that must be removed.

So where does this fit into modern horticulture?

Plant factories are being developed in Japan (Kozai 2013), Taiwan, China and South Korea. All these countries have large populations and limited land and water resources. It is very important to differentiate between fully artificially lighted plant factories and those greenhouse structures that use supplementary light. I do not consider such structures as plant factories. The plant factories I am going to describe are all fully artificially lit ones.

Plant factories can be considered to have two specific roles, namely: To produce high quality nursery seedlings, and to grow plants to maturity.

In current practice the only plants being grown to maturity in plant factories are lettuce and other fast growing plants such as herbs (and of course) both legal and illegal crops of the drug plant cannabis. At this time I will only consider lettuce and herbs.

The production of seedlings (Nichols 2013) for transplanting later into the field or greenhouse has probably the greatest immediate potential, because by using plant factories, high quality seedlings can be produced at any time of the year, to a precise standard—something that is very difficult to achieve even in a greenhouse. As much of the life of many vegetables occurs prior to transplanting, it also provides an excellent opportunity to provide a crop to mature when required, rather than as the weather determines. In the long term it may well be possible to produce plants that have been "hardened off" so that when planted in the field they "jump away", rather than take several weeks to get established. The ability to produce high quality seedlings to a specific date (and standard) at any time of the year would a major advance.

A further aspect may well be the opportunity to control the development of the plant. For example, probably the highest value vegetable transplant of any scale is the grafted greenhouse tomato. The value of this could well be enhanced by accurately controlling the plant environment at and soon after grafting.

Another example might be as a means to obtain synchronous initiation of flowering (curd initiation) of broccoli or cauliflower, or to provide the appropriate environment to ensure that seedlings destined to be used for seed production would flower at the desired time. A particularly important consideration when producing F1 hybrid seed, is that the two parents flower simultaneously.

One of the major advantages of a plant factory is the opportunity to grow a large number of plants in a very small footprint. It is possible to grow at least 4 layers of seedlings in a 2 m high module, and there is no reason not to put modules on top of one another. Such a development will be important in the future for high density population countries such as in Asia, where flat land is at a premium, both for agriculture and for housing. I suspect that this is the reason for the development of plant factories in Japan, and possibly also in South Korea and the People's Republic of China. Another reason, which certainly has long-term importance, is the very real shortage of fresh water throughout the world.

Currently the bulk of this water is used for agriculture (irrigation), but the pecking order is people, industry, and last, agriculture. When water resources become scarce, then agriculture will be the first to suffer. Because plant factories use very little water, they will have a major role to play in the future. The reason for the low water use is because, in theory, all the water used in transpiration can be condensed and recirculated, so that the only water loss is via plant material being harvested and removed. In practice it appears that a water loss of about 15% of transpiration losses will occur through leakage.

THE CHALLENGE

A major problem with plant factories is to identify the optimum environment for crop production. The range of different environments which can be used is huge, and it is important to develop an efficient research strategy. Measuring instant photosynthesis levels using “standard” laboratory equipment (such as Licor) will not provide an integration of dry matter accumulation (or growth), and in the final analysis only growth data will provide this information.

OUR APPROACH

Our first studies involved growing lettuce plants hydroponically (using a Hoagland’s nutrient solution) in a controlled environment room to near maturity, taking regular destructive harvests and varying the CO_2 concentration at weekly intervals. In earlier studies with lettuce we had shown that they grew exponentially until close to hearting, so that it was considered that the weekly relative growth rates would provide a useful measure of the response to different CO^2 levels. Unfortunately the plants did not grow exponentially (the function was logistic, due we suspect to root competition). The plants were grown at 4 different light intensities (930, 566, 417 & 270 µmol.m2.s-1) (Fig. 1), and at 5 different CO_2 levels (500, 1000, 1500, 2000 and 2500 ppm) and showed a reduction in growth rates over time. This was undertaken before LEDs became available, and was with a light spectrum “similar” to sunlight.

In our second study, our approach was to grow plants under a range of different environments and carry out growth analysis over a relatively short time period on the very young seedlings.

Young seedlings grow exponentially, and therefore the logarithm of the plant dry weight against time is a straight line (actually the relative growth rate, and thus in a very short time it is possible to determine the dry matter accumulation of arrange of different plant species.

The three major environmental factors to be considered initially in dry matter accumulation are light (quantity, wavelength, duration), temperature, and CO_2 concentration.

In this study with lettuce we used LED lights (3 levels, 116, 166 & 261 µmol.m2.s-1of the same wavelengths) with a constant ratio of 4:1 red:blue with a very small amount of “white” light with a 23 hour photoperiod, and 3 temperatures and 3 levels of $CO_{2.}$

To overcome any variation in the light levels under each light plots, the trays of seedlings were moved systematically every 24 hours.

Destructive harvest of sample plants were taken a short (2 or 3 or 4) day intervals, and leaf areas and dry weights measured over a period of 3 weeks from sowing.

The plants were grown in small polyurethane foam cubes supplied by Huntsman, suspended into an ebb and flow irrigation system. Following sowing (one seed into each cube the temperature was a constant 20° C for 2 days, to ensure that over the imbibition period there was no high temperature dormancy problems.

Our results (Fig. 2, 3, and 4) clearly demonstrate the importance of all irradiation levels, and CO_{2} levels in determining the relative growth rates. A similar pattern occurred with the 3 temperatures (20° C, 25° C, and 30° C).

Similar studies can be undertaken with a range of different factors, for example there is considerable debate regarding he need for additional wavelengths of light, in addition to the standard red:blue combination, and even the correct ratio of red:blue light has still to be established. This could be easily determined using this very simple research strategy.

CONCLUSIONS

We found in these studies that there was a clear significant increase in the relative growth rates (RGR) of lettuce by increasing the air temperatures from 20-25° C, and a similar increase by increasing the CO_2 level from 500-1000 ppm, but that no further increase at either 30° C or at 1800 ppm of CO_2 occurred. There was no significant interaction between the two major factors. Increasing the light intensity resulted in an increase in RGR at all temperatures and CO_2 levels. It should be noted that 500 ppm far exceeds the normal level of carbon dioxide in a greenhouse, and that even when supplementary CO_2 is provided the level tends to be only 600 ppm due to leakage through the structure. It is possible that at the higher temperatures and light levels there was some moisture stress, and it will be a part of future studies to examine this, and also the reason why there was no CO_2 response above 1000 ppm.

References

Kozai T (2013) “Plant factory in Japan-current situation and perspectives “Chronica Horticulturae, 53,8-11.

Nichols MA (2013) “Quality Vegetable Seedling Production” Practical Hydroponics and Greenhouses, 128, 26-28.

Table 1. Relative Growth Rates (slope of log dry weight plotted against time) of lettuce at 3 CO_2 levels and 3 light intensities

CO_2 (ppm)	Light intensity $\mu mol.m^2.s^{-1}$			
	Low (116)	Medium (166)	High (261)	Mean
500	0.287	0.314	0.334	0.312
1000	0.329	0.337	0.379	0.349
1800	0.326	0.348	0.346	0.340
Mean	0.314	0.333	0.353	

Table 2. Relative Growth Rates (slope of log dry weight plotted against time) of lettuce at 3 temperatures and 3 light intensities

Temperature	Light intensity $\mu mol.m^2.s^{-1}$			
	Low (116)	Medium (166)	High (261)	Mean
20C	0.196	0.238	0.218	0.217
25C	0.329	0.337	0.379	0.349
30C	0.243	0.248	0.247	0.246
Mean	0.256	0.274	0.282	

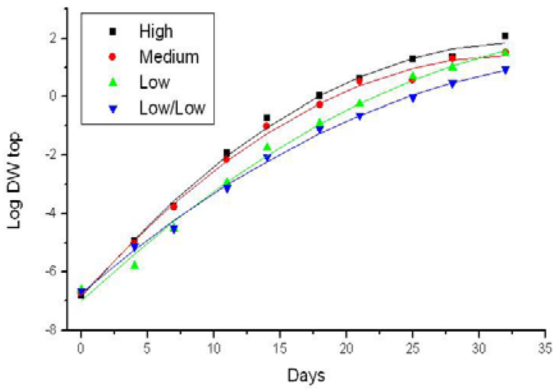

Figure 1. Growth of Lettuce at 30° C and 4 light intensities (930, 566, 417 &270µmol.m^2.s^{-1})

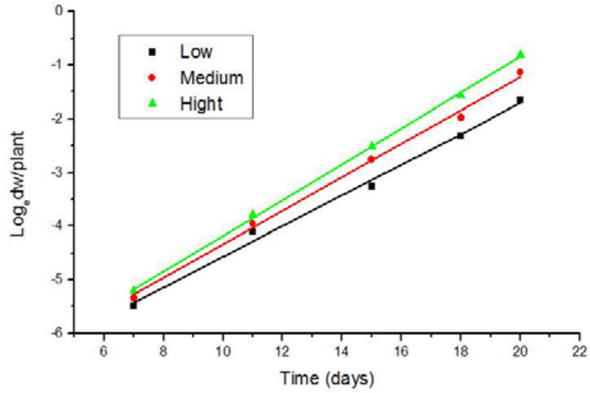

Figure 2. Dry matter accumulation of lettuce at 500 ppm CO_2 and 3 light intensities. (118, 166, 261µmol.m^2.s^{-1})

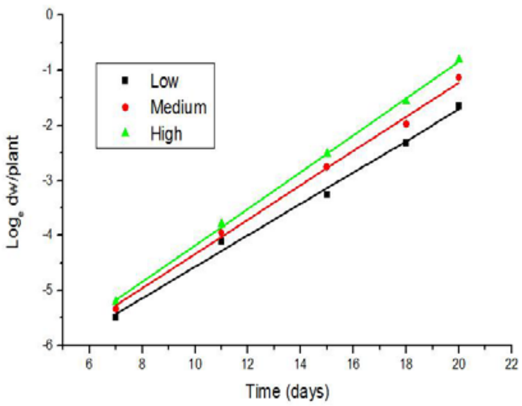

Figure 3. Dry matter accumulation of lettuce at 1000 ppm CO_2 and 3 light intensities (118, 166, 261µmol.m^2.s^{-1})

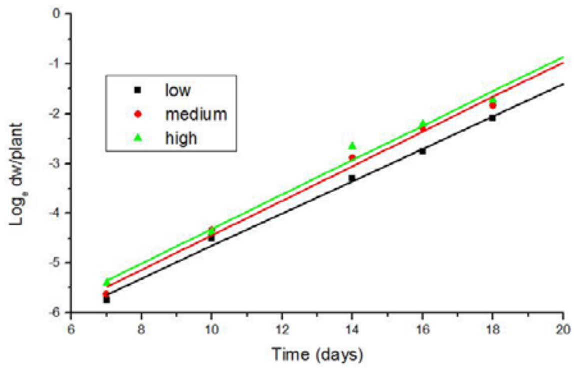

Figure 4. Dry matter accumulation of lettuce at 1800 ppm CO_2, and 3 light intensities. (118, 166, 261µmol.m^2.s^{-1})

Figure 5. Seedling nursery

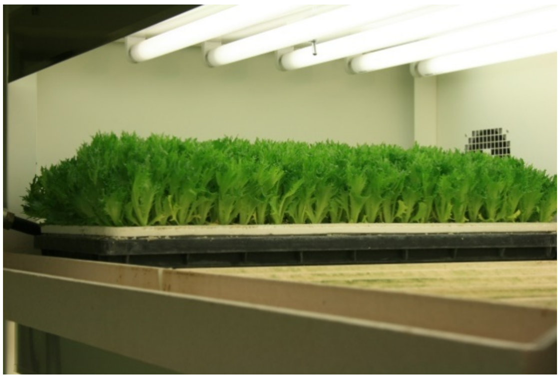

Figure 7. Lettuce seedlings – mid-winter

Figure 9. Lettuce (and cabbage) in our LED trials

Figure 6. Tomato seedlings – mid-winter

Figure 8. Mature lettuce

Figure 10. Lettuce from first experiment

Amaranth sprouts and microgreens – a homestead vegetable production option to enhance food and nutrition security in the rural-urban continuum

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ABSTRACT

Traditional vegetables and vegetable legumes can be a source of readily available daily sustenance when grown in home or kitchen gardens. Lower income groups that lack access to or cannot afford global vegetables and animal protein sources would benefit greatly from the increased availability and consumption of traditional vegetables. Phytonutrient levels of edible parts differ according to the growth stages of the plant and often decrease from the seedling (sprout or microgreen) to the fully developed stage. Sprouts and microgreens can easily be grown in urban or peri-urban settings where land is often a limiting factor, either by specialized vegetable farmers or the consumers themselves. Given their short growth cycle, sprouts and microgreens can be grown without soil and without external inputs like fertilizers and pesticides, around or inside residential areas.

Seedlings from semi-domesticated or even wild species typically have high levels of phytonutrients, good flavor, and tender texture. Several crops or different varieties of the same crop can be mixed to create attractive combinations of textures, flavors, and colors. As sprouts and microgreens are usually consumed raw, there is no loss or degradation of heat-sensitive micronutrients through food processing. AVRDC is currently studying potential differences in the levels of essential micronutrients, bioactive compounds, and consumer preferences of selected traditional vegetables and vegetable legumes at different growth and consumption stages.

The results obtained with amaranth are reported in this paper. Amaranth is increasingly becoming popular as a nutrient-dense leafy green beyond Asia and the Caribbean (Saelinger 2013). The phytonutrient content was assessed at three stages: (a) sprouts, (b) microgreens, and (c) fully grown plants. The comparison included landraces from the AVRDC Genebank and commercially available cultivars. This work may expand the use of genebank materials for specialty produce such as sprouts and microgreens with great potential to improve food and nutrition security for people living in urban and peri-urban settings.

Keywords

Traditional vegetables, sprouts, microgreens, food and nutrition security, rural-urban continuum

INTRODUCTION

Diet-related diseases such as obesity, diabetes, cardiovascular disease, hypertension, stroke, and cancer are escalating both in developed and developing countries, in part due to imbalanced food consumption patterns. Health experts are convinced of the multiple benefits of consuming vegetables and fruit on a regular basis and the World Health Organization recommends that people eat at least 400 grams of fruit and vegetables a day (WHO/FAO 2005), while the World Cancer Research Fund would like to see the consumption of fruit and non-starchy vegetables to beat least 600 grams per day (WCRF/AICR 2007). Based on a published meta-analysis of nutritional epidemiology studies it was estimated that approximately 20,000 cancer cases per year could be prevented in the U.S. by increasing fruit and vegetable consumption by 160 g/person/day (Reiss et al. 2012). Another large study conducted by Boffetta et al. (2010) included nearly half a million persons in Europe and covered all cancer types. The authors concluded that with an average increase of fruit and vegetable consumption of approximately 150 g/d, 2.6% cancers in men and 2.3% cancers in women could be avoided. Looking at specific cancers for which there is good evidence for a benefit from fruit and vegetable consumption, the cancer avoidance effect could be much higher.

One of the most valuable benefits of traditional leafy vegetables is their high content of vitamins, minerals, fiber and other micronutrients essential for human health. Many traditional vegetables contain high levels of β-carotene and vitamin C, and in general have higher vitamin E, folate, calcium, iron, and zinc content and higher antioxidant activity compared with global vegetables (Yang and Keding 2009). Including traditional vegetables in the diet has great potential to combat malnutrition and improve overall health. Lower income groups for whom traditional vegetables are more affordable than common global vegetables or animal meat products will benefit greatly from increased availability and consumption of traditional vegetables.

The high nutritional value of many traditional fruits and vegetables has inspired Unilever to assemble a scientific consortium to identify ‘pre-domesticated’ varieties of crops (mainly fruits and vegetables) that have been changed very little by breeding and might contain significantly higher levels of nutrients than the varieties currently used for food production (Unilever 2012). This conclusion is supported by a review study conducted on 43 garden crops based on United States Department of Agriculture (USDA) food composition data, which revealed a statistically reliable decline of six nutrients (protein, Ca, P, Fe, riboflavin and ascorbic acid) between 1950 and 1999 (Davis et al. 2004). These changes might be due to the replacement of older, more nutritious cultivars with modern ones. Similar trends have been observed in wheat grain (Garvin et al. 2006; Fan et al. 2008) and potato tubers (White et al. 2009). Breeding and selection for high yield may have led to a decline in some essential nutrients.

Phytonutrient levels differ according to the growth stages of the plant and often decrease from the seedling (sprout, microgreen) to the fully developed stage (van Hofsten 1979; Barillari et al. 2005; Nakamura et al. 2001; Ebert 2013a,b). In addition to their high nutritional value, microgreens are considered functional foods with particular health-promoting or disease-preventing properties (Samuoliene et al. 2012). Sprouts and microgreens can be easily produced in urban or peri-urban settings where land is often a limiting factor, either by specialized vegetable farmers or the consumers themselves. Given their short growth cycle, sprouts and microgreens can be grown without soil and without external inputs like fertilizers and pesticides, around or inside residential areas. Moreover, sprouts and microgreens are usually consumed raw, hence there is no loss or degradation of micronutrients through food processing.

Through a new project funded by the Council of Agriculture of Taiwan, AVRDC is studying the levels of essential micronutrients and consumer preferences of selected legume crops (mungbean, soybean) and traditional vegetables (amaranth, mustard, radish) at different growth and consumption stages: (a) sprouts; (b) microgreens - seedlings harvested when the first true leaves appear, and (c) fully grown plants at the usual consumption stage. All five crops are well represented in AVRDC's genebank. The comparison included landraces from the AVRDC genebank and modern cultivars available commercially. Due to the large amount of data, the results reported in this paper are limited to amaranth.

MATERIALS AND METHODS

Plant materials and growing conditions

The following amaranth genebank accessions and commercial lines were used for the experiments:

1. VI044470: Genebank accession; species: *Amaranthus tricolor;* cultivar /pedigree: Ames 5134; origin: USA; acquisition date: March 1995.

2. VI047764: Genebank accession; species: *A. tricolor*; cultivar /pedigree: Lal Shak; origin: Bangladesh; acquisition date: June 2000.

3. 'Juan-Chih-Shing': Commercial line; purchased in June 2013 from local market in Tainan City, Taiwan.

4. 'Hung-Shing-Tsai': Commercial line; purchased in June 2013 from local market in Tainan City, Taiwan.

For the production of amaranth sprouts, seeds were soaked for 9 hours in distilled water, followed by rinsing. Seeds were then placed in a single layer on paper cloth inside perforated plastic trays, which were enclosed in solid plastic boxes for drainage of excess water and to maintain high moisture content for sprout growth. The boxes were kept at room temperature at 26±2^{o}C. The seedlings were carefully watered twice daily. Plant samples were harvested in three replicates at 7 days after sowing for nutritional analysis (Table 1). Another sample was taken at 8 days after sowing for consumer assessment of the produce.

For microgreen production, a mixture of peat moss and vermiculite at a 3:1 ratio was used as substrate. Seed was mixed with sand and broadcast in plastic trays. The substrate was kept moist and the plastic trays were placed on benches inside a greenhouse with a water wall and fan to keep temperatures in the range of 26±2^{o}C. Plant samples were harvested in three replicates at 9 days after sowing for nutritional analysis and consumer assessment (Table 1).

For open field production, seeds were broadcast in field plots at the beginning of October and harvested at the full vegetative growth stage (28 days after sowing) for nutritional analysis and consumer evaluation (Table 1).

Consumer evaluation

Plant samples were assessed at three growth/consumption stages (sprouts, microgreens, fully grown leafy vegetable) for consumer evaluation of sensory aspects, such as appearance, color, texture, aroma, sweetness, bitterness, taste, and general acceptability. Each parameter was rated on a scale from 1-5 with the following attributes: 1 = dislike extremely; 2 = dislike slightly; 3 = neither like nor dislike; 4 = like slightly; 5 = like extremely. Volunteers composed of AVRDC employees and their relatives, trainees and students rated the produce. Sprouts were rated by 53 consumers (36 female; 17 male), microgreens by 34 consumers (23 female; 11 male) and fully grown leafy amaranth by 53 consumers (37 female; 16 male).

For statistical analysis of the consumer acceptance data, Friedman's two-way nonparametric ANOVA was used. The least squares means were adjusted for multiple comparisons of the acceptance rank means of the test varieties using Tukey's Honestly Significant Difference (HSD) test.

Nutritional analysis

About 100-200 g of sprouts, 100-200 g of microgreens and at least 600 g of fully grown plants of each vegetable variety were sent to the AVRDC nutrition laboratory for sample preparation and nutritional analysis. Plant samples were cleaned with distilled water and surface water was removed; plant parts were cut and mixed thoroughly for sampling. Samples were weighed, freeze dried, ground into fine powder and stored at -20 ^{o}C for subsequent analyses.

The protein content was measured with micro-Kjeldahl digestion followed by distillation method (AOAC 1990a). The determination of calcium, iron and zinc contents was performed by ashing procedure, strong acid washing, followed by Atomic Absorption Spectroscopy (AOAC1990b). The determination of total ascorbic acid was carried out as described by Hanson et al. (2004) on the basis of coupling 2,4-dinitrophenylhydrazine (DNPH) with the ketonic groups of dehydroascorbic acid through the oxidation of ascorbic acid by 2,6-dichlorophenolindophenol (DCPIP) to form a yellow-orange color in acidic conditions. Carotenoids including a-carotene, β-carotene, neoxanthin, and lutein were analyzed using high performance liquid chromatography (HPLC) (Hanson et al. 2004). Simple phenolic acids including caffeic acid, chlorogenic acids and flavonoids were analyzed using HPLC as described by Yang et al. (2008). Carotenoids, phenolic acids and flavonoids were identified and quantified with commercial standards. Antioxidant activity was measured using 2,2'-azino-bis(3-ethylbenzothiazoline-6-sulphonic acid) (ABTS) radical (Re et al. 1999) and expressed as Trolox equivalent (TE). Details were described by Yang et al. (2006).

RESULTS AND DISCUSSION

Consumer evaluation of amaranth sprouts, microgreens and fully grown leafy amaranth

Sprouts of genebank accession VI044470 from USA (variety 1) and commercial cultivar 'Juan-Chih-Shing' from Taiwan (variety 3) were consistently preferred by consumers in terms of appearance, texture and taste as well as general acceptability (Fig. 1). High scores for taste and general acceptance were also given for the second commercial cultivar 'Hung-Shing-Tsai' from Taiwan.

Microgreens of genebank accession VI047764 from Bangladesh were highly appreciated in terms of appearance, but disappointing in terms of texture, taste and general acceptability (Fig. 2). Genebank accession VI044470 and commercial cultivar 'Hung-Shing-Tsai' received the highest rating for texture, taste and general acceptability.

Genebank accession VI044470 and 'Juan-Chih-Shing' consistently received highest ratings for appearance, texture, taste and general acceptability at the fully grown stage (Fig. 3). These same two varieties were clearly preferred at the sprouting stage as well. Only at the microgreen stage did the second commercial cultivar 'Hung-Shing-Tsai' receive slightly better ratings.

Significant differences among the four varieties were detected at all three growth stages with regard to different parameters such as appearance, taste, texture and general acceptability, indicating that consumers were able to perceive differences in sensory attributes.

Nutritional analysis of amaranth sprouts, microgreens and fully grown leafy amaranth

Mean dry matter and protein content was highest in fully grown leafy amaranth, followed by amaranth sprouts, while—surprisingly—amaranth microgreens had the lowest dry matter and protein content (Tables 2,4,6), although they were grown for nine days compared with sprouts grown for seven days only. Among 25 types of microgreens assessed by Xiao and co-workers (2012), garnet amaranth microgreens showed a relatively high dry weight percentage of 9.3, much closer to the dry matter content determined for fully grown leafy amaranth and amaranth sprouts in our trials.

Mean protein, Fe and Zn content was also considerably higher in amaranth sprouts compared with amaranth microgreens (Tables 2,4). Only the mean calcium content of amaranth microgreens was 1.6-fold higher than that in amaranth sprouts. Microgreens of the genebank accession VI044470 and commercial cultivar 'Hung-Shing-Tsai' had the highest calcium levels (Table 4). The zinc content of amaranth sprouts of three varieties was almost identical, only accession VI044470 presented a lower content (Table 2). Sprouts of 'Juan-Chih-Shing' and 'Hung-Shing-Tsai' presented the highest iron and calcium content, respectively. Zinc content of amaranth leaves at fully grown stage was similar to that in amaranth sprouts, while iron and calcium content was 1.9-fold and 7.8-fold higher, respectively (Tables 2,6). Compared with microgreens, calcium content was still 5-fold higher in fully grown amaranth leaves (Tables 4,6).

Vitamin C or ascorbic acid is an essential nutrient for the human body—it is required for the biosynthesis of collagen, carnitine and neurotransmitters (Naidu 2003). While most plants and animals have the ability to synthesize ascorbic acid, apes and humans depend on the intake of this essential nutrient through fruit and vegetables or supplementation in the form of tablets. Health benefits attributed to vitamin C include antioxidant, anti-aetherogenic, anti-carcinogenic, and immunomodulator effects. Rose and Bode (1993) mention three principal reasons that enable ascorbate to assume a prominent role as scavenger of free radicals in the human body: (a) it is chemically suited to react with oxidizing free radicals; (b) it is present in the body at sufficiently high concentrations to be effective; (c) it fits into the physiology of cellular transport and metabolism, and thus contributes to the potential for longevity. The recommended daily allowances (RDA) for adults are 90 mg of ascorbic acid per day for men and 75 mg for women (Frei and Traber 2001). Based on clinical and epidemiological studies reduced incidence of mortality from heart diseases, stroke and cancer can be expected with a dietary intake of 100 mg ascorbic acid per day (Carr and Frei 1999).

There was a substantial increase in vitamin C content from amaranth sprouts to microgreens (2.7-fold) and from amaranth microgreens to fully grown leafy amaranth (2.9-fold) (Tables 3,5,7). Consuming 100 g of leafy amaranth at the fully grown stage would provide 79% of RDA for women. There were statistical differences among varieties at the sprout stage and both genebank accessions had the highest vitamin C content (Table 3). At the microgreen and fully grown stage no statistical difference among varieties was noted. Much higher (6.5-fold) total ascorbic acid concentrations were detected by Xiao et al. (2012) in commercially grown garnet amaranth microgreens compared with the concentrations found in our experiments. Among 25 commercially grown microgreen crops, amaranth had the second highest total ascorbic acid content (131.6 mg/100 g FW) after red cabbage in the trials conducted by the aforementioned authors. These vitamin C concentrations are much higher than those commonly reported for mature amaranth leaves ranging from 11.6-45.3 mg/100 g FW (Punia et al. 2004; Mensah et al. 2008). The USDA National Nutrient Database for Standard Reference, Release 23 indicated a vitamin C content of 43.3 mg and 41.1 mg per 100 g FW of edible portion of raw and cooked amaranth leaves, respectively (Ebert et al. 2011), thus falling within the range reported by Punia et al. (2004) and Mensah et al. (2008). Mean vitamin C content of fully grown amaranth leaves reached 59 mg in our trials, thus slightly above the aforementioned levels.

Higher plants exhibit a relatively uniform carotenoid composition and a small number of carotenoids, i.e., the β-carotene, the xanthophylls lutein and neoxanthin as well as those involved in the xanthyphyll cycle (violaxanthin, antheraxanthin, and zeaxanthin), which are ubiquitously present in the photosynthetic membranes of higher plants (Young 1993). The α-carotene is less frequent, but can also be found in a number of plant species. Both, α-carotene and β-carotene are called provitamin A as they can be easily converted by the human body into vitamin A, which is important for maintenance of visual acuity. Carotenoids are the first line of defense against photo-oxidative stress in plants, given their capacity to quench singlet oxygen as well as triplet chlorophylls through a physical mechanism involving transfer of excitation energy followed by thermal deactivation (Ramel et al. 2012). Another mechanism is known as chemical quenching and involves a chemical reaction between the quencher and singlet oxygen.

Both provitamins A (α-carotene and β-carotene) were detected in all three developmental stages and considerably increased from sprouts to microgreens (Tables 3,5). Microgreens of the genebank accession VI044470 had the highest α-carotene and β-carotene content. The level of α-carotene of microgreens of this accession was higher than those found in mature amaranth leaves, while the β-carotene content was similar in microgreens and mature leaves. The β-carotene content of amaranth microgreens reported earlier was 4.6-fold higher (8.6 mg/100 g FW) than found in our experiments and red sorrel microgreens showed even higher β-carotene content of up to 12.1 mg/100 g FW (Xiao et al. 2012).

Violaxanthin, a natural orange-colored carotenoid found in photosynthetic organs of plants, was analyzed in amaranth sprouts but found to be below detectable levels. It reached 0.91 and 1.75 mg/100 g FW in amaranth microgreens and fully grown amaranth leaves, respectively (Tables 5,7)—again much lower than the violaxanthin levels (4.4. mg/100 g FW) reported by Xiao et al. (2012). Neoxanthin was found at all three growth stages, with substantially higher levels at the microgreen and fully grown stage compared to amaranth sprouts (Tables 3,5,7).

Lutein and zeoxanthin are macular pigments that act as optical filters and play a critical role in the prevention of age-related macular degeneration (Beatty et al. 1999).

Macular pigment is entirely of alimentary origin and its density can be augmented through dietary modification. Apart from restricting photochemical retinal injury by screening blue light, macular pigment might also play a role in limiting oxidative damage by quenching reactive oxygen species. The lutein content increased substantially from amaranth sprouts to microgreens (2.18 mg/100 g FW), but was still slightly lower in the latter compared to fully grown amaranth leaves (Tables 3,5,7). These concentrations are again in contrast to the findings of Xiao et al. (2012), who reported 8.4 mg/100 g FW of lutein/zeoxanthin in amaranth microgreens. Microgreens of genebank accession VI044470 and cultivar 'Hung-Shing-Tsai' showed the highest lutein and neoxanthin content (Table 5).

Highly reactive free radicals and oxygen species are inevitably produced in biological systems and are also encountered exogenously. They may oxidize nucleic acids, proteins, lipids or DNA and are known to cause various degenerative disorders, such as Alzheimer's disease, Parkinson's disease, cardiovascular disturbances, cancer, and aging (Prakash et al. 2001; Uttara et al. 2009). Antioxidants are considered a persuasive therapeutic option to combat neurodegenerative diseases given their capability to neutralize free radicals. Fruits, vegetables and herbs contain a wide range of antioxidants comprising phenolic compounds, such as phenolic acids, flavonoids, quinons, coumarins, lignans, tannins, etc.; nitrogen compounds, such as alkaloids, amines, betalains, etc.; vitamins; terpenoids including carotenoids and other endogenous compounds that have a high antioxidant activity (Uttara et al. 2009; Samuoliene et al. 2012). The antioxidant activity is commonly expressed in micromoles of Trolox equivalents (TE) per 100 g (Prakash et al. 2001).

Surprisingly, the antioxidant activity (AOA) of amaranth sprouts was much higher than that of amaranth microgreens and was highest in fully grown leaves reaching 1924 µmol TE with variety 'Hung-Shing-Tsai' (Tables 3,5,7). While sprouts of genebank accession VI044470 had a relatively low AOA, the other three varieties had a high AOA ranging from 1355 TE to 1491 TE—about double the antioxidant activity measured in amaranth microgreens, on average. Microgreens of VI044470 showed only a slight decrease in AOA compared with sprouts, in contrast to the other three varieties.

Hydroxycinnamic acid compounds are an important source of antioxidants and are usually found as esters of organic acid or glycosides in plants or are bound to protein and cell wall polymers (Chen and Ho 1997). These compounds, which include caffeic acid and chlorogenic acid, have a significant effect on stability, color, flavor and nutritional value of food. Caffeic acid concentration notably increased from amaranth sprouts to microgreens to fully grown amaranth leaves (Tables 3,5,7). Chlorogenic acid was detected only in microgreens of genebank accession VI047764 and was below detectable levels in the other three varieties. Chlorogenic acid was not detected in amaranth sprouts and fully grown leaves.

SUMMARY AND CONCLUSION

Genebank accession VI044470 and commercial cultivar 'Juan-Chih-Shing' consistently received the highest ratings for appearance, texture, taste and general acceptability at the sprout and at the fully grown stage. At the microgreen stage, VI044470 and 'Hung-Shing-Tsai' received the highest ratings.

The phytonutrient content showed significant differences among varieties within the same growth stage and also differed between growth stages. Mean protein, Fe and Zn content was considerably higher in amaranth sprouts compared with amaranth microgreens. There was a substantial increase in vitamin C content from amaranth sprouts, to microgreens (2.7-fold) and from amaranth microgreens to fully grown leafy amaranth (2.9-fold). Both provitamins A, α-carotene and β-carotene were detected in all three developmental stages and considerably increased from sprouts to microgreens. The content of α-carotene was the same at the microgreen and fully developed stage, while β-carotene content was slightly higher at the latter stage.

Sprouts and microgreens offer a niche market for vegetable producers and can easily be grown by consumers themselves, especially in urban or peri-urban settings, providing a constant, year-round source of easily accessible, fresh and nutrient-dense produce and serving as educational and therapeutic tool for children in the homestead. Given their extremely short growth cycle, sprouts and microgreens can easily be grown organically, without external inputs like fertilizers and pesticides.

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Table 1. Timetable for production and harvesting of amaranth sprouts, microgreens and fully grown leafy amaranth in 2013

Dates	Sprouts	Microgreens	Fully grown stage
Sowing for nutritional analysis	3 July 2013	2 July 2013	1 October 2013
Harvesting of samples for nutritionalanalysis	10 July 2013	11 July 2013	29 October 2013
Sowing for consumer evaluation	18 July 2013	2 July 2013	1 October 2013
Harvesting of samples for consumer evaluation	26 July 2013	11 July 2013	29 October 2013
Consumer evaluation	26 July 2013	12 July 2013	29 October 2013

Table 2. Dry matter, protein and minerals of amaranth sprouts per 100 g edible portion of fresh weight

Accession/cultivar	Dry matter (g)	Protein (g)	Minerals		
			Ca (mg)	Fe (mg)	Zn (mg)
VI044470	6.13^{b}	1.91^{b}	48.60^{c}	0.92^{c}	0.43^{b}
VI047764	8.80^{a}	2.19^{ab}	27.82^{d}	1.17^{bc}	0.52^{a}
Juan-Chih-Shing	8.64^{a}	2.31^{a}	60.85^{b}	1.68^{a}	0.53^{a}
Hung-Shing-Tsai	8.98^{a}	2.42^{a}	71.33^{a}	1.47^{ab}	0.52^{a}
Mean	8.14	2.21	52.15	1.31	0.50

Values within a column with different letters are significantly different at $P< 0.05$.

Table 3. Carotenoid, vitamin C, antioxidant activity (AOA) and caffeic acid content of amaranth sprouts per 100 g edible portion of fresh weight

Accession / cultivar	Carotenoids					Vitamin C (mg)	AOA (μmol TE)	Caffeic acid (μmol)
	Violaxanthin (mg)	Neoxan-thin (mg)	Lutein (mg)	α-carotene (mg)	β-carotene (mg)			
VI044470	0.00	0.04[a]	0.46[a]	0.01[a]	0.10[a]	8.00[a]	823.00[b]	4.95[a]
VI047764	0.00	0.03[a]	0.43[a]	0.01[a]	0.11[a]	9.98[a]	1442.00[a]	4.79[a]
Juan-Chih-Shing	0.00	0.02[b]	0.38[a]	0.01[a]	0.11[a]	5.00[b]	1355.33[a]	5.26[a]
Hung-Shing-Tsai	0.00	0.02[b]	0.45[a]	0.01[a]	0.10[a]	7.00[ab]	1490.67[a]	5.92[a]
Mean	0.00	0.03	0.43	0.01	0.10	7.59	1277.67	5.23

Values within a column with different letters are significantly different at $P < 0.05$.

Table 4. Dry matter, protein and minerals per 100 g edible portion of fresh weight in amaranth microgreens

Accession/cultivar	Dry matter (g)	Protein (g)	Minerals		
			Ca (mg)	Fe (mg)	Zn (mg)
VI044470	5.33[a]	1.38[ab]	91.00[a]	1.04[a]	0.34[ab]
VI047764	4.43[c]	1.26[b]	69.33[b]	0.71[a]	0.32[b]
Juan-Chih-Shing	4.70[bc]	1.35[ab]	74.33[b]	0.82[a]	0.39[a]
Hung-Shing-Tsai	5.13[ab]	1.55[a]	91.33[a]	1.27[a]	0.37[a]
Mean	4.89	1.39	81.50	0.96	0.36

Values within a column with different letters are significantly different at $P < 0.05$.

Table 5. Carotenoids, vitamin C, antioxidant activity (AOA), chlorogenic acid and caffeic acid content of amaranth microgreens per 100 g edible portion of fresh weight

Accession / cultivar	Violaxanthin (mg)	Neoxan-thin (mg)	Lutein (mg)	α-carotene (mg)	β-carotene (mg)	Vitamin C (mg)	AOA (μmol TE)	Chlorogenic acid (μmol)	Caffeic acid (μmol)
VI044470	0.77[c]	1.00[a]	2.66[a]	0.35[a]	2.34[a]	23.33[a]	639.33[bc]	0.00[b]	14.52[c]
VI047764	0.67[c]	0.75[b]	1.95[b]	0.13[c]	1.87[b]	19.00[a]	567.67[c]	0.35[a]	12.89[d]
Juan-Chih-Shing	0.99[b]	0.62[b]	1.64[b]	0.10[c]	1.37[c]	19.49[a]	680.33[b]	0.00[b]	21.09[a]
Hung-Shing-Tsai	1.20[a]	0.98[a]	2.66[a]	0.27[b]	1.91[b]	18.67[a]	782.67[a]	0.00[b]	16.79[b]
Mean	0.91	0.84	2.18	0.21	1.87	20.13	667.50	0.09	16.32

Values within a column with different letters are significantly different at $P < 0.05$.

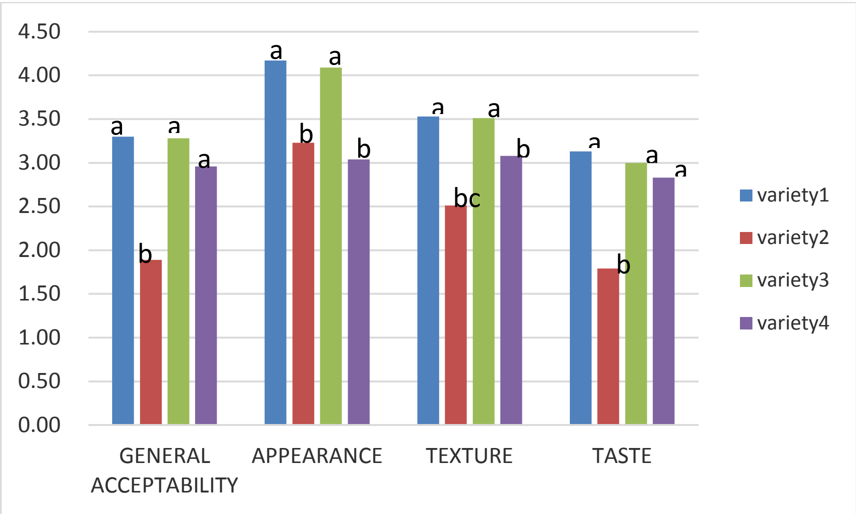
Table 6. Dry matter, protein, oxalate and minerals per 100 g edible portion of fresh weight of amaranth at fully grown stage

Accession/cultivar	Dry matter (g)	Protein (g)	Oxalate (mg)	Minerals		
				Ca (mg)	Fe (mg)	Zn (mg)
VI044470	10.65[a]	2.98[a]	171.38[a]	443.54[a]	2.76[a]	0.42[b]
VI047764	8.96[b]	2.82[b]	287.27[a]	337.31[c]	2.02[c]	0.56[a]
Juan-Chih-Shing	9.39[b]	2.65[c]	249.07[a]	401.27[b]	2.44[b]	0.60[a]
Hung-Shing-Tsai	10.88[a]	3.07[a]	254.17[a]	445.18[a]	2.67[ab]	0.42[b]
Mean	9.97	2.88	240.47	406.83	2.47	0.50

Table 7. Content of carotenoids, vitamin C, antioxidant activity (AOA), chlorogenic acid, and caffeic acid per 100 g edible portion of fresh weight of amaranth at fully grown stage

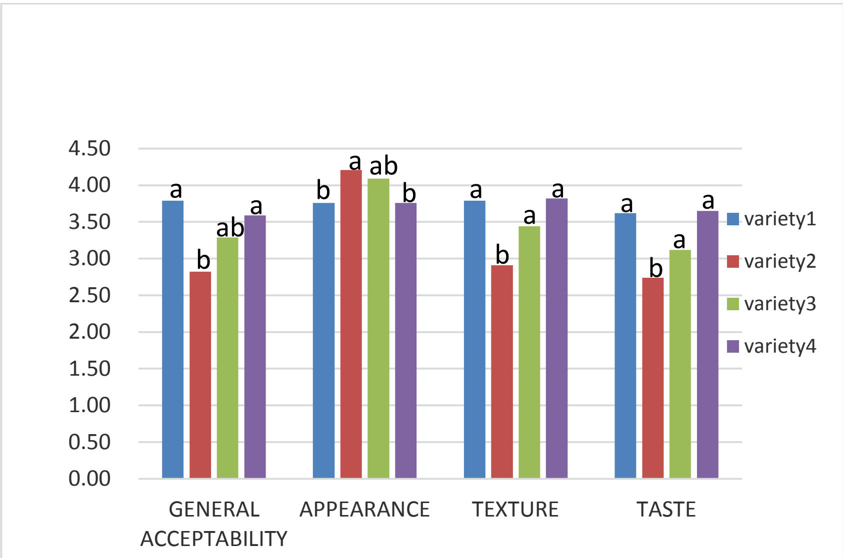
Accession /cultivar	Violaxanthin (mg)	Neoxanthin (mg)	Lutein (mg)	α-carotene (mg)	β-carotene (mg)	Vitamin C (mg)	AOA (μmol TE)	Chlorogenic acid (μmol)	Caffeic acid (μmol)
VI044470	1.43[a]	0.99[ab]	2.61[a]	0.21[a]	1.16[b]	56.33[a]	1815.72[ab]	0.00	40.51[b]
VI047764	2.03[a]	1.51[a]	4.14[a]	0.29[a]	4.45[a]	56.95[a]	1604.09[b]	0.00	39.72[b]
Juan-Chih-Shing	1.79[a]	0.72[b]	2.21[a]	0.12[a]	2.21[ab]	59.37[a]	1643.77[b]	0.00	66.81[a]
Hung-Shing-Tsai	1.75[a]	1.12[ab]	3.03[a]	0.22[a]	2.23[ab]	63.85[a]	1923.55[a]	0.00	49.39[ab]
Mean	1.75	1.09	3.00	0.21	2.51	59.12	1746.78	0.00	49.11

Values within a column with different letters are significantly different at *P*< 0.05.a



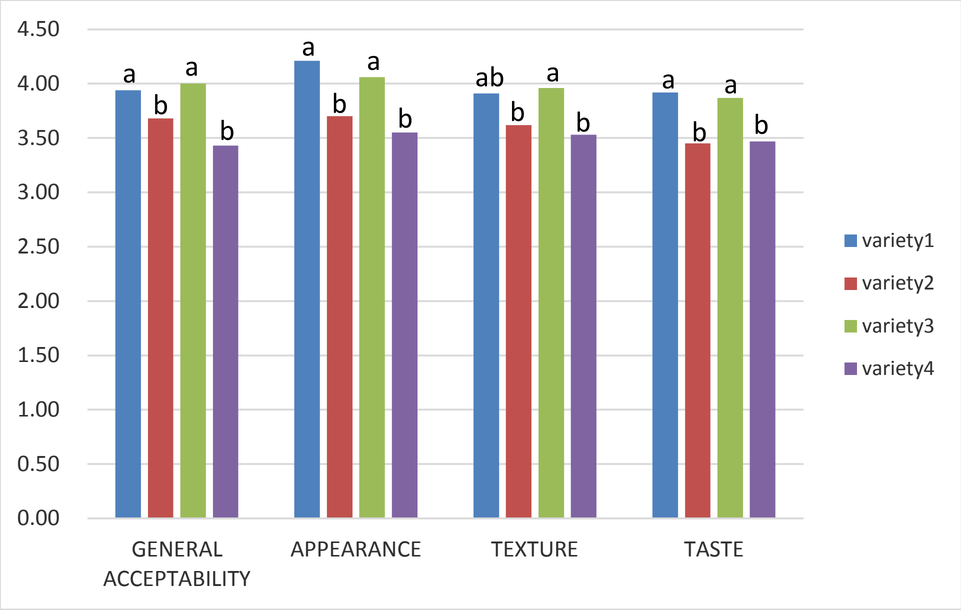
Columns headed by different letters within each of the four parameters indicate statistical difference by the LSMEANS/PDIFF at P>0.05

Figure 1. Results of consumer evaluation of amaranth sprouts



Columns headed by different letters within each of the four parameters indicate statistical difference by the LSMEANS/PDIFF at P>0.05

Figure 2. Results of consumer evaluation of amaranth microgreens



Columns headed by different letters within each of the four parameters indicate statistical difference by the LSMEANS/PDIFF at P>0.05.

Figure 3. Results of consumer evaluation of fully grown leafy amaranth

The organic agriculture food chain of Camarines Sur, Bicol, Philippines

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ABSTRACT

This research was conducted to present the current status of the organic agriculture sector in the Bicol Region. This research comes in the face of stakeholder groups increasingly advocating the need for sustainability through organic production. In the same light, it was observed that the organic movement is gaining momentum with organic products becoming one of the growing segments of the food market. In the Bicol region, where the number of organic farmers and consumers is increasing, organic farmers are starting to carve a niche for their products and a growing number of farm products are being produced organically. As the number of players and subsequent demand increase, it is observed that changes are taking place in the organic produce food chain not only in terms of the volume but in terms of the type of produce itself. Initially being associated with small farmer groups, organic food production is now catching the interest of even private farms/farmers. It is interesting to note that the number of stakeholders is increasing, starting with the non-government sector to the government to church-based organizations. Organic food production is growing, albeit slowly, and the necessary structure and environment should be in place to ensure continuous growth of the sector.

Keywords

Organic Agriculture in Camarines Sur, Organic Production, Demand and Supply for Organic Products

THE ORGANIC AGRICULTURE SCENARIO IN THE PHILIPPINES

Organic agriculture is an “agricultural production system that promotes environmentally, socially and economically sound production of food and fibers and excludes the use of synthetically compounded fertilizers, pesticides, growth regulators, livestock feed additives and genetically modified organisms" (IFOAM, 2008 as cited in the da-bar website). In the Philippines, Abaygar (2008) observed that the organic agriculture sector may still be in “its embryonic phase when compared to agricultural sectors of other countries” but it appears to be at a turning point in its development. A case in point could be the comment of the International Federation of Organic Agriculture Movements (IFOAM) in 2008 that the country’s organic industry was estimated at US$5.2 million, but it appears to be relatively small, featuring mainly locally grown products that are limited in variety (IFOAM 2008). Although small, the industry is still growing at 10-20% annually (www.agribusinessweek.com). The organic production area in the country rose from 3,500 hectares in 2004 to roughly 39,400 hectares in 2006. Estimates also showed an increase of 45% or 52,400 hectares in the 2008-2009 year level (Manghirang as cited by Lesaca 2008). Based on consumer surveys and market studies conducted by the Upland Marketing Foundation

Inc. (UMFI), consumers may not know what organic products are, however, consumers do prefer products that are deemed ‘healthy’. This preference for a ‘healthy’ product is reflected on the premium price that they are willing to pay (Concepcion et al. 2007).

There is a relatively small domestic market for organic foods. Apart from that consumers are now able to find the following organic products in the market: organic rice, fresh vegetables and other food products available in supermarkets and specialty shops and other major organic imports such as honey, tea, coffee, spices, and mostly processed food from the United States. The OCCP website (2009) observed that Filipino consumers as well as expats are buying organic products for personal health reasons and in support of sound environment farming practices. It was also reported that the demand for organic products will be far greater than local production. The major organic produced locally are rice, fresh vegetables, and sugar.

In 2010, the government passed the Organic Agriculture Act of 2010 (RA 10068) which declared it the policy of the State to promote, propagate, develop further and implement the practice of organic agriculture in the Philippines that will cumulatively condition and enrich the fertility of the soil, increase farm productivity; reduce pollution and destruction of the environment, prevent the depletion of natural resources, further protect the health of farmers, consumers and the general public, and help cut expenses on imported farm inputs. RA 10068 further states that the Department of Agriculture (DA) shall thereafter allocate the amount of at least 2% of its annual budget for the implementation of the Organic Agriculture Programs (www.bar.gov.ph).

THE ORGANIC AGRICULTURE SITUATION IN CAMARINES SUR, BICOL

The province of Camarines Sur is one of the six provinces in the Bicol Region in Luzon. Its capital is Pili and the province borders Camarines Norte and Quezon to the north, and Albay to the south. To the east lies the island province of Catanduanes across Maqueda Channel. In terms of size, it is the largest with a land area of 5,266.8 square kilometers.

The region actively promotes an organic culture primarily for its environmental soundness, benefits to human health, changes in consumers’ perception and preference for healthy food products. In general, trend in the promotion of organic farming in Bicol was initiated in 1997 by a private company (Shell Foundation) and Irrigators Associations in Camarines Sur; then in 2007 by parish-based association like the Socio-Pastoral Action Center Foundation Inc. (SPACFI), NGOs, and farmer cooperatives with environmental/sustainable agriculture/organic farming advocacies; and in 2009 by some private entrepreneurs particularly the Organik Bikol Advocateurs Network Inc. (OBAN) members, in 2010 by the academe and then the Local Government Units (LGU’s)/government particularly with the passage of RA 10068 or the Organic Agriculture Act of 2010 (Bordado 2013).

Most organic farmers in Camarines Sur and Camarines Norte are involved in the production and marketing of organic rice, vegetables or farm inputs such as organic fertilizer, particularly vermicompost.

The organic rice chain

Organic rice production comes from traditional rice varieties organically grown without the use of synthetic fertilizers and harmful chemicals. The farmers use seeds given free by some NGO’s or by the Department of Agriculture. Other farmers get their seeds from the Pecuaria Development Cooperative Inc. (PDCI) at a cost of Php

25 – Php 28/kg. PDCI is a certified organic rice producer and trader in the country producing the following varieties of prime organic rice: polished red, unpolished red, white, brown, pink, violet, black, and blended rice. Further, PDCI is able to develop its own organic rice varieties, called "Pecuaria selections." The farmers harvest 70-100 cavans per hectare per cropping per year, which is roughly equivalent to 875 – 1250 kg or an average of 17.5 – 25 sacks per hectare per cropping per year. From the farm the organic rice is delivered using trucks, jeepneys, or tricycles, or it can be picked-up on farm.

Market performance

Organic rice

Some 35% of the farmer-respondents cultivate organic rice just for home consumption. These are the farmers whose production ranges from 5-10 sacks per cropping cycle. It was learned however, that as their volume of production increases, farmers start to sell their goods for the local market or deliver them to interested neighbors and/or consumers.

For those who produce organic rice for the market, 75% of them sell directly to the Pecuaria Development Cooperative Inc. (PDCI) who is also the major supplier of UMFI and whose outlet includes supermarkets in Manila and Bicol region. At the same time, PDCI also entertains walk-in buyers just like the other farmer-respondents. Other outlets identified by 12.5% of the respondents included the Weekend Market. With the assistance of cooperatives and NGO's, the market for the rice farmers and vegetable farmers has expanded to include other municipalities, cities and even Metro Manila (Figure 1).

The organic palay/rice is packed at 40 or 50 kg/sack. At the retail outlets, organic rice is normally packed in bags of 2-5 kg. Price ranges from Php 40-60/kg (Table 1). Aside from organic rice, some 27% of the respondents sell organic rice seeds to industry associations such as the Socio-Pastoral Action Center Foundation Inc. (SPACFI) or to other seed growers.

Organic vegetables

Rice may be the major domestic organic product produced in Camarines Sur. However, most of the farmers interviewed were also involved in the production of upland vegetables. In the case of Camarines Norte farmer-respondents, although they are also into organic rice production, a majority of the farmers interviewed were also involved in vegetable production.

The Organik Bikol Advocateurs Network Inc. (OBAN) which is based in Pili, Camarines Sur, is mostly engaged in the production of organic vegetables especially lettuce. The most popular variety of lettuce grown is romaine, red corral and green corral. The association also produces assorted vegetables which are distributed to some of the restaurants, supermarkets and weekend market in the province.

In the municipality of Ocampo (still in the province of Camarines Sur), the Cagmanaba Association of Neutral Domain for Union Yield of Organic Farmers Group (CAANDUYOG) produces organic palay and vegetables like cucumber, squash, bitter gourd, bell pepper, eggplant, lettuce, radish, carrots, pole sitao, Baguio beans and white gourd. The organic palay is milled in PDCI who is also their major market outlet. The organic vegetables are sold in the Weekend market in Magsaysay, Naga City and Food Terminal in Cagmanaba.

In the province of Camarines Norte, the municipalities of Basud, Talisay, and Labo produce organic palay and organic vegetables like pole sitao, white gourd, tomato, eggplant, Baguio beans, white gourd, squash and papaya. The distributor of organic palay is the Socio-Pastoral Action Center Foundation Inc. (SPACFI) located at Nazareth Center, Baldivino, Daet. The organic vegetables are brought to the nearest market outlets in Camarines Norte such as Panganiban, Labo and Daet market.

It has become common for small farmers to be formed into groups like Rinconada Movement for Environment and Sustainable Agriculture (RINCOMESA) and CAANDUYOG and most of the groups are NGO/PO-assisted social enterprises. Church-based social enterprises are also growing in number like Socio-Pastoral Action Center Foundation Inc. (SPACFI) and Sta. Rita de Cassia who are all involved in the production of agricultural inputs, organic animal (native pig), and organic vegetables.

The distribution channel is fairly the same for all types of vegetables. The organic vegetables are sold directly from the farmer-producers to wholesalers (normally represented by local markets) or industrial buyers like restaurants who are known for their organic products. In certain cases, the consumers go straight to the farmer-producers for their vegetable requirements. For organic vegetables, the estimated average volume based on volume sold directly to consumers, with no middlemen, was about 58% in 2011. The estimated volume sold by producers through direct-to-retail was about 25%. The estimated volume sold through wholesale market channels was 16%. The direct-to-retail category includes products sold through the Food Terminals in their respective municipalities as well as the Weekend Market initiated by Organik Bikol Advocateurs Network Inc (Fig. 2).

Farm gate price

According to the farmer-respondents, farm-gate price of organic products, both for vegetables and rice is “minimal” and is quite affordable for all types of buyers. Table 2 lists the average farm-gate and retail prices of major vegetables grown in the provinces of Camarines Sur and Norte.

Retail prices

Organic product retailers follow the cost-plus pricing policy where an average of Php 520/kg is added to the wholesale or farm-gate price.

Drivers of growth in the sector

From anecdotal sources and discussion with farmers and other stakeholders, it became evident that there are some factors which seem to push the growth of the industry in the Bicol Region. These factors can be grouped into consumer-related, supplier-related, marketing and government-related factors.

Consumer-related factors

Anecdotal sources point to the positive effects of increased consumer health concerns to the growth of the organic food sector. Zotos (1999:92) presented the case of marketing organically produced food products in Greece and commented that “fairly radical changes in consumer perceptions about food safety have occurred over the last decades. Consumers are concerned about the many additives mentioned on food products and suspicious of the need for modern food-processing technology.” At present, in terms of trends and movements of consumer preferences, the market for products that are deemed healthy is increasing. It is even said that demand for organic product is growing at a pace where demand outstrips supply; thus, organic food products are supply, not demand-constrained. It is estimated that demand for organic products will exceed the locally produced supply since consumers are becoming aware of organic food, the need for a healthy lifestyle and have better access to them (www.agribusinessweek.com).

The same changes are being observed in the province. For instance, in an interview with PDCI officers, they related that they have noticed an increase in number of walk-in organic rice buyers who were referred/asked by their physicians to go organic and shift from white to brown rice. This maybe an indication of another market segment waiting-to-be served. However, one problem which the sector faces is the high price or the "premium" price normally associated with organic products. This effectively limits the potential market for organic product to include only those in the middle-to-upper income classes.

Supplier-related factors

Camarines Sur and Norte are major producers and suppliers of organic rice/palay, organic vegetables, and organic fertilizer in the region. On the supply side, it is important to note that organic farmers and farmers association espousing organic farming are on the rise. Previously, it was just PDCI who was advocating organic production; then, other groups started coming out such as RINCOMESA, CAANDUYOG and other Church-based social enterprises like the Socio-Pastoral Action Center Foundation Inc. (SPACFI) and Sta. Rita de Cassia.

The presence of such support groups could help explain why the organic produce middlemen in the province are increasingly reducing their reliance on spot markets for their major input requirements. Instead, it was observed that vertical coordination between producers and other chain members are becoming tighter particularly because most of the farmers are members of industry associations or cooperatives. In fact, even local parish churches are becoming active in the promotion of organic agriculture farming and are willing partners of local government units in the promotion of such an advocacy.

However, just like other fresh produce products, organic products are characterized by perishability, seasonality, and a strong dependence of supply on climatic conditions. In effect, such problems impact on and raise uncertainties about volume and prices. Compounding the problem on the seasonality and variability of agricultural production is the fact that production is normally carried out in small farm units. In Camarines Sur and Norte, the average farm sizes for rice production range from 5000 m^2 – 3 hectares. However, other commodities are also planted, effectively reducing the space allotted for rice production. In reality, these characteristics pose challenges to the supply chain.

Institutional and Government-related factors

Industry associations are becoming active in the promotion of organic farming and subscribe to sustainable agriculture. RINCOMESA members are practitioners and advocates of organic agriculture and environmental protection.

Even government organizations and local government units have joined the advocacy for organic agriculture. To illustrate, DA and the National Organic Agriculture Program (NOAP) were tasked to formulate the necessary requirements: 1) regulations and guidelines, 2) certification and accreditation, 3) market promotion and networking, 4) organic information for producers, handlers and processors, and 5) development and extension. Further, under Section 8 of EO 481, the DA, DOST, state universities and colleges (SUCs) and other concerned agencies, are directed to develop, enhance, support and consolidate activities and related technologies to protect the environment and improve organic matter depleted agricultural soils, reduce cost of production, improve product quality and increase value-added for global competitiveness of organic produce. All these developments imply that policymakers and other interested groups are bent on ensuring the successful implementation of organic agriculture/farming, not just in the province but in the entire country.

CONCLUSION AND STRATEGY IMPLICATIONS

The organic agriculture sector is growing, albeit, slowly. Over the years, the evolution of the sector is manifesting itself in the type and volume of production. Having started with rice, it now also includes vegetables, some farm animals and even farm inputs such as organic fertilizer. The people involved and the roles they play have similarly evolved (Table 3). Previously the roles were typically played by a single household or farmer, but now they have expanded and involve several key stakeholders.

The interest in organic agriculture is not only ecological or environmental but involves health and wellness as well. The players involved are not just marginalized farmers; interest has been generated even among the more affluent private farms. In fact, organic agriculture has become a common cause for almost every sector of our society: agricultural, academe, industry, NGOs, government and even the church. Such is the impact of organic agriculture, which may be reflective of the desire of our society not just for healthy products but for production processes that are sustainable in nature, of production activities that seek to address the triple bottom line of people, profit and planet.

Implications for marketing

- Consumers are increasingly looking at and reading the labels. This implies a need for certification and information among the buyers.
- There is a big potential market for organic food products since the current market for organic products are mostly professionals and those belonging to middle to high income groups. The other players may be inspired to follow the lead of one of the organic farmers who purposely sell for a little less so that those belonging to other income classes like the low income or average income groups with income of at least Php 9,061 per month, based on the "Family Income and Expenditure Survey" (FIES) of the National Statistical Coordination Board (NSCB), can still enjoy healthy products.

Implications for policy making

The Department of Agriculture (DA) and the National Organic Agriculture Program (NOAP) were tasked to formulate the necessary regulations and guidelines, certification and accreditation, market promotion and networking, organic information for producers, handlers and processors, and development and extension. The certification and accreditation has to be done fast. In a dialog with some organic farmers, they also lament the expenses associated with certification. Hence, efforts should be made to minimize expenses for certification. Secondly, academe can be trained to certify or to assist in the certification process so certification does not have to be centralized in one office, therefore facilitating the process.

The academe can be tapped to provide the necessary training needed by the practitioners and can provide the expertise needed for postharvest and processing activities. This would contribute to increased shelf-life and value-addition to crops.

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Table 1. Price of organic palay

Product Description	**Pricing Scheme**
Organic palay	Php 1,200 per sack P15/kg-dry P12/kg-wet
Red Rice	Php 40/pack (2-5 kg/pack)
Brown Rice	Php 48-60 per kg
Black Rice	Php 60 per kg

Table 2. Average prices of organic vegetables in Camarines Sur and Norte, 2011

Product Description	**Farmgate price**	**Retailers' Buying and Selling Prices**	
		Buying	**Selling**
Cucumber	Php 40	P40	P45
Squash	Php 12-20	Php 12-20	Php 15-25
Ampalaya	Php 40-60	Php 40-60	Php 60-65
Bell pepper	Php 60-70	P70	P75
Upo (white gourd)	Php 20	P20	P25
Patola	Php 10-15/pcs	P15	P20
Eggplant	Php 15-35	Php 20-35	Php 25-40
Lettuce	Php 40-180	Php 40-180	Php 45-200
Radish	Php 20 -30	Php 20 -30	P25 – 40
Carrots	Php 40	Php 40	Php 50
Long sitao	Php15-20/bundle	Php15-20/bundle	Php 20-25/bundle
Baguio beans	Php 30		
Tomato	Php 40		
Gabi leaves(dried)	Php 10-17		
Gabi leaves(fresh)	Php 6/bundle		
Sili	Php 25		
Cassava leaves	Php 4/bundle		
Peanut	Php 25		
Sweet potato	Php 10-15		
Cassava	Php 5 per kg; Php150/sack		

Table 3. Mapping the activities in organic products food chain input supply

Input Supply	Farm Production	Processing	Trading	Market
Purchase/ transport seeds, fertilizer and other inputs	* land prep * planting * harvesting * transport	* drying * bagging * transport	* weighing * buying * storing * transport *selling	* weighing * quality control * logistics
Typically performed by small farms		typically performed by processors/ wholesalers	typically performed by traders	typically performed by end-users

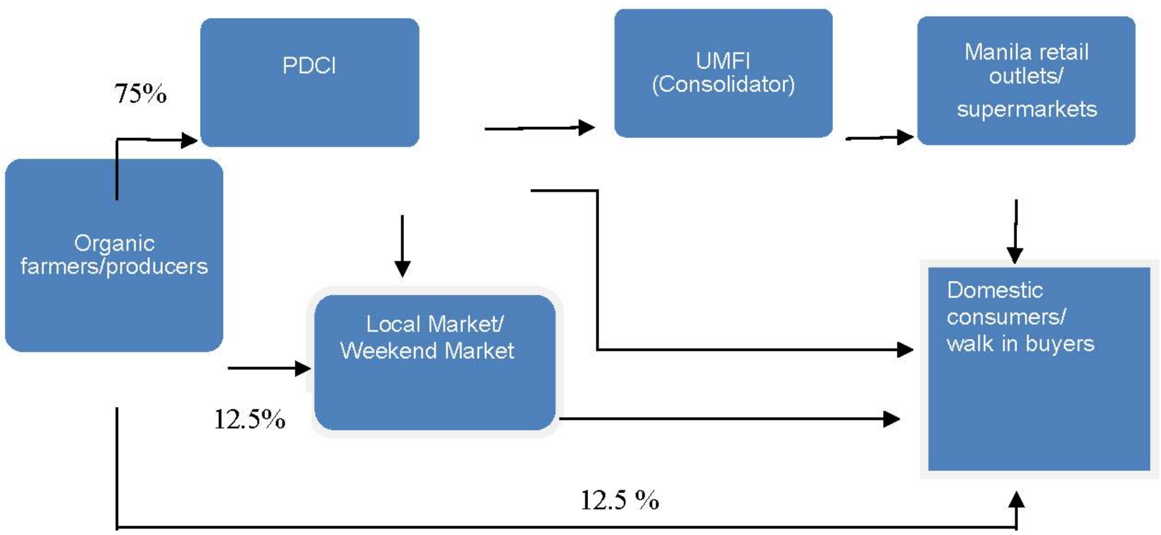

Figure 1. Organic rice chain

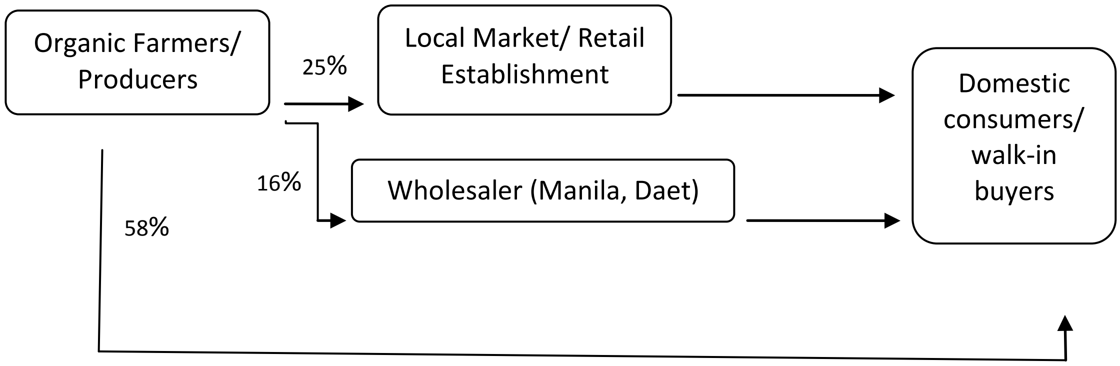

Figure 2. Organic vegetables chain

Mapping vegetables – understanding the food system of greater Bangkok, Thailand: A web-based Collaborative Research Environment

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ABSTRACT

Urban and peri-urban vegetable production and marketing systems have the potential to contribute to poverty reduction, food and nutritional security, local economic and community development, social inclusion of marginalized groups and women in particular, as well as to enhance urban environmental management by increasing biodiversity and the productive reuse of organic wastes. This project looked at 4 components of the overall food system: Smallholder vegetable producers, community gardeners, markets, consumers and street vendors. To better understand the linkages and importance of each of these components a so-called pilot Collaborative Research Environment (CRE) was developed. The core of the CRE consists of a central, spatially enabled database and a range of associated tools for distributed data entry, for remote and real-time monitoring of the incoming data, for data analysis, and last but not least for data presentation. The tools include the required Geographic Information System (GIS) functionality for spatial analysis and map-based visualization.

In the pilot study the data included in the CRE comprises empirical data from different sources such as questionnaires and surveys, spatial information on production areas in relation to vegetable diversity as well as information on producers, traders and consumers.

Some results of study concerning the different target groups show that: The producer survey shows the importance of market demands and prices influencing the decisions on which kind of crops and vegetables are grown. Other important factors here are farmers' skills and habits as well soil and water conditions. All those are strongly interrelated. Plant diseases and pests as well as climate and weather conditions are identified as major challenges for the vegetable producers. However,

47% of the producers produce more than ¾ of their self-consumed vegetables. For the community gardeners' urban gardening in Bangkok is not about food security in the sense of essential food provision: More than 70% of the interviewees never face difficulties in providing enough food for their family and around 20% rarely do, mainly because of poor harvests. However, a lot of the interviewed people refer to the problem of chemical pollution of market vegetables.

Wholesale markets play a big role for the food security in the Greater Bangkok. About 52% of products from Si Mum Muang Market stay in the Bangkok Metropolitan Area and 85% in the Greater Bangkok Area (including surrounding provinces). Many products come from the North and Northwest of Thailand but a considerable share is also grown in the periurban area around Bangkok. A number of perishable products like e.g. lettuce and kale are mostly grown in the proximity of the megacity. This once again proves the importance of periurban agriculture for food security in Bangkok. More than 70% of the local markets and over 50% of street vendors and restaurants buy at wholesale markets Si Mum Muang and Talad Thai.

Regarding consumption the survey identifies clear differences between men and women. Vegetables are eaten by 65% of male and 80% of female participants. 41% of the male and 51% of the female interviewees eat fruits. For milk products the distribution can be grouped into 32% male and 41% female consumers. 65% of men and 70% of women eat meat minimum every day. Fish/seafood are eaten 24% by men and 28% by women. It is noticeable that women are consuming all food groups more frequently. Other differences get obvious looking at different age groups. It gets clear that food habits are changing. Regarding food purchase and consumption, local markets are of extraordinary importance in Bangkok. The most common challenge for consumers in vegetable usage is the price.

Keywords
Biodiversity, Collaborative Research Environment (CRE), food security, vegetable production, community gardens, consumption, marketing, urban and periurban agriculture,

URBAN AND PERI-URBAN VEGETABLE PRODUCTION

Urban and peri-urban vegetable production and marketing systems have the potential to contribute to poverty reduction, food and nutritional security, local economic and community development, social inclusion of marginalized groups and women in particular, as well as to enhance urban environmental management by increasing biodiversity and the productive reuse of organic wastes. In order to understand the food system, a holistic approach combining quantitative and qualitative methods has been applied in this project. Bangkok's food system comprises of producers, markets, street vendors and consumers, who interact with each other on different spatial and temporal scales. The system is not static but subject to changes and fluctuations depending on external and internal political, socio-economic and geographic drivers.

This project investigated the potential of a GIS-based Collaborative Research Environment (CRE) as an innovative tool to enable researchers, policy makers and the public to find information on a range of factors that affect access to healthy, affordable food, thus, addressing abovementioned constraints. Food mapping has been defined as the process of finding out where people produce, process, purchase and consume food, and what the food needs of local people are. It is a type of needs assessment that aims to identify the geographical areas or communities that have the greatest needs in terms of access to food. Food mapping is one method used to describe and measure a community's level of food and nutritional security and is therefore not just about producing spatial maps describing physical and economic access to food. The food maps will be able to describe how people feel about local food access, for example, how culturally acceptable and appropriate it is, how convenient it is to access, how appealing it is, how safe it is to eat as well as if people have the skills and confidence needed to prepare healthier food options. Most of this goals where completed, however, an interesting finding of the study is, that so called "food deserts" are non-existing in the context of the target groups in Greater Bangkok. This does not imply, however, that such deserts are not affecting other parts of the Thai society.

The producer system changes e.g. due to rapid land use changes in periurban Bangkok, which can be clearly identified with satellite image time series. But the producer system also responds to consumer demands, new trends and food habits emerging along with the urbanization process. Market processes and political changes (e.g. the opening of the ASEAN market by 2015) may change production pattern dramatically in the future.

In early April 2012, an inception workshop was organised at Kasetsart University in Bangkok, bringing together the main stakeholders of the project, including researchers and students. At this workshop, based on the project proposal, research approach and objectives were specified. Studying the entire food chain from production to consumption from a bottom-up perspective and exploring options for up scaling were important components of the project. The main focus was on farmer communities, wholesale markets, community gardens, as well as consumers and street vendors.

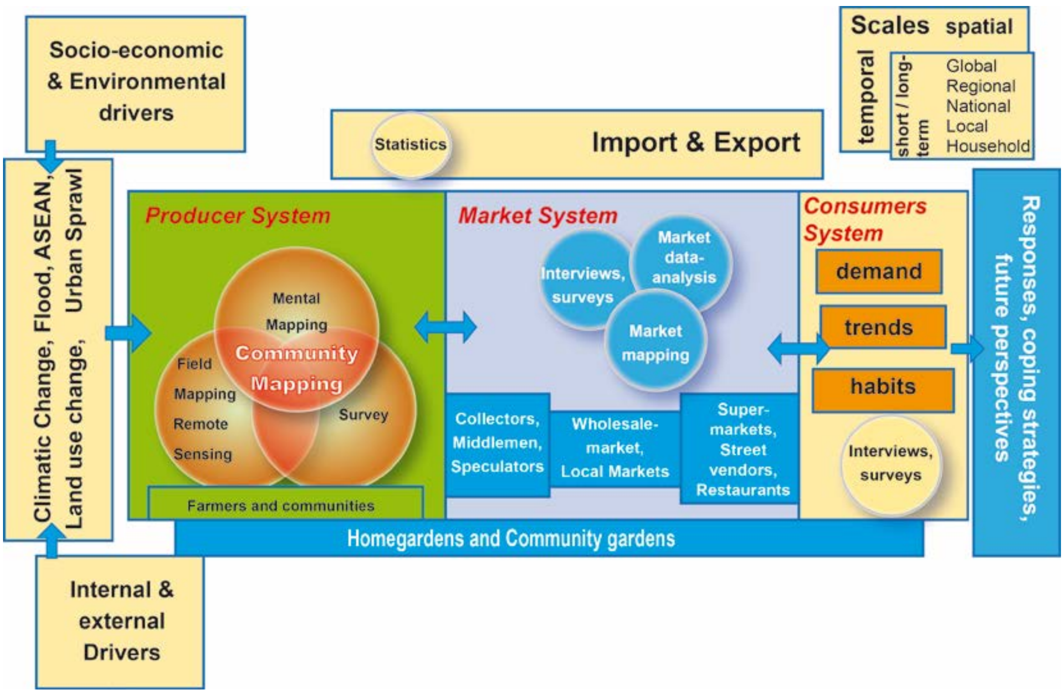

Figure 1: Conceptual framework of the food system and research approach in Bangkok

The pilot study was organized in two field campaigns, one in 2012 (April – June) carried out by an advanced group of Master students and another one in 2013 (April – August), carried out by a group of 16 German Master students together with their Thai counterparts. The first campaign was rather an orientation campaign to build the team, develop and test questionnaires in the field, to learn field and mental mapping, to train Thai and German students, and to adjust the methods to improve the second campaign. In September 2013, a final workshop took place in Thailand, where results were presented to the stakeholders and further action was discussed.

METHODS

A set of methods was used to capture the food system from different perspectives. The project aimed at gaining quantitative measurable data on food systems as well as qualitative data expressing people's needs, priorities etc. These data are organised in a Geographic Information System along with vegetable production sites that are captured via field mapping to account for the spatial dimension and patterns of food production. In 5 different locations, 30 surveys took place and a total area of about 1.274,000 m² was mapped (Fig. 2).

The data was firstly fed, organized and stored in an internet-based Collaborative Research Environment (CRE) combined with a Geographic Information System (GIS), from where it afterwards was exported into spread sheet and statistical software respectively to a non-internet based GIS for further analysis.

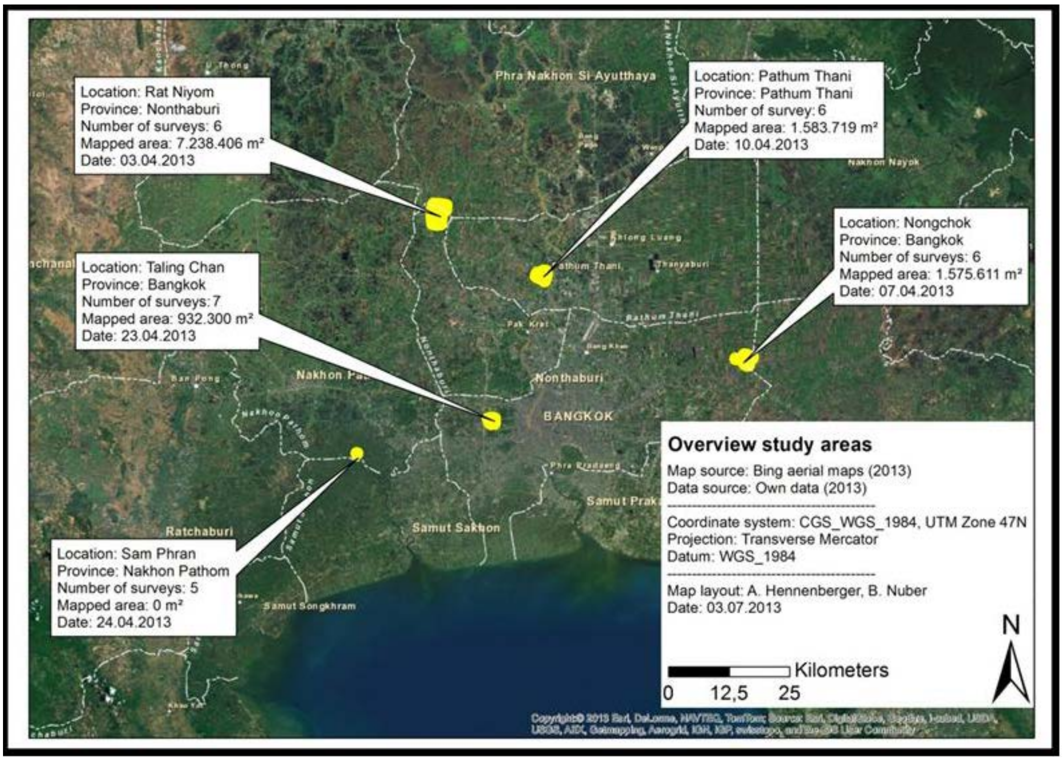

Figure 2: Overview location and short information study areas

Community mental mapping

Community mapping can be defined as "local mapping, produced collaboratively, by local people and often incorporating alternative local knowledge" (Perkins 2007: 127, similar: Parker 2006: 470). It is therefore a strategy worth considering when researchers deal with unknown socio-cultural spheres and spatial contexts. Community mapping aims at gaining qualitative information about the spatial perception of a certain aspect or issue presented to a group of people. Spatial elements and characteristics are considered to be part of individual and collective perception, which can be manifested on a map. It is a method that is increasingly applied in the scientific community, especially by geographers (Glaser et al. 2007, Perkins 2007, Parker 2006). For instance, Open GIS alternatives such as OpenStreetMap or even the applied CRE of the vegGIS can be viewed as communal mapping projects (Omsrud and Craglia 2003, Kingston 2007). Martinez-Verduzco et al. (2012) conducted community mapping in the context of land use mapping in similar combination of GIS-based methods to separate coffee plantations from natural vegetation. A critical approach shows the implications of community mapping for the re-organization of land use in Northern Thailand (Roth 2006).

In design of this research project the community mapping consists of two different methods: sketch mapping and scale mapping. The two methods are different from each other, since the sketch mapping is conducted on a blank sheet of paper and is therefore not as structured as the scale mapping drawn on a given satellite image. Furthermore, the instructions and the aims of both methods differ: In the sketch mapping the participants are asked to draw everything that comes to mind with regard to their personal and collective food system and their perception of the community as a whole. In addition to the information on the map, there is valuable information to be gained in the discussion between community members. In the scale mapping, the main goal was to clarify boundaries of the community and known ownerships of fields, which are drawn on the sheets individually.

Figures 3, 4, 5: Mental mapping session and related products (photos: H. Karg)

As part of the applied methodology, the community mapping aims at gaining qualitative data about the food systems in communities in periurban Bangkok.

Mental maps are cognitive maps drawn by members of the community showing their personal point-of-view perception of their own world. Mental maps provide information on perceived importance of spatial features (e.g. whether they are drawn at all, or at which size), perceived distances, directions, and in general how people order their space around them.

Community mental mapping takes place in the communities after arranging an appointment in order to gather as many community members as possible. The main activity is drawing a sketch map, i.e. a hand-drawn map on a blank sheet of paper without spatial features indicating scale and location (Fig. 3, 4, 5). After this actual mental mapping session, farmers are asked to indicate their own field on a printed satellite image (A1 format) showing the extent of the study site - referred to as scale mapping. They can also add other spatial features that were subject of the sketch mapping session before (e.g. markets, community boundary, etc.). In addition to the drawn map, information can be extracted from the discussion which takes place while drawing and which should be encouraged by the facilitator.

Remote sensing and eCognition

Up to now, data on urban and peri-urban agriculture (UPA) is mainly collected through field sampling methods. These methods suffer from manifold practical and economic limitations. This means that spatial and temporal dynamics of UPA must be derived from sparse samples. Furthermore, these ground sampling techniques do not allow the surveillance of continuous measurements of specific variables within a certain area. They are therefore not easily applicable to analyse larger areas in a way that is suitable to support the formulation of sustainable policies for urban resource management.

With the development of ever more sophisticated Remote Sensing (RS) and Geographic Information System (GIS) techniques, the (semi-)automated detection and analysis of UPA is getting more accurate and cost- as well as time-efficient. The temporal and spatial availability of RS data and versatile advancements of the technologies to process and analyse that data makes RS-based approaches increasingly suitable for UPA research.

Up to now, there have been only relatively few attempts to analyse UPA with RS/GIS techniques. One example is the study by Van den Berg et al. (2001) on the spatial distribution of urban agriculture in Bamako and Ouagadougou. By combining visual interpretation of a satellite image and the analysis of GIS datasets, such as streets and water bodies, the authors calculated the likelihood of the presence of urban agriculture in different areas of the cities. Ifatimehin and Musa (2008) investigated on the applicability of geoinformatic technology in evaluating urban agriculture and urban poverty in a Nigerian city. Dongus (2009) investigated the relationship between UPA and the occurrence of mosquito larvae in Dar es Salaam. Even though he applied GIS techniques and the visual interpretation of remotely sensed imagery, a quantification of the agricultural production was not intended.

However, most of the earlier attempts to investigate UPA (e.g. Van den Berg et al. 2001) widely depended on coarse resolution remotely sensed imagery such as Landsat TM and ETM+ with multispectral resolutions of 30 m. As these resolutions are not sufficient to detect small scale UPA in heterogeneous urban environments, high-resolution satellite data was used in this study.

Conventional pixel-based methods that have been applied in the analysis of coarse resolution satellite images such as unsupervised classification and maximum likelihood supervised classification are not necessarily adequate for the analysis of high-resolution remotely sensed images. One reason being that these classification methods fail to incorporate the high spatial content and associated information in the classification scheme (Blaschke and Strobl 2001).

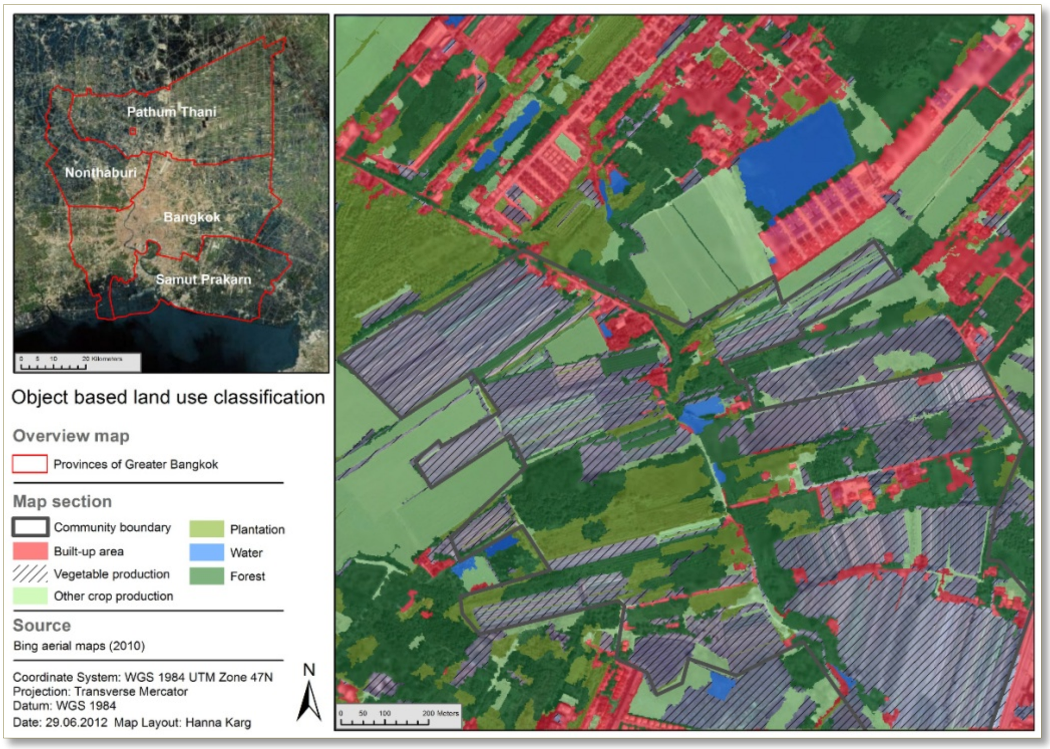

Figure 4: Object based small-scale land use classification

Therefore, a different classification was emphasized in this research project. In order to capture areas under cultivation within the city boundaries as accurately as possible, an object-based classification (McKeown 1988) approach was implemented using DefinienseCognition Developer 8.0 software (Fig. 6).

It could already be demonstrated that object-based approaches are much more suitable for the interpretation of high-resolution satellite images than common pixel-based methods. While the latter analyses the spectral characteristics of single pixels, this approach looks at pixel regions as objects or features, evaluating pixels within their context. Therefore other characteristics such as shape and texture play a more important role than just the spectral reflectance. As vegetable production sites usually have distinct spectral as well as textural characteristics that can be easily detected, object-based classification methods proofed to produce highly accurate results in this study. By defining training areas for the segmentation and classification process, the whole classification scheme can be easily scaled up (Fig. 7).

Another advantage of an object-based analysis of high-resolution data in comparison to the common pixel-based methods and coarse resolution data is the accuracy in detecting small-scale agriculture such as backyard gardens. Agricultural production on these small-scale patches tended to be often overlooked due to limitations in spatial data resolutions. However, it plays a crucial role for the food production in heterogeneous urban and peri-urban environments.

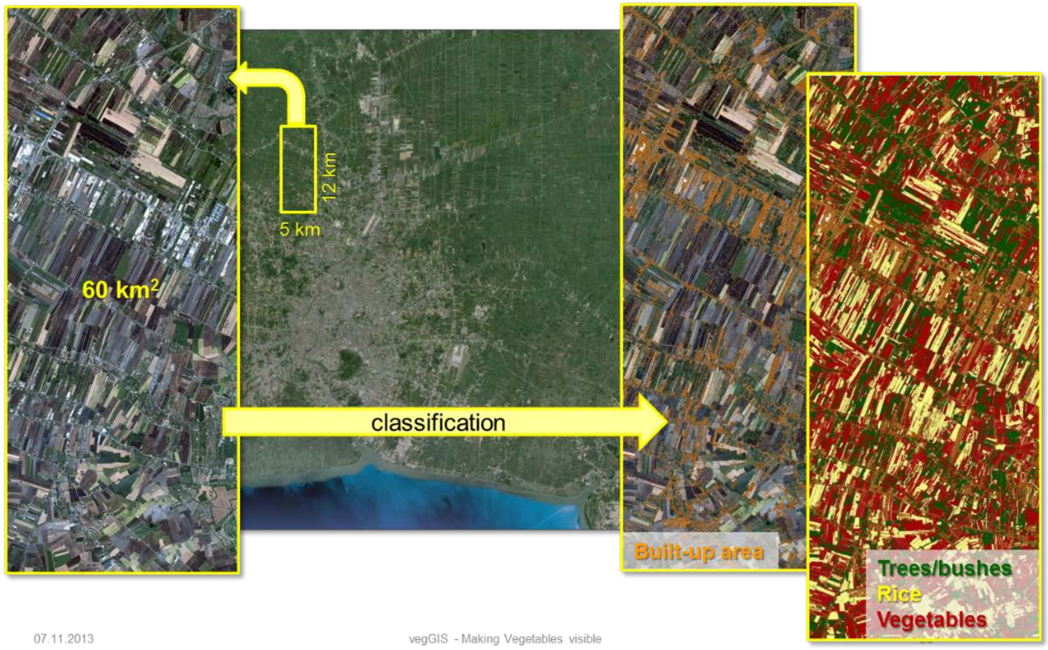

Figure 5: Object based identification of vegetable fields

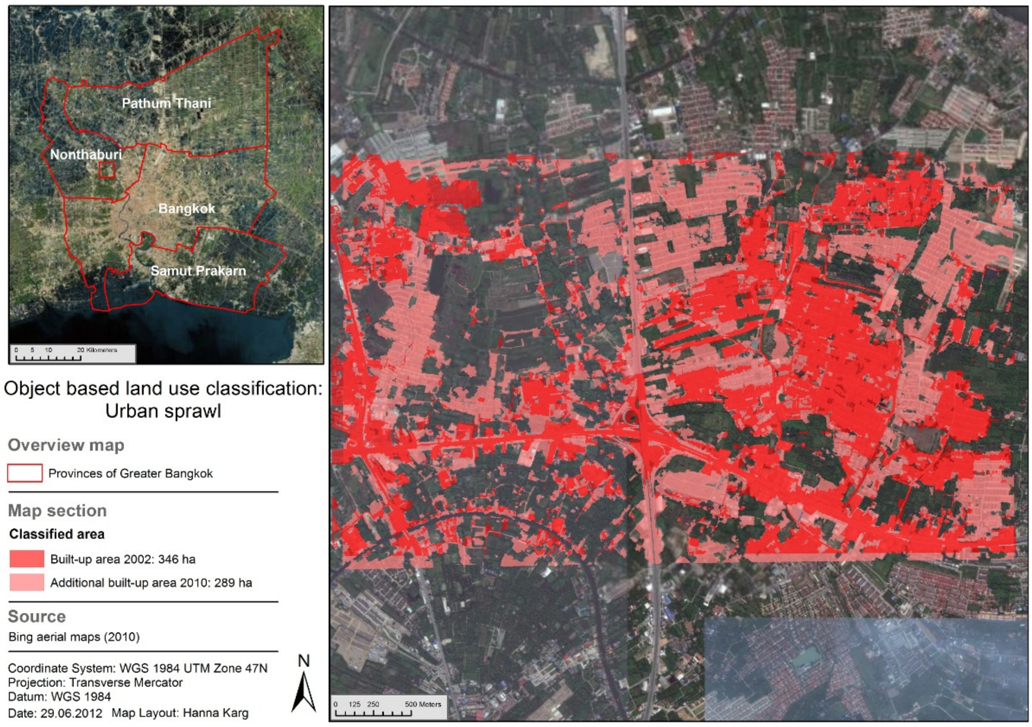

Figure 6: Object based urban sprawl analysis

Object-based classification methods implemented with eCognition are also highly suitable for the detection of urban sprawl, a significant feature of Bangkok´s urban and periurban development. Figure 8 shows the increase in built-up area in periurban Bangkok.

Based on high-resolution satellite images, the built-up area was detected for the years 2002 and 2010. The analysis showed that the urban area in this example increased from 346 ha in 2002 to 635 ha in 2010 – an increase of more than 80 % in only eight years.

By applying the same classification schemes on a larger-scale, a cost-efficient and accurate analysis of urban growth and urban and periurban agriculture (UPA) can be achieved.

MAJOR RESEARCH FINDINGS

The Collaborative Research Environment (CRE)

The complexity of the research topic demanded a well-organized and transparent data management. As many people were involved in the data collection, a functional and reliable method of managing the collected data was required. While different groups for the different parts of the research project were formed, it was important that all data was stored in a standardized and centralized way, assuring data accessibility and accuracy for all involved people.

For this purpose, a web-based collaborative research environment (CRE) was developed within the project. This web application provides an easy to use and around the clock available data collecting and sharing platform for the project members. In this way, several people were able to work on the same data stock and data exchange between the different research groups was facilitated. Furthermore, data monitoring and backing up could easily be done remotely from the German counterpart while the data was collected and entered in the research location.

While usually – especially when dealing with spatial data – special software and knowledge is necessary for the data handling, our web-based application allows the access requirements for the users to be quite low. Internet availability is the only requirement to participate in the data collection. The web application provides all necessary tools for the collection of spatial and common data. A user and group management allows the definition of roles, tasks and permissions and enables collaborative work on the data. All data is stored in a centralized and spatially enabled database. Data model definitions, where data types and metadata is specified, take care of standardized and validated data. Beside the on-line data monitoring and visualization, the centralized and standardized way of data storing enabled on the fly data conversions in several common data formats for the analysing and further processing with external software. This way, easy data access for all participating people was ensured. Moreover, data protection and long term availability are extremely simplified with this centralized and standardized way of data storage.

In the run of the project, we were able to accomplish the implementation of a functional data management tool with low costs and within a very short time frame.

Producers

The study shows that food insecurity is currently not an issue for the interviewed farmers in periurban Bangkok. None of the farmers suffered from hunger. Even extreme weather conditions pose only minor challenges to the farmers. This conclusion refers only to the farmers' households in the periurban region and not to the overall population of Greater Bangkok. In the future, however, various environmental changes might endanger the food supply of the urban and the periurban areas, especially regarding vegetables:

- Available arable land in periurban Bangkok is being reduced by urban sprawl respectively by the ongoing development of settlement compounds. Rising prices for development sites might seduce farmers to sell their arable land.
- Global climate change may increase the likelihood of extreme weather events such as higher temperatures, droughts, heavy rainfalls and floods.

- Aging farmers and the unwillingness of the younger generation to work as farmers might cause a different land use of formerly cultivated land.

In general, variables influencing the farming system are household size, age, skills and education of the farmers, economic circumstances, certification and mainly the location of the farms.

The results show that the dynamic and heterogeneous characteristics of the Greater Bangkok area developed different types of communities. The collected data allow a very good understanding of the research sites regarding the spectrum of the cultivation, especially for vegetables, the marketing systems of the farmers, the socioeconomic structures, the agricultural practices, and the influences on agricultural production.

The study shows that the periurban area contributes significantly to the food system of Greater Bangkok by supplying it with fresh fruits and vegetables.

The study provides sufficient data for a classification of small scale land use based on a remote-sensing approach, thus allowing up scaling to larger area.

Markets

The findings show that wholesale and local markets play a major role for food and nutrition security in the Greater Bangkok Area. The comparison with the results of the producer and consumer survey shows that wholesale markets like Talad Thai and Si Mum Muang are important linchpins in the complex food supply chain as producers deliver their products to Si Mum Muang or Talad Thai and local markets and street vendors buy the products there to sell them again all over the city. The study identified origin of most of the traded vegetables (Fig. 9) and to some extent as well the destination of vegetables within the system.

52% of products from Si Mum Muang Market stay in the Bangkok Metropolitan Area and 85% in the Greater Bangkok Area (including surrounding provinces). Lots of products come from the North and Northwest of Thailand but a considerable share of mostly perishable, leafy vegetables is also grown in the periurban area around Bangkok. This again proves the importance of periurban agriculture for food and nutrition security of a megacity like Bangkok.

According to the merchants one of the most important quality criteria for vegetables is the level of pollution with pesticides. A big problem here is that non-toxic (or less toxic) vegetables can be exported for example to the European Union, whereas highly polluted and toxic vegetables are mainly consumed in Thailand.

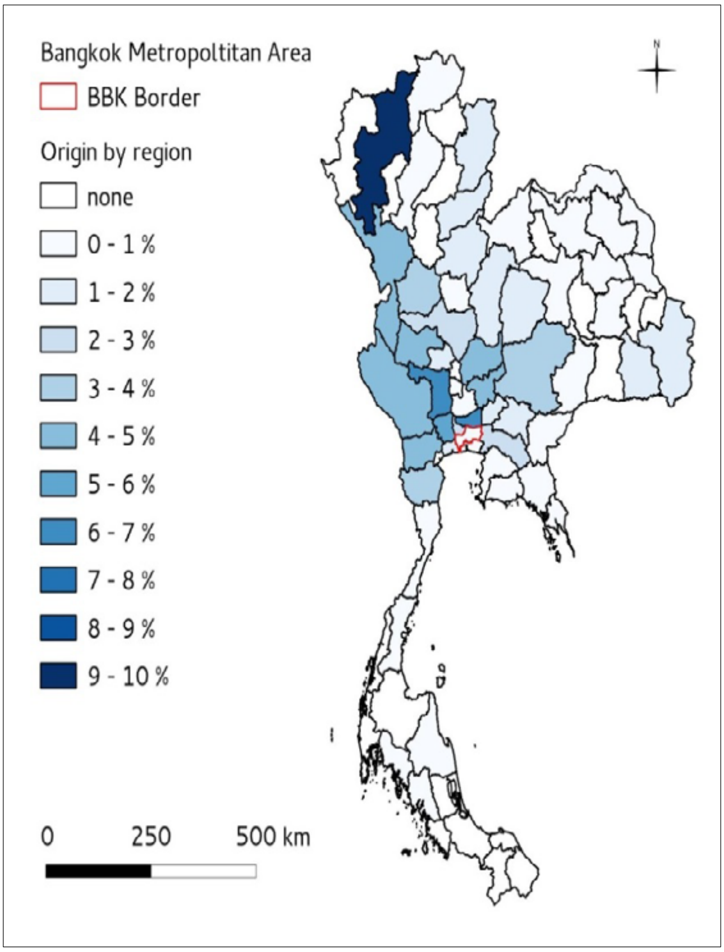

Figure 7: Origin of all 156 recorded vegetable species by regions of Thailand traded at Si Mum Muang and Talad Thai in Bangkok

Community gardens

All gardens examined are based on the principles of mutual aid and solidarity. They are actively supported by specific communities. According to the different forms of support and different origins four types of gardens were identified: 1) district office garden and learning centres; 2) learning centres managed by NGOs; 3) community gardens supported by district offices; and 4) independent community gardens. Whereas the gardens of type 1 and 3 are dependent on district office support, the gardens of type 2 and 4 are self-organized bottom-up initiatives. This typification of the different gardens illustrates that community gardens in Bangkok are not always bottom-up but also top-down initiatives coordinated at district level.

Another important result of the study concerns the aspect of food safety. Vegetables produced and sold in Thailand are assumed to be contaminated to a high degree with pesticides, which is perceived as a health risk by many people. Therefore, the majority of the people interviewed named food quality and the health issue as the main motivation to participate in urban gardening projects. What motivates people to engage in community gardening is not so much food and nutrition security in terms of quantity, but security in the sense of quality and health.

Urban gardening in Bangkok is not a phenomenon among the poorest people in the city but includes the poor. Nearly half the sampled group has to deal with a monthly income significantly lower than the Thai average income. Low-income groups like housekeepers, retired or unemployed persons as well as students make up about one third of the sample. Higher incomes are found among the officers who represent almost one quarter of the respondents.

Remarkably, most of the people being active in community gardening have a fairly high educational background. Here it becomes evident how profound education from schools, trainings or even universities goes hand in hand with the increased ecological awareness among the interviewees.

Although, urban gardening is not a new activity, nearly half of the interviewees got involved in gardening during the last year, almost a quarter of them have been involved in it for more than five years. Clearly visible in these numbers is a positive trend towards gardening in the city. This is also confirmed by the high demand for trainings regarding urban agriculture and the production of organic fertilizer.

Street vendors and consumers

By categorizing street food vendors into different categories such as for example age groups, booth types, male and female vendors or by type of sold products it was possible to gain a more detailed and sophisticated view of this business. Street vendors are a typical “urban” phenomenon; they play a much lesser role in peri-urban areas of Bangkok. From the observed 103 street vendors, 30 different vendors are selling fruits, 30 are selling all kinds of dishes and meals and 33 street vendors are selling non-processed vegetables, which are all together embedded and linked with three markets, namely Pak KlongTalad, KhlongToey Market and Mahanak Market. 30 different vegetable species and 12 different fruit species are sold in 10 different locations which have been surveyed. Complicated systems of fee regulations, divided by location, booth types and administrations are hard to comprehend even after the survey.

The important role of street vendors for Bangkok´s food supply has been demonstrated in the consumer survey. Nearly two out of five consumers buy street food for lunch and circa one of three for dinner. But most frequented by consumers - independent on their sex and age - are local markets, though at some local markets street food vendors are selling as well. Most relevant for consumers is “the closest possibility to buy food”, this fact highlights the great local value of street food vendors which are to find all over Central Bangkok.

Vegetables and fruits are essential for Bangkok´s food system. At least three out of four people, regardless of the sex and age, consume vegetables minimum every day. Fruits are eaten by every second consumer at least once a day. Among the most eaten vegetables the majority we find cucumber, kai-lan (Chinese kale), head cabbage, carrot, kangkong (water spinach or water morning glory), pak-choi (leafy cabbage), coriander, tomato and eggplant.

Our data underpin the importance of indigenous vegetables in the local food habits with more than 150 different vegetable species being traded in Bangkok markets. More than one fourth of the respondents grow their own vegetables and fruits. In this way they improve their food and nutrition security even if most of them cultivate on a small scale.

The common challenge for consumers in vegetable usage is assumed to be the price. The major issues concerning positive aspects of vegetables are the freshness, followed by the appreciation of organic vegetables, price, cleanliness and good quality at all. Contrary to the expectation the price would be the fundamental argument for the buying decision, consumer rather prefer fresh and healthy vegetables.

Besides the mere scientific results of the study, this pilot project has influenced a large number of German and Thai students and researchers, trained in getting access to the important question of food and nutrition security and nutrition in a megacity of Southeast Asia. Vegetables have largely been overlooked in the past and one goal of this pilot study was to make vegetables in Thailand more visible.

ASSESSMENT OF RESEARCH FINDINGS

With Bangkok being representative for rapidly urbanizing Southeast Asia, the innovative methodological approach and corresponding research findings of this pilot project have contributed significantly to make the role of vegetables in a megacity's food system more visible, which are often overlooked in traditional approaches that focus on carbohydrate rich staples only. With the continued population shift from rural to urban areas in Southeast Asia, increasing and changing demands for food will have strong but unpredictable effects on rural and urban livelihoods. In the past three decades, Southeast Asia has achieved significant economic progress, which, however, has not translated into improved nutrition in a number of the countries of the region. While these countries continue to deal with the problems of infectious diseases and undernutrition i.e. deficiencies in energy, protein, essential vitamins and minerals - they are at the same time experiencing an upsurge in non-communicable disease risk factors such as obesity and overweight, particularly in the rapidly increasing urban settings, a phenomenon that is dubbed as “triple burden of disease”. To ensure safe, nutritious and culturally appropriate food is available, accessible and affordable year-round is one of the most pressing concerns in the region, a situation that is aggravated by climate change, which poses a major risk for the region and exacerbates existing development problems such as population growth, rapid urbanization, increasing competition for natural resources, and environmental degradation.

Vegetables production in urban and peri-urban areas of Southeast Asia are one of the interventions that have the potential to improve food and nutrition security in the region, generating additional income, contributing to better health, and promoting gender equity. Home and community gardens can provide a wide variety of fruits and vegetables throughout the year, thus contributing significantly to not only a nutritious diet for family members but also offering opportunities for income generation through sale of extra produce. Results show the importance of peri-urban areas to supply nutritious food as well as the major challenges for vegetable producers, namely biotic and abiotic stress factors such as diseases and pests as well as unfavorable weather conditions which can be addressed by the research agenda of AVRDC and its partner agencies. The usage of a GIS-based Collaborative Research Environment (CRE) proved to be essential to understand the complexities of urban food systems, particularly those of mega cities. The use of an object-based classification approach using so-called eCognition software to detect vegetable production sites proofed to produce highly accurate results and has great potential for upscaling.

Future research needs

In a small pilot project designed to develop appropriate methods, not every aspect of the food system could be highlighted accordingly. Regarding the importance of vegetables for food and nutrition security further research on the provision and quantification of micronutrient flows is needed. The project has shown that mapping of larger vegetable growing areas is possible, but up-scaling still needs to be done. Food safety and hygiene are other factors to look at, especially in the context of street vendors but all along the food chain. Although so far not considered is the aspect of food losses and food waste from the producers to the consumers and beyond. It is suggested to also include other commodities of the food system into future research, which are often overlooked in traditional approaches, such as fruits, herbs, mushroom and fish.

SUMMARY

This project looked at four components of the overall food system: Smallholder vegetable producers, community gardeners, markets, consumers and street vendors. In order to better understand the linkages and importance of each of these components a so-called pilot Collaborative Research Environment (CRE) was developed. The core of the CRE consists of a central, spatially enabled database and a range of associated tools for distributed data entry, for remote and real-time monitoring of the incoming data, for data analysis, and last but not least for data presentation. The tools include the required Geographic Information System (GIS) functionality for spatial analysis and map-based visualization.

In the pilot study the data included in the CRE comprises empirical data from different sources such as questionnaires and surveys, spatial information on production areas in relation to vegetable diversity as well as information on producers, traders and consumers.

Some results concerning the different target groups:

The producer survey shows the importance of market demands and prices influencing the decisions on which kind of crops and vegetables are grown. Other important factors here are farmers' skills and habits as well soil and water conditions. All those are strongly interrelated. Plant diseases and pests as well as climate and weather conditions are identified as major challenges for the vegetable producers. However 47% of the Producers produce more than ¾ of their self-consumed vegetables. For the community gardeners' urban gardening in Bangkok is not about food security in the sense of essential food provision: More than 70% of the interviewees never face difficulties in providing enough food for their family and around 20% rarely do, mainly because of poor harvests. However, a lot of the interviewed people refer to the problem of chemical pollution of market vegetables.

Wholesale and local markets play a big role for food and nutrition security in the Greater Bangkok. About 52% of products from Si Mum Muang Market stay in the Bangkok Metropolitan Area and 85% in the Greater Bangkok Area (including surrounding provinces). Many products come from the north and northwest of Thailand but a considerable share is also grown in the peri-urban area around Bangkok. A number of perishable products like e.g. lettuce and kale are mostly grown in the proximity of the megacity. This once again proves the importance of peri-urban agriculture for food and nutrition security in Bangkok. More than 70% of the local markets and over 50% of street vendors and restaurants buy at wholesale markets Si Mum Muang and Talad Thai.

Regarding consumption, the survey identifies clear differences between men and women. Vegetables are eaten by 65% of male and 80% of female participants. 41% of the male and 51% of the female interviewees eat fruits. For milk products the distribution can be grouped into 32% male and 41% female consumers. 65% of men and 70% of women eat meat minimum every day. Fish/seafood are eaten 24% by men and 28% by women. It is noticeable that women are consuming all food groups more frequently. Other differences get obvious looking at different age groups. It gets clear that food habits are changing. Regarding food purchase and consumption, local

markets are of extraordinary importance in Bangkok. The most common challenge for consumers in vegetable usage is the price.

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Farmers' markets in developing and developed countries

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SYNOPSIS

In developing countries, farmers' markets have successfully established a link between producers and consumers of nearby communities and synchronized supply of food available with the available buyers. This idea and approach took its birth probably centuries ago in villages and rural communities to fulfil their requirement of food, before towns and cities came into existence, but these also exist today as weekly farmers' markets in many locations. In developed countries, during the course of time, farmers' markets have increased in number, size, nature and scope. They have become popular among common people who have a preference for fresh and traditional fruits, vegetables, flowers, fast food and drinks and other daily needs of particular ethnic interest. The paper discusses and illustrates characters and developments of farmers' markets, observational visits, genetic resources availability and prospects for farmers' markets in both developed and developing countries.

Keywords

Farmers' market, common man's market, vegetables, melons, fruits, berries, genetic resources, ethnic influence.

INTRODUCTION

In developing countries, farmers' markets have successfully established a link between producers and consumers of nearby communities and synchronised supply of the food available with the potential buyers. I would like to call it a 'common man's market' because of the active participation of small producers and of common people with limited income. This idea and approach took its birth probably centuries ago in villages and rural communities to fulfil their requirement of food, before towns and cities came into existence, but these also exist today as weekly farmers' markets or road side markets in many locations. In developed countries, during the course of time, farmers' markets have increased in number, size, nature and scope. They are becoming popular among common people who have a preference for fresh and traditional fruits, vegetables, flowers, fast food and drinks, and other daily needs of particular ethnic interest.

CHARACTERS OF FARMERS' MARKETS

Infrastructure: The farmers' market does not have any permanent structure, unlike common or typical markets, which have a permanent structure either in developing or developed countries. But for sure the location of the farmers' market is permanent, and known to all consumers both in developing and developed countries.

Site: In towns, the site of the farmers' market is located permanently either in an open or roofed area, whereas in villages both covered and open areas are used at a permanent location. In some places, streets or parking lots are used. For example, the main farmers' market occupies an authorised parking lot in Orange County, Los Angeles. The main farmers' market in Minneapolis has its own permanent structure.

Timing: By definition, the farmers' market is a weekly market, preferably on the weekend with some variations depending on location.

Freshness of local food: It is mainly a producers' market; they bring their fresh produce of mango, banana, apples and avocado, potato, rice, wheat, corn, beans and melons or pickles and any art products, etc. Here is the platform where local freshly cooked food is served. It is the centre of the availability of locally produced fresh raw food materials as well as freshly cooked native and common food.

Consumers' choice: Some housewives wait through the week to get to the farmers' market to obtain particular items e.g. bitter gourd and palak (not available in common market). They like to buy fresh vegetables and herbs for the week. Children like to go to taste some organic candies, ice-cream and juice. Girls like roses or some ethnic tops and earrings. The dads like to taste and buy some melons or good sweet corn. The parents prefer to buy fresh ethnic vegetables and fruits. But the whole family likes to enjoy freshly prepared pakodas, tikkies, bhajis, steamed corns and peanuts, hamburger sausages, pizzas, sandwiches, tortillas, etc.

Ethnic influence: In developing countries, farmers' market participants have continued to keep the ethnic influence, particularly in food markets. The food the community likes and its preparation are preferred. The consumers like the taste and flavour of the fresh and processed food prepared, which are primarily organic.

Economy: In the absence of middlemen in general, the cost of the produce is most reasonable for consumers and the producer-seller gets the reasonable price he/she proposes. The general impression we learnt was that the price was quite reasonable.

The above observations are mainly based on the selected cities visited in USA and Asia and on ad hoc observations elsewhere, including Nigeria.

DEVELOPMENT IN FARMERS' MARKETS

Progressive development in farmers' markets has taken place in both developing and developed countries.

Number: The number of farmers' markets has increased worldwide, apparently because of population increases in each city, state, nation, region. In other words, it is because of increase in consumer demand. At present, there are more farmers' markets in any city than three decades ago. Another new development is the number of active days in a week when farmers' markets are held. In some cities they are open twice a day, including weekends.

Characteristics: In infrastructure, there has been a relative improvement, from open stand and trucks opened for presentation, toward portable structures. Nowadays almost every seller has his/her temporary structure, which is good for produce as well as for the buyers under the sun. Keeping the farmers' market character of fresheners, the items on sale have increased multi-fold. In the early days, we used to see fruit and vegetables only, spices, herbs, beans and grains, animal products, cheese, candies and juices, cosmetics, clothing, jewelry, etc., and now the contribution of freshly cooked food is growing large. Another thing which is visible now is the availability of organic food products.

Increased choice and opportunities: With regard to freshly cooked food in farmers' markets in the USA, the volume and menu has changed significantly compared to three decades ago. The small food vans have improved to well-equipped food trucks producing at large volume to meet the demand of the growing number of consumers. The local menu has become international, meeting the requirements of varied consumers and populations. These developments are creating more choices and attracting more people to visit these markets. Prices are rising every year but not up to excessive increases, as experienced in common markets.

VISITING FARMERS' MARKETS

It is fascinating to visit farmers' markets and enjoy looking at fresh products and buy which you like the most. Since childhood I learnt the art of selecting good quality vegetables and fruits, which continued with age, but with the eye of a plant breeder and a consumer.

Asia

Dinapore, Bihar, India: During the 1940s as a child I was residing near the bank of the Sone River which produced plenty of quality vegetables. It was fascinating to see the fresh vegetables, fruits, grains in jute bags and fishes coming into the weekly farmers' market with the space provided by the local administration. Even today, the weekly market is held on a large space with even more products and rush of customers. There is large scope to improve infrastructure, grading and packing.

Bangalore, Karnataka, India: During the late 1960s, I visited a number of weekly fruit and vegetable markets in Bangalore and most of the towns and villages in Karnataka. The smell of fresh products and crowd of customers was observed everywhere. But the business of traditional city market is presently influenced by the coming in of cooperative society, e.g. Hopcoms, daily street markets and food chains. In spite of all these developments, the popular city market continues to be as strong as before and farmers' weekly markets still thrive in villages.

Bangkok, Thailand: For communities, the farmers' market remains important and essential. In spite of the fast growth of food chains, individual food stores, the importance of farmers' markets has not lessened. Like in other countries, the farmers' market is predominant in both urban and rural areas, where both fresh and cooked food are available.

Java, Indonesia: Depending on the regions the variation in fruit and vegetables is significant in different farmers' markets in Java (Fig. 1).

Farmers' Market in Southern Java, Indonesia

Africa

Ibadan, Nigeria: Whether in large cities like Ibadan or Lagos, and small towns all over the country, the weekly farmers' markets are popular places, where fresh leafy and other vegetable, tubers, tropical fruits, meat, fish and others were commonly available. The products on sale were 'as-is'—yet to be cleaned, graded or packed. But many of the products were objects to appreciate. The fresh indigenous products mostly like papaya, plantain, pineapple were giant size, in kilos, whereas varieties of leafy vegetables were plentiful, with large leaves. At the same time tomatoes and thick, small and spined okra were available all over southern Nigeria.

United States of America

The farmers' market has been in existence primarily as a weekly market since time immemorial in rural areas, small towns and cities across the globe. With the change of time, increase in population with villages becoming towns and towns becoming large cities, the activities enlarged but as an unorganized sector. These markets either on roads or in open spaces, either in open or under temporary shade, became transformed into manual carts, mobile vans and trucks in different countries. But some characters remained the same even today and they are (a) items of daily needs, (b) freshness of vegetables and fruits (c) availability of local foods and (d) location on streets or empty spaces under temporary structures.

Recognizing the fact he regularly goes to department stores, Dr. Nath walked commonly to buy fresh vegetables from the nearby street vendors. This summer he visited a number of farmers' markets in USA, particularly in Minnesota and in California.

In all these markets, (a) almost all items of daily needs were available, (b) mostly local produce were exhibited, (c) all fresh vegetables and fruits brought from the field were available, (d) home products like pickles, candies, juices, cheese, snacks were on sale. These markets on streets stretched from 1 to 3 blocks of communities to more than a kilometre depending on the size of the city and the space available, clearly identified for this purpose. In Minneapolis, the major farmers' market was located at a fixed place with open-cum-permanent structure known popularly to most of the residents. The area was divided into vegetables, fruits, flowers, and household materials. Some of the fresh and dry flowers, some varieties of fruits and many Asian vegetables uncommon in the regular food chain stores were available.

Farmer's market near Los Angeles

Variation in potatoes

Variation in peppers

Variation in chilies

Variation in *Solanum* and beans

Segregation in tomatoes

In Los Angeles, near Orange County, the large popular farmers' market was held in a permanent parking area during the weekend. The whole market is organized under temporary structures that are removed by evening to make space for parking during the week. Like in Minneapolis, this market carried almost all kinds of locally grown fruits and vegetables. Locally grown different kind of berries and plums with different colours were very attractive to the eye and to taste. With regard to vegetables, they were plenty in kind but it was interesting was to see freshly harvested Asian vegetables not available in regular food chain stores of the city. The details of the farmers' market in Orange County can be accessed through the website: http://orange.cfbf.com/.

Tomatoes

Variation in Asian gourds

Cucurbit diversity

Carrot varieties

Different kinds of leafy vegetables

Pumpkin and mustard leaves

Apart from large farmers' market, visits also were made to small farmers' markets near Minneapolis and Los Angeles, which were spread on streets up to a block or in much smaller space than large markets. These markets were limited to locally grown fruits and vegetables. A close study of these markets revealed interesting results:

Families' interest: There was great enthusiasm among the families to visit farmers' markets with a hope to get some fresh produce or something new and uncommon in regular food stores. It seemed consumers were looking for freedom from market-driven food of regular food chains and felt happy to enjoy consumer-driven food available in farmers' markets.

Produce: Among vegetables, several of the ethnic Asian vegetables not commonly available in regular markets were available in farmers' markets. The Asian crops available in these markets were bottle gourd, bitter gourd, ridge gourd, sponge gourd, pumpkin, brinjal, and among leaves were basella, coriander, mint, pumpkin leaves, bitter gourd leaves, mustard leaves, Coccinea leaves, squash and pumpkin flowers, Chinese cabbage, etc. Other common crops were sweet corn, capsicum, tomato, apple, peaches and melons and among fruits, apples, peaches, plums, berries, melons, avocado, etc.

Genetic Resources: It was interesting to see the rich collection of germplasm of tropical Asian vegetables in the USA. Residents of European origin preferred European vegetables which dominated the common food stores, and also because of obvious reasons like climate suitability and ethnicity. With the growing population of Asian or Latin American people in the USA, the production and consumption of tropical vegetables is likely to rise. Some colors and shapes of vegetables and fruit were quite rare as shown in the photos.

Genetic Variation: It was clear from observation that there was hardly genetic uniformity in any of the Asian vegetable crops, so much so that about one pound of beans had not even five beans alike, or a basket of chili had not even three chili fruits alike, which was quite a contrast to a pound of vegetables in regular food chain stores, where all fruits were quite uniform. This significant variation can be seen in the photos.

Food Evolution: About 50 years ago, the foods in Bangalore were predominantly ethnic of Karnataka, but now with the coming in of populations from other states, all kinds of Indian food is available and it seems there is a growing trend of mixing menus of one state with other states. There seems a similar evolving trend in large cities of the USA where cocktail of Asian food with American or Latin food is emerging. New forms of pizza or biriyani or Mexican food are available. The ethnic Vietnamese, Thai, Indian, Mexican and other food with typical flavour and taste are available in cities such as Chicago or Los Angeles.

Price: The prices of produce in farmers' markets are relatively lower than in department food stores, which attracts consumers.


Different berries


Quality melons

The observations made highlight the trend that these independent farmers' markets will soon evolve from an unorganized into an organized sector. In this process, urban and peri-urban agriculture will find a way to organize itself to support the development of growing cities and urban populations.

PERSPECTIVE

If we examine the development of common markets over the course of three or four decades, the small stores became big stores, then expanded to department stores, and now malls are expanding all over the world but within and near cities and the limit seems to be the sky.

Relatively, farmers' markets are deeply rooted in the lives of the common people and are committed to the communities in which they belong. They progressed with relatively less speed but remained alive and healthy. They meet local requirements for fresh food. The sellers and buyers are often from the neighbourhood. The proper assistance of the government and public to promote farmers' markets will go a long way in the interest of the food sector to benefit common people. Since the sellers and buyers are known, it requires the will of the local administration to provide space for shops and parking, and necessary permission to hold the market and keep the area clean. Farmers' markets offer value in freshness, choice, reasonable prices and nearness for those who need it. Because they are local in nature, they cannot fulfil the requirements of a city's entire population, and hence pose no threat to chain stores and malls.

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From harvest to table: Enabling informed nutrition choices and greater access to nutritious vegetables in southern Bangladesh

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ABSTRACT
In Asia low income families often suffer from poor access to healthy foods and low ability to make good nutritional choices. The Agriculture and Nutrition Extension Project (ANEP) has been supporting vulnerable families to make healthy food choices in southern Bangladesh since January 2012. The ANEP aims to sustainably raise agricultural productivity, promote effective market linkages and nutritional awareness to improve the nutritional behavior of poor rural and urban households. ANEP brings together iDE, World Fish, CIMMYT, IRRI, Save the Children, and CODEC and is funded by the European Union (EU).

ANEP urban interactive nutrition education sessions aims to increase knowledge on maternal, adolescent and child nutrition and improve skills to support practice of age specific appropriate feeding behaviours. This is complemented by the promotion of adoption of seasonal producing vegetable varieties which are both high in vitamins and micronutrients and commercially viable. To bring nutritious vegetables to market, ANEP developed durable commercial linkages between rural producers and markets serving low-income urban consumers using a Participatory Market Chain Approach (PMCA).

Program data indicates increases in vegetable productivity (bitter gourd 28%, bottle gourd 34%, and sweet gourd 40% per decimal); and evidence of improved nutrition behaviours amongst urban adolescents - 70% can indicate one iron enriched food (BL 53%) and 50% know iron-rich foods are required during menstruation (BL 7%). The data suggests that using targeted nutrition education in combination with agricultural inputs and rural-urban market linkages delivers synergies that can improve nutrition behaviours amongst the most vulnerable.

Keywords
Health and nutrition aspects of vegetables, food consumption and nutrition in the 21st century, and measures to improve the role of vegetables in nutrition.

INTRODUCTION
Bangladesh has made incredible progress in the last decade in terms of improving their Human Development Index (HDI) Report. Its HDI has increased by 81% in the last 30 years, as reported in the 2010 Human Development Report[1]. Bangladesh has shown high increase in certain areas of the HDI, like primary education, gender parity, agricultural growth, but poverty and malnutrition remain a major problem in the

1 UNDP Human Development Report 2010. http://hdr.undp.org/en/reports/global/hdr2010/

country. Bangladesh is ranked 129th out of 169 countries in the 2010 Human Development Index (HDI), and 68th in a list of 79 countries in the 2012 Global Hunger Index (GHI).

More than 40 million Bangladeshis are undernourished by the FAO's definition—not having access to adequate amounts of safe, nutritious food to sustain a healthy and productive life.[2] There is chronic under-nutrition of children below 5 years of age with at least 16% of them being acutely undernourished, affecting an estimated 41%[3] and approximately 7 million children are able to fully develop in their physical and mental capacities. About one third of adolescent girls in Bangladesh suffer from anemia and micronutrient deficiency, and one in four is too thin for their height. With more than two in three girls married before the age of 18, the risk of early pregnancy and giving birth to a baby that weighs too little is very high. Currently, more than one in five newborns has a low birth weight[4].

The EU understands food security in terms of four key dimensions: availability, access, use and stability.[5] Funded through the EU Technology Transfer for Food Security in Asia (TTFSA) Program, the Agriculture and Nutrition Extension Project (ANEP) is a multi-country program supported by the European Union (EU) to develop market linkages between rural and urban areas and promote exchange of expertise and technologies between agricultural and research institutions in Nepal and Bangladesh. ANEP seeks to improve the food security and nutrition of poor and vulnerable households through technology transfer for increased agricultural productivity, nutrition education and rural-urban market linkages to support food and nutrition security, and the development of 'grass-roots' institutions to ensure the benefits continue beyond the duration of the action.

The focus of this paper is on the agriculture-nutrition linkages developed under ANEP in Bangladesh. These linkages combine interventions to support the consumption of nutritious foods through a behavior change communication (BCC) strategy. The strategy aims to improve knowledge of maternal, adolescent and child nutrition and impart skills to support the practice of age specific appropriate feeding behaviors; it also emphasizes interventions to increase the access and availability of nutritious foods through rural-urban linkages to drive nutritious foods into under-served areas of the market using a Participatory Market Chain Approach (PMCA). The project in Bangladesh has realized results that suggest that using targeted nutrition education in combination with agricultural inputs and rural-urban market linkages delivers synergies that can improve nutrition behaviors amongst the most vulnerable.

2 UN, 2012. Food and Agriculture Organization of the United Nations (FAO), The State of Food Insecurity in the World. http://www.fao.org/docrep/016/i3027e/i3027e00.htm (11/2013)

3 Bangladesh Demographic and Health Survey BDHS 2011; HIES 2010.

4 World Food Programme. http://www.wfp.org/countries/bangladesh/overview. (7/2013)

5 Directorate-General for Development and Cooperation – EuropeAid, Technology Transfer for Food Security: Helping Asia's Poorest. EU. 2012.

THE AGRICULTURE AND NUTRITION EXTENSION PROJECT (ANEP)

ANEP is a partnership between International Development Enterprises (iDE)[6], World Fish, CIMMYT, Save the Children International, and national partners in Bangladesh (CODEC) and Nepal (CEAPRED and BES). The overall objective of ANEP is to improve the food security and the nutrition of the poor and vulnerable households, especially women and children. The specific objectives are (i) to improve the food security and nutrition of smallholders by introducing and facilitating the adoption of productive and environmentally sustainable agricultural technologies to improve their livelihoods; and (ii) to create or improve market linkages to improve food and nutritional security of both rural producers and urban consumers. ANEP has is a specific focus on value chain development, particularly adapting and transferring the Participatory Market Chain Approach (PMCA).[7]

Agriculture and Nutrition Extension Project (ANEP)

Target Groups: The target groups of ANEP are the poor and vulnerable rural farming and urban laboring households. The activities focus on households that include pregnant and newly lactating mothers, children of 0-5 years of age, and women of reproductive age. ANEP reaches over 60,000 households across Bangladesh and Nepal, which includes directly working with 8,000 rural and 8,000 urban beneficiaries[8].

Operational Area: The project operates in the Nepal Terai districts of Nawalparasi, Rupandehi, and mid-hills districts of Rukum, Surkhet. In Bangladesh, it is working in Barisal Sadar, Mehendiganj, and Hizla Upazilas in the Southwest of the country.

The ANEP works in three inter-related results areas:

Result Area 1: Increased productivity for smallholders

Introducing innovative, affordable and environmentally sustainable technologies can increase the farmers' productivity and enhance the nutritional value of their produce. Therefore ANEP facilitates the transfer and adoption of agricultural technologies to the small farmers in the vegetable, fisheries and field crops sectors. Activities implemented under this component include:

(i) Mobilizing farmers in business-oriented informal producer groups that help to improve collective decision-making and planning and enable the farmers to coordinate purchase of inputs, access production technologies and sales of their products;

(ii) Facilitating production and sales strategies for the smallholders by bringing them together with private sector actors in Production and Sales Planning Meetings (PSPM) where production plans can be coordinated and information shared among the stakeholders for effective planning for production; and,

6 The project is being led by iDE, an international non-profit with a mission to enable poor rural households to participate effectively in high-value agriculture market systems and to progress from subsistence to commercial farming.

7 Bernet T., Thiele G. and Zschocke T., 2006. *Participatory Market Chain Approach (PMCA) – User Guide.*

International Potato Center (CIP) – Papa Andina, Lima, Peru.

8 Briefing Note: Agriculture and Nutrition Extension Project. (2/2013)

(iii) Demonstrating productivity-enhancing technologies through the relevant private sector actors, who are interested in producing and promoting these technologies to the smallholders.

Result Area 2: Improved food security and nutrition

Low-income families often suffer from low access to healthy foods and poor ability to make good nutrition choices. ANEP focuses on ensuring the increased supply for nutritious foods coupled with training and counselling sessions to impact the uptake of nutritious food of the household members. The project carries out activities to improve access to nutritious food for both rural and urban low-income households through:

(i) Mobilising and forming nutrition education groups for vulnerable families: 16,000 urban and rural households in Nepal and Bangladesh were formed into groups based on the project target beneficiaries.

(ii) Supporting low-income families to make better-informed nutrition choices through nutrition training and counselling sessions with the aim to build up the capacities of these household members to care for themselves and pass on the knowledge to others.

(iii) Developing and improving market linkages between rural and urban areas to improve the access of nutritious foods for the urban low-income households. ANEP facilitated to develop commercial linkages between rural producers and markets that are serving the low-income urban households. These were done through a Participatory Market Chain Approach (PMCA) where the private sector actors are able to interact and purchase products from the producer groups from a collection point.

Result Area 3: Develop grassroots institutions

ANEP understands the need to develop the strength of grassroots institutions that can carry forward the progress from the project in a sustainable manner. Thus, during the course of the project, ANEP focuses on building the capacity of the private sector actors, create appropriate market infrastructure and develop the local existing institutions to become an improved market system on their own. Some of the major activities include:

(i) Reaching scale through supporting local service providers, who are provided the capacity to be able to provide improved products or services to the smallholders. A "fee-for-service" model is enhanced and promoted to ensure a win-win scenario for both the service providers and the smallholders.

(ii) Strengthening local organizations to improve smallholders' access to food markets by increasing the capacity of the producer groups to be able to aggregate their produce and negotiate for better prices. Selling through Collection Points also serves as a means for reducing costs and availing better market information from the traders.

(iii) Developing agricultural capacity through national and international linkages that ANEP is able to provide while facilitating the growth in these different sectors in the two countries. The project also works by partnering with local NGOs whose capacities are also built regarding the Market Development/ M4P Approach.

ENABLING INFORMED NUTRITION CHOICES AND GREATER ACCESS TO NUTRITIOUS VEGETABLES IN ANEP

The ANEP in Bangladesh focuses its urban nutrition interventions in rural and peri-urban areas of Barisal Division. According to the HKI/ IPHN Nutritional Surveillance Project (NSP), it has been identified that Barisal has a high level of food insecurity and malnutrition. The NSP findings for Barisal Division in 2001 show that household food insecurity, diarrhea and malnutrition were more common than in most other divisions in the country.

The very high prevalence of wasting in mothers (37-49%), which indicates a serious or critical food insecurity problem is consistent with the very high percentage of households that had taken a loan for food (20-45%) and the very low household energy intake (38% <1805 kcal/person/d). One-fifth (20%) of households lacked access to clean drinking water and 66% did not have a closed latrine, which may explain the very high prevalence of diarrhea in children (8.3% - 13.9%). According to international criteria, child wasting (8-17% in children aged 0-59 months) was a serious or critical problem at different times of the year, while the prevalence of child stunting (46-50% in children aged 0-23 months and 60-67% in children aged 24-59 months) and underweight (46-50% in children aged 0-23 months and 58-71% in children aged 24-59 months) were 'very high' throughout the year[9].

ANEP in Bangladesh has mobilized some 5000 rural and 5000 urban households (HHs) as the target for project activities. These include vulnerable HHs such as those including pregnant and lactating women and mothers and caregivers of children under 5 years old, and in rural areas those with low access to land (less than 150 decimals – around 1.5 acres).

Behaviour change communications as 'demand creation' for nutritious foods amongst target communities

The target communities are reached directly through interactive nutrition education sessions bi-monthly with information and hands on training on essential nutrition and hygiene actions. Intensive one-to-one counseling is also done during HH visits; especially to the one having difficulty practicing proper feeding behavior. Fathers and male members of families are also very important to reach as they play a vital role in decisions making and buying food for the family. ANEP reaches fathers, grandfathers in an innovative approach engaging them in an educative video show with a quiz competition to change their food buying preferences. Through these activities ANEP focuses on the vulnerable families to become more aware of their nutritional needs and food habits, and encourages them to be the leaders in spreading the knowledge and promoting better nutritional habits for the larger rural communities.

Market-based interventions to increase the production of nutritious foods

In the vegetable sub-sector, ANEP focuses on the adoption of off-season varieties that are high in micronutrients and are commercially viable, such as okra, red amaranth, tomato, Indian spinach, and sweet gourd. Along with this, the promotion of technologies included cost-effective technologies such as the treadle pump, integrated pest management (IPM) and micro-vermi-compost (MVP) which resulted in higher productivity of these vegetables in the region. In aquaculture, ANEP introduced technologies to encourage smallholders to acquire more nutritional and commercial value from their ponds, through carp-poly culture. The effective use of small ponds

9 Nov, 2002. Nutritional Surveillance Project Annual Report 2001. "Nutrition and Health Surveillance in Barisal Division"

allowed the smallholders to grow small nutrient-dense fish and integrated vegetable cultivation on the pond dikes to support the nutritional uptake of the household.

'Pushti Melas' to drive the supply of nutritious foods into urban areas

The PMCAs bring together the rural producers and urban low-income consumers through events like Pushti Melas (Nutrition Fairs). These nutrition festivals or farmers' markets have entertainment that attracts urban consumers to whom the farmers and mobile traders can sell fresh produce. The increase in supply of nutritious foods complements the ANEP nutrition education component, which increases knowledge of basic nutrition practices. This event also has nutrition education thorough demonstrations of how to prepare low cost nutritious recipes, folk songs focusing on better nutritional practices, and Meena cartons on the importance of exclusive breast feeding, proper complementary feeding and hand washing.

PRELIMINARY RESULTS FROM BASELINE AND FORMATIVE RESEARCH

Primary data collection for project baseline and the informative research were collected during October 2012 and December 2012, respectively, in urban slums of Barisal, Bangladesh.

Method

This program data includes a feeding and buying survey with 350 low income urban consumers in control and treatment groups, age-specific feeding practices (0-59 months children), and buying preferences amongst urban consumers. A market survey was undertaken amongst control and treatment markets (3 and 4 respectively) and LSPs (10 and 8 respectively). Also a qualitative investigation was undertaken using FGDs and KIIs which measure knowledge nutrition practices, feeding practices and hygiene amongst urban households. The entertainment choices, such as songs about healthy foods, cooking demonstrations, and cartoon showings for children, reinforce the nutrition theme[10].

Results

Urban and rural HHs were reached with focused BCC to grow and improve the intake of locally available nutritious vegetables and small fishes. Proper knowledge, skills and technology has been transferred to rural beneficiary HHs. At the same time events like nutrition fairs bring the rural producers with their fresh produce to urban slum communities, and engage male members trying to bring change in their buying preferences are showing results by bringing positive changes in buying patterns among the beneficiaries. More nutritious vegetables and fish are being bought by urban consumers; 54% of treatment group are buying 2-3 nutritious foods compared to 17% of control group (2 foods only) (7 day recall data). The number of customers also has been doubled for treatment LSPs (100% increase) compared to 18% for control and the volume of business/sales increased by 55% amongst treatment LSPs, compared to 18% in control group.

To maximize the intake of protein and calcium at a low cost, ANEP has promoted practices like eating small fish with bones and heads and ensuring intake of at least one animal source everyday specially for PLW and children U5s. As a result,

10 Agriculture and Nutrition Extension Project (ANEP): Quarter 7: MRM Report. 2013.

63% of the treatment group are feeding nutritious foods (small fish with bones, eggs, chicken) to 7-9 months children, compared to 29% control group (24 hour recall).

Thus, it can be seen that the purchase habits of low-income customers have changed, given their improved access to and knowledge about healthy food uptake. It can be inferred that the combination of nutrition education and improved agricultural productivity and enhanced rural-urban market linkage work together to encourage better consumption patterns. Improving the supply of nutritious produce to urban areas greatly increases the ability of vulnerable low income families to access nutritious foods. This enables better nutrition and food security habits for both rural and urban low-income households.

CONCLUSION

Enabling informed nutrition choices and increasing access to fresh nutritious vegetables through nutrition fairs is already showing positive change in the feeding behaviours of low income vulnerable families in southern Bangladesh. The data suggests that using targeted nutrition education in combination with agricultural inputs and rural-urban market linkages delivers synergies that can improve nutrition behaviors amongst the most vulnerable.

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Effectiveness of different processing methods in reducing HCN content of jack bean seed (*Canavalia ensiformis*) and its products

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ABSTRACT

Jack bean (*Canavalia ensiformis*) has great potential as a soybean substitute as well as another protein source. Farmers are reluctant to cultivate it because of its low economic value due to high hydrogen cyanide content (HCN). Cyanide can be removed from the seeds gradually by applying various combinations of processing methods. This study aims to reduce the HCN content of tempeh, tofu and modified flour of jack bean seeds below the threshold that is safe for consumption. The results showed that by extending soaking period in calcium salts followed by heating reduced HCN content of the beans to a level around 70% of the seeds' initial content. In addition, fermentation process was also effective in reducing HCN, so that the tempeh produced contained HCN at concentration as low as 1.2 ppm, tofu < 2.0 ppm and 5.0 ppm in flour. All of these values are well below the standard safety limit set by FAO. The HCN content of the initial seed was 14.83 ppm, therefore as much as 92% reduction was obtained for tempeh, 91% for tofu, and 66% in flour. Safety limit of HCN content in cassava flour specified by FAO is < 10 ppm.

Keywords

HCN, Jack bean, Ca-salts.

INTRODUCTION

The genus *Canavalia* spp. comprises 48 species of underutilized annual legumes widely distributed and indigenous to the tropics. Although it is rarely edible to man, total yield of dry seeds can reach up to 2.5 t/ha (Sridhar and Seena 2006). Raw *Canavalia* seeds contain about 300 g/kg protein and 600 g/kg carbohydrates (Rajaram and Janardhanam 1992). Hence, they have great potential as a protein source as well as raw material for food production. The majority of pulses and leguminous seeds contain significant levels of secondary metabolites that fall into anti-nutritional factors (ANF) categories, such as saponins, tannins, flavonoids, alkaloids, trypsin (protease) inhibitors, oxalates, phytates, haemagluttinins (lectins), cyanogenic glycosides, cardiac glycosides and gossypol. Most of these secondary metabolites elicit very harmful biological responses, while some are widely applied in nutrition and as pharmacologically active agents (Oakenfull and Sidhu 1989; Soetan 2008). Hydrogen cyanide (HCN) is released from the cyanogenic glycosides when seeds of *Canavalia* spp. is macerated, which allows enzymes and cyanogenic glycosides to come together. Cyanide can cause death if consumption reaches a dose 0.5-3.5 mg HCN/kg weight.

Processing generally reduces some antinutritional compounds (Muzquiz et al. 1996; Hajos and Osagie 2004; Jimenez-Martinez et al. 2004) including HCN and cyanogenic glycosides. It can be eliminated by soaking and removal of testa prior to boiling (Soetan and Oyewole 2009). Seeds of *C. gladiata* contain 50 ppm of HCN as in most legumes (Laurena et al. 1994). However, Okolie and Ugochukwu (1989) reported HCN up to 1093, 285, 953 mg/kg in dry seeds, testa and cotyledons of *C. gladiata*. HCN content of raw seeds of *C. ensiformis* and *C. cathartica* is 0–11.2 and 13 mg 100 g. Soaking (24 h) and boiling (3 h) reduces HCN tremendously in cotyledons (Okolie and Ugochukwu 1989). Fermentation reduced cyanide in soaked seeds (Tawali et al. 1998). Cooking and fermentation reduced cyanide in soaked seeds to safe levels (Soetan and Oyewole 2009). The aim of this study was to determine HCN content of Jack Bean (*C. ensiformis)* seeds, tempeh, tofu and flour made from the seeds and the influence of length of soaking in various Ca-salt solutions toward HCN residu in the beans.

MATERIALS AND METHODS

Status of the beans

Dry mature seeds of *Canavalia ensiformis* (L.) DC. were obtained from Damar Sindoro Sumbing Farm Kandangan Temanggung, Central Java, Indonesia.

Tempeh starter

Tempeh was produced with commercially available tempeh starter. The starter used was Raprima brand produced by PT. Aneka Fermentasi Industry Bandung, Indonesia.

Soaking process

Five hundred grams of cleaned jack bean seeds in three replicates were weighed for each treatment that comprised: 24 h; 48 h; 72 h periods of soaking in tap water (control), saturated $Ca(OH)_2$, CaCO3 and 10% $CaCl_2$. Excess of soaking water was ensured throughout the soaking period. After the expiration of the soaking time, the water was discarded and the beans were dehulled for further tempeh manufacturing or ground for tofu processing.

Tempeh manufacture

The laboratory method of tempeh production described by Simon and Ko (1975) was used with some modifications.

Tofu manufacturing

The bean milk were prepared according to Tan et al. (2013) with modification. Soaked jack bean (80 g) was added with 200 ml (1:2.5, w/v) of tap water and ground for 5 min at a high speed in a food blender. After grinding, the slurry was filtered through a muslin cloth and squeezed by hand to obtain bean milk (You et al. 2012). Bean milk obtained was brought to a boil for a while (maintained for 3 min) and then cooked over moderate heat for 30 min by stirring continuously, or otherwise until a right consistency for gel formation was obtained, then followed by setting for gel formation as the concentrated beans milk was allowed to cooling down.

Flour preparation

After washing the beans at the end of its respectively soaking period, the beans were added lactic bacteria and fermented further. They were washed again at the end of fermentation and then ground for 5 min at a high speed in a food blender. The slurry obtained were drum dried and further dry-ground in hammer mill grinder to the final fine powder of 100 mesh size.

Determination of cyanide

AOAC (1986) for Hydrogen Cyanide determination in beans was used. Concentration of CN^- was calculated using the relationship 1 ml of 0.02M AgNO3 = 1.08 mg of HCN. Values of the samples were obtained from the mean of triplicate measurements.

RESULTS AND DISCUSSION

The effect of length of soaking on HCN content of jack bean seeds

The results showed the decreasing levels of HCN with soaking time increment (Table 1). The effect of length of soaking employed in the present study were found to reduced significant levels of HCN content at $\alpha = 0.05$. The prolonged soaking in water, $CaCl_2$, $CaCO_3$ and $Ca(OH)_2$ for 72 hours respectively followed by cooking for 30 minutes reduced HCN content of the beans to 78.68 %, 78.62%, 62.74% and 74.12% (Table 1). When considering the effect of these various Ca-salt soaking mediums for HCN reduction, all the presently studied Ca-salt soaking solutions have not exhibited any significant difference compare to water.

Although soaking with water showed the HCN content of the beans at about the same concentration with those soaked in calcium salt solutions, but physical and color changes were observed on the beans soaked without Ca-salts addition. However, these physical and color changes did not occured in the case of calcium salts were added except in lime $Ca(OH)_2$ solution. A remarkably maintained good physical and color of the beans observed by using 10 % $CaCl_2$, there were no any physical and color degradation shown such as those found in beans soaked in solely water or in lime solution. This is of greatest important for tofu manufacturing as color is a prime quality criteria. Moreover, obtaining intact seeds (without physical and color changes) that has low HCN content would open the possibility of a wider utilization of this safe to eat beans obtained.

Soaking in water (as control), although was able to reduce the HCN content but the seeds become soft, altered and slightly discolored after prolonged soaking for more than 48 hours, which render the seeds can not stand further heat processing. Soaking for 3 days is the most effective method for leaching out HCN and is a handy method that could allow for greater utilization of the HCN-free Jack Bean legume seeds obtained as the functional properties of proteins and carbohydrates can still be maintained. The effectiveness of the use of some calcium salt solutions in maintaining the condition of the seed therefore is of primary importance.

Chemical differences of soaking solutions lead to differences in their final pH at the end of soaking periode (Table 2) which further caused some changes in bean seeds and ultimately to the end products obtained.

Figure 1 shows that extending the soaking time to 72 hours released almost all the HCN residue from the beans and as a result the HCN concentration after prolonged soaking is below the threshold determined by FAO. Standard threshold levels of HCN produced by cyanogenic glikokogen in plants (tubers, nuts and seeds) is determined by the FAO at 50 mg/kg (or 50 ppm). Below the threshold (<50 mg / kg or less than 50 is still safe to consume. Values in excess of 100 ppm are considered a danger to health (Haque and Bradbury 2002). The FAO safe level for total cyanide content of cassava flour is 10 ppm (FAO 1991; Cardoso et al. 1998).

Tempeh was produced at the end each soaking periode of 24, 48 and 72 hours from all of Ca-salts soaked beans. The HCN content of tempeh made from beans soaked for 24, 48 and 72 hours in $Ca(OH)_2$ solution were 5.14 ppm, 3.86 ppm and 1.28 ppm. Similarly, for tempeh made with beans soaked in $CaCO_3$ solution gave results equal to 4.51 ppm, 3.85 ppm and 1.28 ppm and the HCN contents of the tempeh produced with beans soaked in 10% $CaCl_2$ solution for 24, 48 and 72 hours were 5.15 ppm, 3.87 ppm and 1.28 ppm (Fig. 2).

The highest HCN residue concentration of tempeh was obtained from those that were produced with beans soaked for 24 h. Its mean value amount to about 4.5 ppm. However, this value is still lower than HCN content of the bean soaked for 72 hours before entering the tempeh manufacturing steps, which showed HCN concentration mean at around 5.5 ppm. The mean of HCN content of tempeh made from beans soaked for 48 was 3.8 ppm. However, extending the soaking time to 72 h released almost all the HCN residue from the beans and as a result the HCN concentration found in tempeh less than 1.0 ppm.

Cyanide can cause death if consumption reaches a dose 0.5-3.5 mg HCN/kg weight. However, all tempeh produced at the end each soaking periode of 24, 48 and 72 h from all of Ca-salts soaked beans contained a very low HCN, soaked in water without Ca-salt addition included. Therefore, it is safe to consume. Their HCN content far below the threshold levels determined by the FAO.

Similar results were observed for tofu (Fig. 3). A maximum level of reduction of HCN of tofu produced was obtained from those that were produced with beans soaked for 72 h. Its residue mean value amounts to about only 1.2 ppm. The mean of HCN content of tofu made from beans soaked for 48 h equals to 3.7 ppm. Similarly, tofu made with the beans soaked for 24 h shows a mean value at around 4.8 ppm.

Beans ground after soaking in $Ca(OH)_2$ solution turned brown in colour and hence it was not further processed into flour, therefore only flour obtained from beans soaked in $CaCl_2$, $CaCO_3$ solutions as well as in water (control) were further processed into dry flour and analyzed their HCN contents. The flour obtained from $CaCl_2$ and $CaCO_3$ solutions resulted in clean white flours.

The results (Table 3) showed the effect of fermenting the beans slurry with lactic acid bacteria prior to drying. The addition lactic acid bacteria (LAB) is quite effective in lowering the HCN content of the slurry. However, this only lasts until the end of day 2 (48 hours), then the HCN contents tend to remain unchanged after 48 hours as in beans soaked for 72 hours. However, all of the HCN concentration of the flour obtained are still below the threshold determined by FAO. The WHO safe level for total cyanide content of cassava flour is 10 ppm (FAO 1991; Cardoso et al. 1998). Besides, whenever these flours which exhibit HCN contents in the range of 5.0 ppm to 6.5 ppm are processed further into new food products, their HCN content might be decreased as reported elsewhere.

CONCLUSIONS

Prolonged soaking in water, a process necessary to reduce the HCN content of jack bean seeds to safe levels, alters the beans either physically, chemically and microbiologically. The effectiveness of the use of some calcium salt solutions in maintaining the condition of the seed therefore is of greatest importance.

HCN residue left in tempeh had a concentration that was much lower than the threshold determined by FAO in plants as well as in cassava flour. Effect of processing on the jack beans especially soaking, dehulling and boiling followed by fermentation reduced HCN tremendously in the beans and tempeh produced. Similarly, the method applied for tofu processing, which consists of soaking, grinding and cooking, was capable to released almost all of HCN content of the beans to the level that is safe to consume as well. Fermenting the bean slurry with LAB prior to drying has the potential to increasing the quality of jack bean flour. All the flour obtained contained HCN at a level below the threshold determined by FAO.

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Table 1. Effect of various Ca-salts soaking mediums on HCN reduction

Soaking medium	Initial HCN content (ppm)	HCN content at the end of each soaking periode (ppm)			Reduction (%)	Cooking 30 minutes (ppm)	Reduction (%)
		24 Hours	48 Hours	72 Hours			
Water (control)	14.83	10.33	8.84	5.18	65.06	3.16	78.68
$CaCl_2$	14.83	10.54	10.98	5.20	64.95	3.17	78.62
$CaCO_3$	14.83	9.91	8.40	9.06	38.93	5.53	62.74
$Ca(OH)_2$	14.83	12.03	8.98	6.30	57.57	3.84	74.12

Table 2. pH of different media during prolonged soaking

Soaking medium	Replication	Initial pH	24 Hours	48 Hours	72 Hours
Water (control)	1	7.96	6.33	5.97	5.95
	2	7.98	6.34	5.98	5.93
$CaCl_2$	1	8.4	6.41	6.15	5.84
	2	8.39	6.42	6.16	5.85
$CaCO_3$	1	9.47	6.98	6.63	6.51
	2	9.45	6.99	6.64	6.5
$Ca(OH)_2$	1	12.9	12.77	12.7	12.36
	2	12.89	12.76	12.7	12.33

Table 3. HCN residue in jack bean flour obtained

Soaking medium	Initial HCN content (ppm)	HCN content at the end of each soaking period (ppm)					
		Before Fermentetation			After Fermentetation		
		24 Hours	48 Hours	72 Hours	24 Hours	48 Hours	72 Hours
air	14.83	10.33	8.84	5.18	6.475	6.442	5.385
CaCl2	14.83	10.54	10.98	5.20	6.399	6.430	6.471
CaCO	14.83	9.91	8.40	9.06	6.443	6.423	6.399

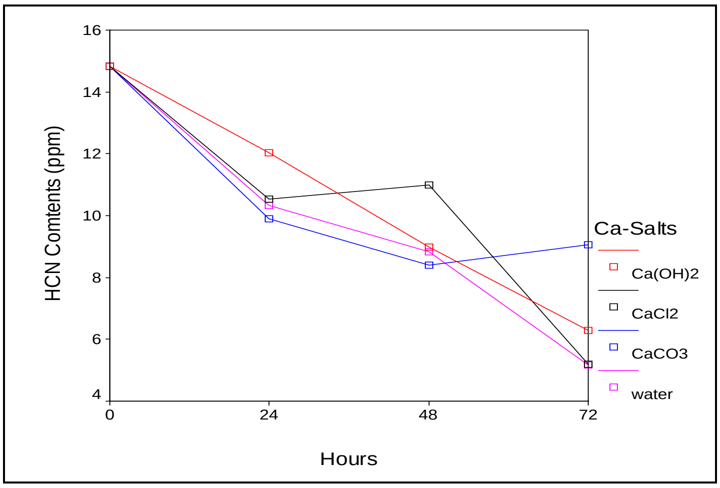

Figure 1. Effect of length of soaking on HCN content of jack bean.

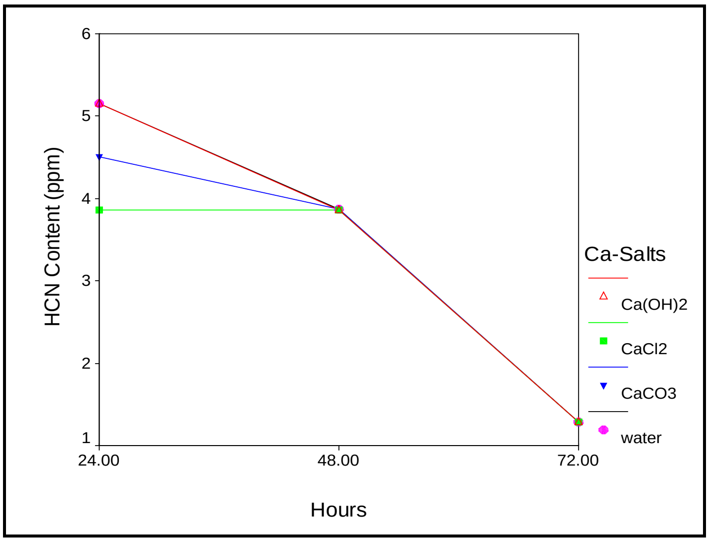

Figure 2. Effect of length of soaking on HCN content of jack bean tempeh.

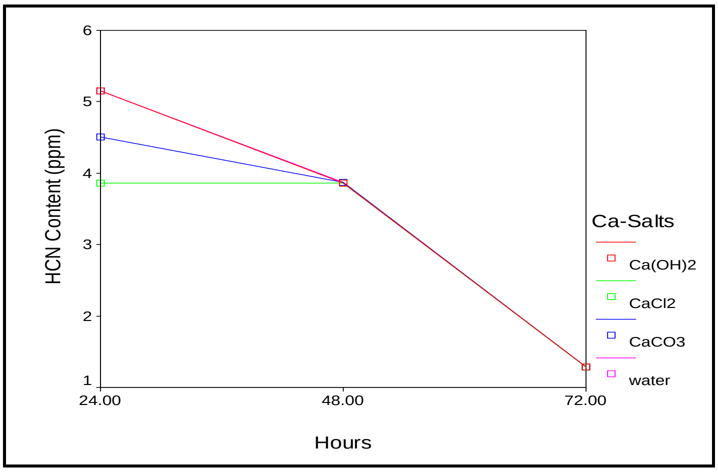

Figure 3. Effect of length of soaking on HCN content on jack bean tofu.

Nutrient composition and sensory evaluation of drumstick (*Moringa oleifera* Lam.) leaf products

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ABSTRACT

Drumstick (*Moringa oleifera* Lam.), an indigenous underexploited tree, is now valued for health care. It provides pods and leaves for vegetables, and has various nutraceutical values. Nutrient composition of pods and leaves of drumstick KDM-01 (Bhagya, a recently released variety from University of Horticultural Sciences, Bagalkot during 2012) and S-6/4 (Dhanraj) and sensory evaluation of products that contained dehydrated drumstick leaf powder at different levels was carried out at College of Horticulture, University of Horticultural Sciences, Bagalkot, Karnataka, India.

There was no significant difference observed between the varieties with respect to proximate composition of pods and leaves. In micronutrient composition, pods showed significant difference between the varieties in ascorbic acid, phosphorus, potassium and magnesium contents. The pods of variety KDM-01 were significantly higher in ascorbic acid (138.54 mg/100 g), phosphorus (109.70 mg/100 g) and magnesium (24.50 mg/100 g) content. Whereas, the pods of the variety S-6/4 was significantly higher in potassium (265.28 mg/100 g) content. In leaf micronutrient composition, KDM-01 variety showed significantly higher ascorbic acid (17.48 mg/100 g), calcium (2399.11 mg/100 g) and copper (0.081 mg) contents than variety S-6/4 (15.82 mg/100 g, 2081.77 mg/100 g and 0.073 mg/100 g, respectively). Whereas, the leaf of S-6/4 was significantly higher in iron (28.56 mg/100 g) than KDM-01 (27.36 mg/100 g).

With regard to sensory evaluation studies, the acceptability of *Thalipattu* incorporated with 5% fresh leaves was accepted highly, followed by 5% dehydrated leaf powder. Rice *Kichadi* prepared by incorporation of 7.5% dehydrated drumstick was accepted most, followed by control (without incorporation of drumstick leaves). Products incorporated with drumstick leaves at different levels showed corresponding elevation in micronutrient composition. Drumstick leaves are an outstanding indigenous source of highly digestible protein, calcium, iron, ascorbic acid and vitamin A, and can be exploited either in fresh or in dehydrated form in traditional food items. This would help in alleviating micronutrient deficiencies in a cheaper and most affordable way.

INTRODUCTION

Micronutrient deficiencies are more common in developing countries and the cause for their high prevalence is low dietary intake by populations and poor availability of micronutrients. Iron deficiency is the most common nutritional problem worldwide and contributes to maternal deaths in pregnancy and parturition. In India 79% of children between 6 to 35 months and women between 15 to 49 years of age are anaemic (Krishnaswamy 2009). Vitamin A deficiencies are estimated to cause 600,000 deaths whereas zinc deficiencies cause 400,000 deaths annually. The most sustainable approaches to increasing the micronutrient status of populations are food-based strategies, which include food production, dietary diversification and food fortification. Food-based intervention focus on natural, processed, or fortified foods alone or in combination as the primary tool for improving the quality of diets and for overcoming and preventing malnutrition and nutritional deficiencies.

Green leafy vegetables are rich sources of iron and other essential micronutrients, but they are discarded and are not used for human consumption. Drumstick leaf (*Moringa oleifera* L.) is one of them, which is available at no cost. The leaves are micronutrient-dense and provide more vitamins per mouthful than any other leaves. It is commonly said that drumstick leaves contain more vitamin A than carrots, more calcium than milk, more iron than spinach, more vitamin C than oranges and more potassium than bananas and that the protein quality rivals that of milk and eggs.

Drumstick leaves can be utilized in multiple ways by incorporating them into existing products and formulations of health foods using techniques of dehydration. Devising several simple and acceptable micronutrient-rich recipes containing drumstick leaves would not only bring variety to the diet but also help in combating micronutrient deficiencies. Therefore, we studied nutrient composition and sensory evaluation by utilizing the dehydrated drumstick leaf powder to enhance the nutritional quality of traditional products.

METHOD

Two varieties of drumstick (kdm-01 and s-6/4) pods and leaves were procured from the Research Field Unit, Department of Vegetable Science, College of Horticulture, University of Horticultural Sciences, Bagalkot. The other ingredients used for the preparation of formulations were procured from the local market.

Proximate composition (protein, fat, crude fibre, carbohydrate and moisture), vitamin A and ascorbic acid content of pods leaves and incorporated products were analyzed by using the standard procedure of AOAC (2004). Mineral estimation of the samples was carried out by the method of Ranganna (1986).

Preparation of drumstick leaves for drying

Fresh, green, undamaged, non-insect infested leaves were sorted out and the stalks of the leaves were cut from the main branches. Leaves were washed thoroughly three to four times under running water to remove the adhering dust and dirt particles. Washed leaves were spread on cotton cloths on the working table for shade drying in a well-ventilated room until the leaves were dried completely and became crisp and brittle to touch. The dried leaves were powdered, stored in airtight containers in a refrigerator and used for incorporation in traditional products *Thalipattu* and *Kichadi*.

Product formulation

Two products, *Thalipattu* and *Kichadi*, were selected for incorporating dehydrated drumstick leaves powder. *Thalipattu* is a mixed cereal and legume pancake-like product consumed for breakfast. Bengal gram flour (25 g), rice flour (25 g), fine semolina (25 g) and whole wheat flour (25g) were mixed together. Onion (40 g), tomatoes (20 g), half green chili (finely chopped), ajwain (1 g), cumin seed powder (1 g) and salt (3 g) were added to flour mixture and made into a stiff dough with water. The dough was rolled with roller and pin to have a diameter of about 5 inches and roasted by using oil (5 ml) on a nonstick tawa. Then it was turned upside down so that it was roasted on both sides. The dehydrated drumstick leaf powder at 2, 5, 7.5, 10% levels and 5% fresh drumstick leaves were incorporated into the flour mixture. The dough without addition of drumstick leaves served as control.

Kichadi is a pressure-cooked product prepared by using rice (70 g) and a legume, green gram dhal (30 g). Onion, chili, salt, mustard seeds, cumin seeds, oil and curry leaves were added for the product preparation. Rice and green gram dhal were washed thoroughly and cooked in a pressure cooker until soft. Seasoning was given with a little oil, mustard, cumin, chopped onion, chilli and curry leaves and mixed together with the cooked rice and green gram dhal mixture. During cooking the *Kichadi* was prepared by incorporating dehydrated drumstick lead powder at 2, 5, 7.5 and 10% levels and 5% fresh drumstick leaves. The *Kichadi* without incorporation of drumstick leaf served as control.

Sensory evaluation

The formulated products were subjected to sensory evaluation with the help of panel of 20 members using 9-point hedonic ranking scale for appearance, colour, texture, taste and overall acceptability (Swaminathan 1987). The product without dehydrated drumstick leaf powder and fresh leaves served as control. The data was compiled and analyzed statistically.

Statistical analysis

Statistical analysis for nutrient and micronutrient composition of drumstick pods and leaves was carried out by Student's 't' test. The sensory evaluation data was subjected to ANOVA (Panse and Sukathme 1967) and 'F' test was carried out to know the significant difference among the products that were developed.

RESULTS AND DISCUSSION

Proximate composition of drumstick pods and leaves

Proximate composition of drumstick pods and leaves are presented in Figures 1 and 2. The moisture content of the pods of Dhanraj and Bhagya was 87.95 and 87.41%, respectively, whereas, leaves contain 76.22 and 75.83%, respectively and there was no significant difference between the varieties. Protein content was slightly higher in the pods (3.50%) and leaves (6.11%) of Bhagya than Dhanraj (3.43% and 5.87%, respectively) though there was no significant difference between the varieties. Fat content was higher in Dhanraj pods (0.12%) and leaves (1.83%) than Bhagya (0.10 % and 1.71%, respectively). Crude fibre content was more (4.93%) in Bhagya pods than Dhanraj (4.66%) whereas, leaves of Dhanraj (2.50%) was higher amount than Bhagya (2.46%). The pods and leaves of Bhagya (4.06% and 13.89%) variety was higher carbohydrate than Dhanraj (3.84% and 13.58 %, respectively). The difference between the pods and leaves of two varieties with regard to proximate composition were found to be statistically insignificant.

Vitamin and mineral composition of drumstick pods and leaves

Vitamin and mineral composition of drumstick pods and leaves are depicted in Table 1 and Table2. In pods of Bhagya the ascorbic acid content was 138.54 mg/100 g and it was significantly different than the pods of Dhanraj (121.43 mg/100 g). The same trend was also observed in ascorbic acid content of leaves, where in the leaves of variety Bhagya was higher (17.48 mg/100 g) ascorbic acid than the variety Dhanraj (15.82 mg/100 g). Vitamin A content of both varieties was on par with each other in both the pods and leaves. However, the leaves of Bhagya (18.12 mg/100 g) was higher in Vitamin A than Dhanraj (16.46 mg/100 g).

In mineral composition there was significant difference between the pods of two varieties with respect to phosphorus, potassium and magnesium content. Phosphorus and magnesium content of pods of variety Bhagya (109.70 and 24.50 mg/100 g) was higher than Dhanraj (104.92 mg/100 g and 23.37 mg/100 g, respectively).

In leaves, significant difference was observed in calcium, iron and copper content. The leaves of variety Bhagya was higher in calcium (2399.11 mg/100 g) than Dhanraj (2018.77 mg/100 g), whereas, the iron content was higher in variety Dhanraj (28.56 mg/100 g) than Bhagya (27.36 mg/100 g). The leaves of Bhagya (0.0187 mg/100 g) was higher content of copper than Dhanraj (0.073 mg/100 g). There was no significant difference in phosphorus, potassium and magnesium content in the leaves of two drumstick varieties.

Incorporation of drumstick leaf powder in product and sensory evaluation

Blanched and dehydrated drumstick leaf powder was incorporated in to *Thalipattu* as noted above. Products were evaluated for sensory quality by a panel of judges. Results of sensory analysis are presented in Table 3. The control sample was given scores ranging from 6.523 to 7.364 for different quality attributes. Addition of 5% fresh drumstick leaves enhanced the quality attributes *viz.*, colour, flavour, taste, texture and overall acceptability over the control. Incorporation of dehydrated drumstick leaf powder at 7.5% and 10% levels lowered the scores of all the attributes of the product. However, there was no significant difference observed with taste and texture of the product at all levels of incorporation of dehydrated drumstick leaf powder. Overall acceptability of *Thalipattu* with 5%, 7.5% drumstick leaf powder and 5% fresh leaves were on par with the control. Significant differences were found in colour, flavour and overall acceptability. Addition of dehydrated drumstick leaf powder brought down the scores of colour and flavour of *Thalipattu.*

Sensory analysis scores of *Kichadi* are presented in Table 4. Colour of the *Kichadi* prepared by incorporation of dehydrated drumstick leaf powder at 5%, 7.5% and 5 % fresh leaves were on par with the control, however, the scores of 5% fresh leaves incorporation was higher than control. Scores for the colour of the *Kichadi* was significantly brought down by the incorporation of 10% dehydrated drumstick leaf powder. In all the other quality attributes also 10% incorporation of drumstick leaf powder showed significant difference with lowest scores except in texture. However, the incorporation of drumstick leaf powder at levels of 5% and 7.5% improved all the quality attributes *viz.*, taste, texture and over all acceptability. No significant difference was observed in texture of *Kichadi* at all levels of incorporation.

Products incorporated with dehydrated drumstick leaf powder showed a remarkable increase in all their micronutrient content (Table 5 and Table 6). The iron content of *Thalipattu* was found to significantly increase from 7.12 mg in control to 9.85 mg/100 g for the 10% dehydrated drumstick leaf powder incorporated product. Vitamin A content also increased extraordinarily. A serving size of two *Thalipattu* (100 g) can provide the daily requirement of Vitamin A for an individual.

Iron, calcium, vitamin A and vitamin C content of *Thalipattu* increased from 7.12 mg, 74.70 mg, 121.71 mcg, 17.62 mg, respectively in control to 9.85 mg, 314.65 mg, 1767.32 mcg and 18.34 mg, respectively for the 10% dehydrated drumstick leaf powder incorporated product. Significant difference was also found in all the micronutrients by the incorporation of dehydrated drumstick leaf powder at 5% and 7.5%. A similar trend was observed in the *Kichadi*. The incorporation of dehydrated drumstick leaf powder at 10% enhanced the iron (8.17 mg), calcium (302.33 mg), vitamin A (1776.63 mcg) and vitamin C (12.94 mg) when compared to control (5.43 mg, 62.18 mg, 37.46 mcg and 11.44 mg, respectively).

Similar observations have been reported by Kaveri et al. (2004) who incorporated dehydrated *Peucedanum graveolens* in wheat papads. Mineral, vitamin and fiber content of greens incorporated into papads increases remarkably. Addition of dehydrated greens (*Amaranthus paniculatus* and *Peucedanum graveolens*) increased nutrient density of *Mathri* and *Thalipattu* (Gupta and Prakash, 2011). Ingestion of meals containing provitamin A rich carotenoids from yellow and green leafy vegetables improved the total body vitamin A pool size and Hb concentration and decreased anaemia rates in Filipino school children (Maramag et al. 2010).

From the above observations, it can be concluded that drumstick leaves and pods are rich source of nutrients. Sensory evaluation of products incorporated with different levels of dehydrated drumstick leaf powder revealed that they could be incorporated in traditional products *Thalipattu* and *Kichadi* at levels of 7.5% with no detrimental effects on sensory quality. Addition of dehydrated drumstick leaf powder increased the nutrient density of all products. Value addition of traditional products with dehydrated drumstick leaf powder can be advocated as a feasible food- based approach to combat micronutrient malnutrition.

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Table 1. Vitamin content in drumstick pods and leaves (per 100 g)

Vitamins	Pods		't' value	Leaves		't' value
	Bhagya	Dhanraj		Bhagya	Dhanraj	
Ascorbic acid (mg)	138.54	121.43	7.061**	17.48	15.82	4.648**
Vitamin A (mg)	0.136	0.14	NS	18.12	16.46	NS

**Significant at 1 % level
NS: Non Significant

Table 2. Mineral composition of drumstick pods and leaves

Minerals	Pods			Leaves		
	Bhagya	**Dhanaraj**	**'t' value**	**Bhagya**	**Dhanaraj**	**'t' value**
Calcium (mg)	30.28	31.49	NS	2399.11	2018.77	4.90**
Phosphorus (mg)	109.70	104.92	6.101**	207.68	207.55	NS
Iron (mg)	5.29	5.91	NS	27.36	28.56	6.296**
Potassium (mg)	260.18	265.28	6.944**	1347.40	1362.25	NS
Magnesium (mg)	24.50	23.37	10.336**	364.62	371.58	NS
Copper (mg)	0.073	0.076	NS	0.081	0.073	8.50**

**Significant at 1 % level
NS: Non Significant

Table 3. Sensory analysis of *Thalipattu* by incorporation of drumstick leaf powder and fresh leaves

Level of incorporation of drumstick	Quality characteristics				
	Colour	**Flavour**	**Taste**	**Texture**	**Overall acceptability**
5% DDP	6.102	6.579	7.215	6.523	7.056
7.5% DDP	5.897	6.102	6.841	6.682	6.635
10% DDP	4.897	5.635	6.364	5.841	6.000
5% DFL	8.056	7.317	7.476	7.158	7.635
Control	7.364	6.523	6.579	6.635	6.738
CD± SEm	1.273±0.54	1.118±0.47	NS	NS	1.002±0.43

DDP: Dehydrated drumstick powder
DFL: Drumstick fresh leaves

Table 4. Sensory analysis of *Kichadi* by incorporation of drumstick leaf powder and fresh leaves

Level of incorporation of drumstick	Quality characteristics				
	Colour	**Flavour**	**Taste**	**Texture**	**Overall acceptability**
5% DDP	6.943	6.023	7.056	6.761	7.158
7.5% DDP	6.284	5.579	6.125	6.364	6.341
10% DDP	5.476	4.658	5.079	5.635	5.102
5% DFL	7.364	6.158	6.579	6.500	6.784
Control	7.215	6.420	6.602	6.341	6.841
CD± SEm	1.069±0.45	1.318±0.56	1.122±0.48	NS	1.049±0.44

DDP: Dehydrated drumstick powder
DFL: Drumstick fresh leaves

Table 5. Nutrient composition (per 100 g) of *Thalipattu* by the incorporation of drumstick leaves

Treatments	Protein (g)	Fat (g)	Crude Fibre (g)	Ash (g)	Iron (mg)	Calcium (mg)	Vit-A (mcg)	Vit-C (mg)
Control	13.40	12.45	2.07	1.93	7.12	74.70	121.71	17.62
5% DDP	13.82	12.54	2.19	2.02	8.49	195.10	1025.99	16.47
7.5%DDP	14.15	12.57	2.25	2.04	9.16	254.42	1355.89	16.85
10%DDP	14.27	12.63	2.32	2.10	9.85	314.65	1767.32	18.34
5g DFL	14.09	12.53	2.14	2.03	7.46	96.72	472.57	27.29
CD (1%)	0.510	0.047	0.036	0.021	0.020	0.742	2.849	0.353
SEm±	0.116	0.011	0.010	0.008	0.014	0.166	0.634	0.078

DDP: Dehydrated drumstick powder
DFL: Drumstick fresh leaves

Table 6. Nutrient composition (per 100 g) of *Kichadi* by the incorporation of drumstick leaves

Treatments	Protein (g)	Fat (g)	Crude Fibre (g)	Ash (g)	Iron (mg)	Calcium (mg)	Vit-A (mcg)	Vit-C (mg)
Control	13.17	10.96	1.43	1.78	5.43	62.18	37.46	11.44
5% DDP	13.39	11.05	1.55	1.88	6.79.	182.45	929.95	12.14
7.5%DDP	13.55	11.09	1.60	1.91	7.49	242.77	1356.97	12.60
10%DDP	13.68	11.15	1.67	1.96	8.17	302.23	1776.63	12.94
5g DFL	13.15	11.06	1.46	1.90	5.78	84.62	365.92	23.07
CD (1%)	0.127	0.033	0.021	0.016	0.025	1.903	75.105	0.420
SEm±	0.031	0.005	0.014	0.011	0.005	0.420	16.75	0.093

DDP: Dehydrated drumstick powder
DFL: Drumstick fresh leaves

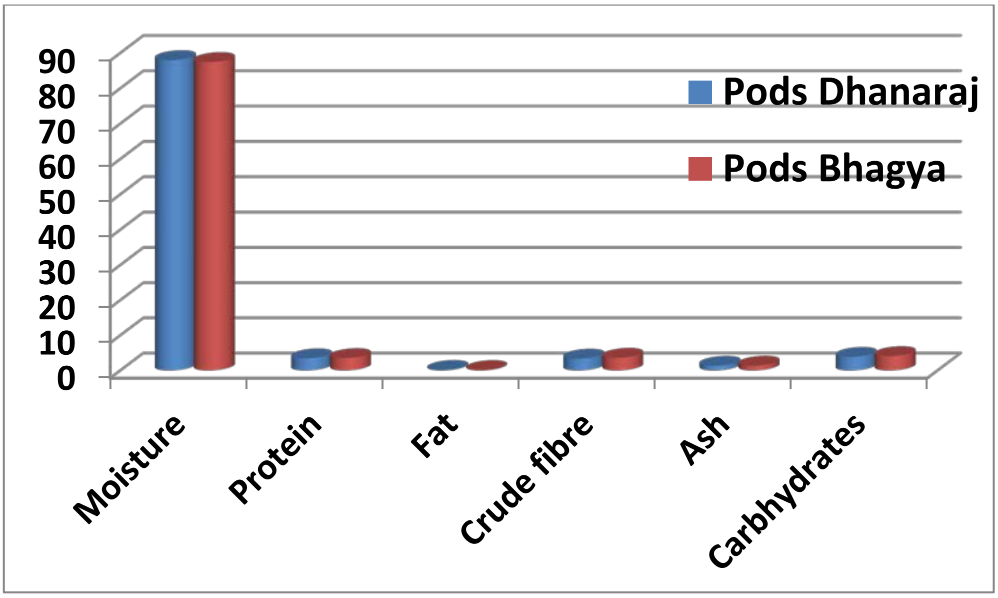

Figure 1. Proximate composition of drumstick pods

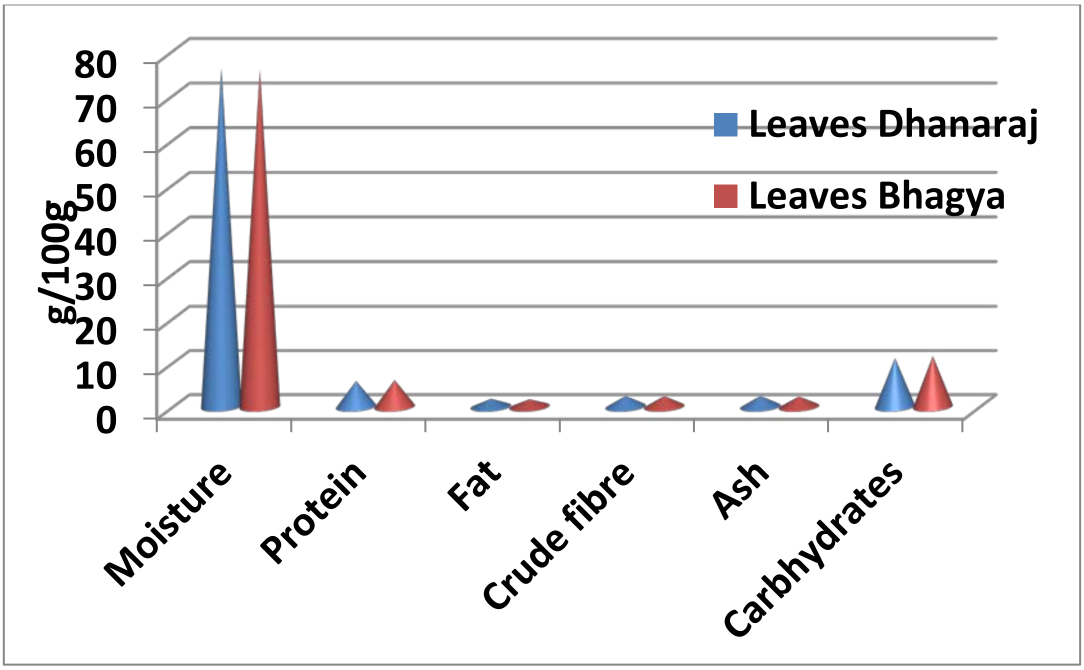

Figure 2. Proximate composition of drumstick leaves

Farm profitability and value chain management of tomato growers: a case study from India

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ABSTRACT
Vegetable crops have strong potential for income generation to make farming a viable proposition. But the major constraints encountered by vegetable growers, especially tomato, including perishability, market price fluctuation and escalating cost of cultivation mar the prospects. In this context, supply chain management and market efficiency have a crucial role to play. This study addresses farm profitability and value chain management among tomato growers of Trichy district, Tamil Nadu state in India. A sample size of 100 respondents was selected using multistage random sampling technique and a pre-tested questionnaire was used for the survey. Findings revealed skewed price spread at the farmer's end. At the same time Shepherd's index was also very low (1.22) referring market efficiency to be dismal. Marketing cost of the farmers was seen largely influenced by transportation cost itself. A majority of the tomato growers perceived the need of vegetable clusters in a positive light. But 47% were unaware of the market intelligence and price forecasting spearheaded by the use of Information and Communication Technology (ICT) tools. The study suggests widening the use of ICT tools in the development of agricultural clusters to bring out not only horizontal integration of vegetable growers but also vertical integration of all members of the supply chain to better the prospects of farm profitability.

Keywords
Price spread, Market efficiency, Marketing efficiency, ICT tools, Agri-clusters.

INTRODUCTION
India is the second largest producer of vegetables that accounts about 16.2% of the world production. Horticulture sector alone contributes 28% of the agricultural gross domestic product of the nation coupled with 56% of the total agricultural export earnings (NHB 2012). Growing demand for fruits and vegetables induced by rising incomes and changing consumption patterns along with declining farm incomes because of rising costs and stagnating food grain productivity has necessitated diversification towards high-value crops like vegetables in recent times. Apart from the attribute of income enhancement, these high-value crops have potential to generate additional employment opportunities in farming due to their labour-intensive character (Weinberger and Lumpkin 2006). This is why it is a win-win opportunity when it comes to the cultivation of vegetables.

From the ecological point of view, diversification with vegetables benefits farmers in the aspect of crop rotation. Monocultures have resulted in the emergence of various problems like over-exploitation of the groundwater resources, depletion of soil fertility, and higher susceptibility of crops to the attack of various insect-pests and diseases (Sidhu 2002). Agricultural growth and development in particular is in a fix in India as the national target of 4% growth in agriculture (NHB 2012) is yet to be achieved despite the best efforts being made over the years. It is not an exaggeration to state that stagnating productivity, falling income and growing indebtedness and farmers' suicides have become the hallmarks of Indian agriculture (Sidhu 2002). Thus, to improve income, provide gainful employment and save natural resources from further degradation, diversification from grain crops to high-value crops like vegetables has emerged as an important strategy for agricultural growth (Sekhon and Kaur 2004).

There was a clear economic advantage in producing vegetables as compared to field crops, but lack of marketing facilities has been the major impediment (Navadkar 2005). Transportation costs and marketing margins of both retailers and wholesalers have been identified as the major reasons for high marketing costs of vegetables, adversely affecting the profitability of such crops (Kumar et al. 2004). Issues of high cost of packing, high commission, high transportation costs, delayed payments to the farmers and existence of malpractices in the marketing of vegetable crops often find mention among research community (Kumar 1999; Kumar 2004; Elenchezhian 2004; Navadkar 2005). There are reservations on the potential of agro-processing to boost vegetable production due to lack of sufficient demand for processed vegetable products and very high capital requirements for such initiatives (Sidhu 2002). On the marketing side there has been a significant negative relationship between the market arrivals and vegetable prices (Khunt et al. 2006). There are large variations in the share of vegetable producers in consumer's rupee as well as marketing margins across different marketing channels. Due to inefficient vegetables marketing systems, consumer's prices do not reflect the producer share (Ranveer Singh 1994). The margins of middleman in private trade channels are so high that producers seldom obtain 40 % of consumer's price (Bhupal 1986). Most of the vegetable growers sold their produce through commission agents and direct sales to retailers or consumers were negligible (Subramanyam 1988). As a result, market intermediaries tend to apportion greater margins on the pretext of sharing larger proportion of producer's risk (Radha and Prasad 2001).

The market plays an important role in determining the pattern as well as pace of diversification in favour of high-value crops. The adoption of these crops not only depends on socio-economic characteristics of the farmers, but also on production and market characteristics of these crops such as amount of capital investment required, cost of production, prices realized, marketing margins and marketing efficiency. While large capital requirements and high cost of production may sometimes deter adoption, higher margins and efficient markets may attract farmers to go for such crops.

We carried out an in-depth supply-chain analysis of tomato crop in the Trichy district of Tamil Nadu, South India. Tomato was selected for analysis due to its importance in production as well as consumption patterns. The crop is also highly perishable and highly price volatile. Like other cultivators, independent local tomato farmers fail to create valuable regional production and marketing systems to remain competitive in the market. Thereby farmers do not have an overview over the produced quantities. Unsure about the quantities to sell, tomato farmers hardly can influence any prices. Thereby the study has estimated the costs and returns from cultivation, identified different supply-chain systems and associated margins and finally has looked into the perceptions of farmers about the need of tomato specific vegetable clusters spearheaded with market intelligence through Information and Communication Technology (ICT) tools. The specific objectives of the paper include (i) estimating farm profitability, price spread and market efficiency for tomato crop; (ii) understanding constraints faced by tomato growers in the existing market chain, and (iii) assessing how tomato specific vegetable clusters would improve supply chain management and in turn farm remuneration.

SAMPLING METHOD

The study has used both primary and secondary data collected from the farmers and different market functionaries associated with marketing of the selected vegetables for the year 2013. The survey was conducted in the Andanallur block of Trichy district known for largest acreage under tomato cropping. Almost all major tomato varieties of Tamil Nadu including PKM 1, Red Ruby, US 108 and Laxmi 5005 were cultivated in the study area. As tomato farmers were spread over all the 25 villages of the block, a multi-stage random sampling technique was followed. Major tomato growing villages were first obtained from the block level agricultural and horticultural officials. From the obtained list, 10 villages were randomly chosen. Then the list of tomato growers of all the 10 villages was obtained from the village administrative officers, village *panchayat*[1] presidents and local agricultural input dealers. This was followed by randomly selecting 10 farmers each for every village already under consideration. The data were collected by a well-structured pre-tested questionnaire. The marketing data were collected from a random selection of 20 traders and 20 retailers in the Trichy wholesale market. Focus group discussions among farmers were also carried out to better understand marketing situation and farm level profitability. The study period was between September and December 2013. Costs, returns, vegetable disposal systems and marketing margins were calculated by using simple tabular analysis. STATA 11.2 software package was employed for further analysis.

Tools of Analysis

Price spread analysis

Price spread in general is referred to as the difference between the price paid by the ultimate consumer and that received by the growers per unit of the commodity (Acharya 2004). Price spread analysis would estimate the share of different market functionaries in the consumer's rupee and this would often facilitate the understanding of the relative efficiencies and otherwise of alternate marketing channels. For our study, the concurrent margin method was used to analyze the price spread. There is an inverse relationship between farmer's net share and the length of marketing channel (Sarker 1992), i.e. the larger the marketing channel, the lower the farmer's net share. Price spread analysis was carried out as:

Price spread = (Price paid by consumers) - (Net price received by farmer)

Marketing efficiency

This is the ratio of consumer's price to the total marketing costs and margins. The higher the ratio, the higher would be the efficiency and *vice versa*. Marketing efficiency is evaluated by marketing margin, price received by the producer, cost of marketing and profit share of traders **(**Hugar 1984). In this study, Shepherd's

1 Administrative unit by which villages are locally governed in India

Index (Shepherd 1972) has been used to analyze marketing efficiency as the ratio of total value of goods marketed to the marketing cost as follows,

Marketing Efficiency = **CP / MC + MM**

Where,

ME = Marketing efficiency

CP = Consumers' purchase price

MC = Marketing costs

MM = Marketing margins

Market efficiency

Market efficiency was determined by analyzing marketing cost function of the farmers. Different types of models were used to analyze the influence of various factors on marketing cost, finally a double log regression model of the following type was fitted:

$$\ln MC = \ln a + b_1 \ln X_1 + b_2 \ln X_2 + b_3 \ln X_3 + e_t$$

Where,

MC = Marketing cost incurred by farmers (Rs/qtl)

X_1 = Quantity of vegetable marketed in quintal

X_2 = Distance transported in km

X3 = Number of labour days engaged in post harvest operations

a = Constant term

e_t = Disturbance term

b_1, b_2 and b_3 are regression coefficients

Marginal value

In order to test the efficiency, the ratio of marginal value (MV) to the marginal factor cost (MFC) for each input should be computed and tested for its equality to 1, i.e. MFC/ MVP = 1. The marginal value of a particular factor represents the additional to gross marketing cost in value term caused by an additional one unit of that factor, while other factors are held constant. The most reliable, perhaps the most useful estimate of MV is obtained by taking factors (Xi) as well as gross marketing cost (Y) at their geometric means. In this study, marginal value has also been computed for the variables influencing marketing cost of tomato farmers.

Garrett's ranking technique

To find the significant constraints of the farmers in accessing markets, Garret's ranking technique was used (Garrett 1981). As per this method, respondents were asked to assign rank for all the factors and the outcome of such ranking was converted into score value with the help of the following formula:

Per cent position of the constraints faced = 100(R_{ij}-0.5) N_j

Where,

R_{ij} = Rank given for the i^{th} factor by the j^{th} respondent

N_j = Number of factors ranked by the j^{th} respondent

By referring to Garrett's table, the estimated per cent position of the constraints was converted into scores. Then for each factor the scores of each individual were added and the mean values obtained were considered to be most important and then were ranked accordingly.

Results and Discussion

Land resources and cropping pattern

The average size of operational holding for tomato growers was 0.63 ha. Some of the vegetable growers were observed to be leasing-in some chunk of land to increase their operational area in order to improve their economies of scale. But for tomato the leasing-in of land was not a common sight. The crop was cultivated only once in a season starting from June onwards.

Cost of cultivation and returns

On an average the total cost of cultivation for tomato growers was estimated at Rs 48,951/ha (Table 1). Within the variable costs of cultivation, the share of human labour exceeded 50%, indicating the labour-intensive character of the tomato crop.

The seed and nursery-raising were other important cost components accounting for 25% and 16% of the variable costs respectively. Expenditure on fertilizers and pesticides was also a significant cost item. The share of fixed cost in total cost was at 18% and the rental value of land constituted for almost three-fourths of the total fixed cost. The gross returns for tomato crop was Rs. 105,923/ha while the returns over variable costs was Rs. 56,972/ha.

Disposal pattern and marketing channels

In the study area the tomato crop was marketed through three different modes, namely village traders, commission agent/wholesaler, retailer and sometimes directly to the ultimate consumer. The pattern of tomato farmers disposing off their produce through these channels along with the proportion of their produce is shown in Figure 1.

Findings revealed that more than 90% of the produce was disposed off through wholesalers and a small proportion was sold directly to consumers. Although the tomato growers tend to diversify their market portfolio by selling directly to consumers to realize better prices for their produce, the relatively small capacity of the channel to handle large volumes of the produce creates a hindrance to sales. Hence, their increased dependence on the commission agents/wholesalers for selling their produce and relatively greater vulnerability to sharp fall in prices in times of excessive production. The three supply channels being pursued for marketing of the tomato crop were:

> Channel I: Producer - Village trader - Commission agent/Wholesaler - Retailer - Consumer
>
> Channel II: Producer - Commission agent/Wholesaler - Consumer
>
> Channel III: Producer - Consumer

It was found that direct selling to consumers (Channel III) though was smallest in handling production, but was found to be the most efficient as it ensured not only the maximum price of the produce to the farmers but also largest share in the consumer's rupee (*vide* table 2). The prices of tomato and producer's share in consumer's rupee varied inversely with the length of the channel. Inclusion of more number of market intermediaries in the supply chain appropriated significant margins of the producers. This seems to be happening for facilitating easy and quick marketing of large volumes of the produce. However, intermediaries, especially wholesalers did not appear to be helping farmers in getting better prices.

Marketing costs and margins in the supply chains

The marketing costs, margins, price spread and Shepherd's Index for tomato have been presented in Table 2. Under producer-village trader-wholesaler-retailer-consumer supply channel the marketing costs incurred by village trader, wholesaler and retailer were: Rs. 37.42/qtl, Rs. 12.67/qtl, and Rs. 22.41/qtl, respectively. The sample farmers didn't have significant marketing costs when selling directly to village traders. In producer-wholesaler-retailer-consumer supply chain, the marketing cost incurred by producer was Rs. 37.36/qtl while the marketing costs of wholesaler and retailers remain the same.

The producer's share in consumer's rupee was found to be Rs. 38.31 under producer-village trader-wholesaler-retailer-consumer and it was Rs. 54.50 in the case of inclusion of another intermediary, i.e. village traders. As the links of supply chain got reduced, the share of producer in consumer price increased, indicating higher market efficiency under integrated supply chain systems.

Price spread and market efficiency

The marketing channel among Trichy district tomato farmers started with village traders and flowed through commission agent cum wholesalers, retailers and ended with consumers. The cost incurred by the tomato farmers in the way of commissions were not included in working out the price spread to avoid double counting since these items were covered under profit margin of commission agents. It was found that tomato was available to retailers directly from commission agents at 10 kg onwards. Farmers selling in wholesale market directly incurred cost on grading, packing, transport, and commission of 15% on the value of sales to the commission agent who arranged for the sales. Commission charges constituted a larger share varying from 4.59% of the consumer's price. Usually the commission agents did not take the title to the produce and they merely negotiated the purchase and or sale (Nawadkar 1991). But in this case of tomato supply chain the wholesalers were seen performing the role of commission agents as well. They took the title to the goods they handled, they bought and sold on their own gain or loss depending on the difference in the sale and purchase prices. The price spread was at 61.69% and 45.5% in the case of Channel I and Channel II respectively (Table 2). The high amount of price spread for tomato was due to perishability and high fluctuation in prices. Since the marketing cost and marketing margin in relation to consumer's price were higher, Shepherd's Index of marketing efficiency was very low for tomato in both Channel I (1.22) and Channel II (1.73).

Marketing efficiency

To evaluate the factors influencing marketing cost of tomato farmers a double log type of marketing cost function was fitted and the results of the regression analysis are presented in Table 3. Findings revealed that 72% of variation in marketing cost of tomato was explained by selected independent variables *viz*. quantity of tomato marketed, $X_{1;}$ distance travelled to the market, $X_{2;}$ and labour involved in postharvest operations, X_3. Regression co-efficient for quantity marketed was at negative referring that every increase in quantity marketed would adversely affect the marketing cost, thus favouring the farmer but it was found not significant.

The distance to the market and labour involved were found positively impacting the marketing cost and were at 0.089 and 0.178 respectively, given other variables are kept constant. The marginal values imply that for every kilometer increase in distance to the market from mean level the marketing cost would increase by Rs.1.43 and for every number of days increase in labour meant for postharvest operation from mean level, marketing cost would increase by Rs.0.16 per quintal of tomato. This could only mean that increasing productivity (presently at 18.5 t/ha) will not serve unless the spatial distribution of production is taken care of. Focus group discussions revealed that the farmers perceive a loss of 20-25% of the tomato harvest due to lack of postharvest and proper storage facilities.

Farmers' perception of constraints

Garrett's ranking analysis revealed that price volatility was the major impediment (64.77%) perceived by farmers (Table 4). Lack of technical support was the next major constraint (58.40%) followed by escalating cost of cultivation (53%). Shortage of labour (51.55%) was cited at both production and marketing ends. The farmers had no idea of market requirement and market contracts were not heard of. At times when farmers sell off directly to wholesalers a number of marketing problems like low consumer preference, higher frequency of picking and less acreage cobble up leading to small quantities brought to the market for which the commission agents/ wholesalers might not have much interest on marketing. About 47% of tomato growers were unaware of market intelligence and price forecasting given through ICT tools viz., *kisan*[2] call centre and mobile SMS (Table 4).

Farmers' perception of the supposed impact of tomato clusters

Vegetable clusters are a geographically bounded concentration of interdependent and complementary farmers, connected to each other by using the same technology, technical know-how, and agro-inputs. The prospect of better remuneration from vegetable cultivation gets often blurred by perishability of produce, highly volatile market prices and escalating cost of cultivation. Thereby such vegetable clusters can pave way for knowledge transfer, development and diffusion of innovations and trustful cooperation and can lead to spatial organization of production (Martin, 2001) Clusters can also result in shared costs for infrastructure, the buildup of a skilled labour force, transaction efficiency, and knowledge spill-overs leading to firm learning and innovation (Pyke and Sengenberger 1992).

In Figure 2 an attempt has been made to showcase the purported opportunities of tomato clusters to the farm community. First of all, tomato clusters can effectively check asymmetricity which is a common feature in the marketing of agricultural produce. Transparent nature of marketing would go in a long way enabling the farmers to know the requirement of markets and plan cultivation accordingly. Empowering tomato clusters with ICT tools is an unavoidable feature as they have a vital role to play in making clusters actually work. As farmers would be better equipped with the market intelligence of knowing consumer demand, spatial distribution of cropping would become possible resulting in lesser chances of glut thereby improving market efficiency. At the same time as clusters enabled by ICT would be offering better chances for the farmers to plan their cropping and also to

3 farmer

take better decisions, transport costs can greatly be curtailed, thus, improving marketing efficiency as well.

With tomato clusters becoming full flung, postharvest losses could also be avoided with more importance being given to agro-processing opportunities. As the value chain management moves up to agro-processing sector, the durability option of sale of produce also gets widened, giving a fillip to market efficiency. Moreover when value addition prospects get realized, the marketing efficiency possibility improves as well. The possibility of marketing contracts not only improves price spread to the advantage of the farmers but also increases the chances of rise in farmer's share itself. In essence tomato clusters flanked with ICT tools would pave way to sustainable remuneration and when the risk of income failure also gets reduced to an appreciable account then improvement in farm profitability gets ensured.

As can be seen from Figure 3, tomato farmers in the study area prefer the introduction of tomato clusters over the present marketing channel. On a scale of five, farmers perceive that tomato clusters empowered by ICT tools are likely to enable them in both production and marketing aspects. ICT is an umbrella term that includes any communication device or application (like radio, television, internet, mobile phones, etc.) that is put to the service of farmers in both production and marketing aspects. Farmer's perceive that the option of tomato clusters along with ICT would be the best (4.65) when it comes to the consistency of quality followed by the option of Present Market Channel + ICT (3.82). However with the present market channels option, farmers perceive that maintaining consistency in quality is largely difficult (2.5).

In all the fronts of post harvest handling (4.87), ability to meet sudden changes in orders (4.8), price competitiveness (4.69), managing risk of crop failure (4.67), application of good agricultural practices (4.5), and ability to supply adequate quantity (4.5) farmers perceived that the introduction of vegetable clusters facilitated by ICT would be of great advantage. Even the introduction of ICT tools in the present market channel is perceived to be beneficial. The only area in which the farmers are comfortable with the present marketing channel is the degree of coping with the payment flexibility (4.0). It seems that the farmers are so familiar with the market intermediaries in the present market channel that even the tomato clusters with all its intended benefits is considered to be risky. But it becomes very clear that the ICT tools should be made widely prevalent and easily accessible in a full-fledged manner before integrating all the production and marketing services with tomato clusters.

CONCLUSION

Tomato cultivation has strong potential for income generation, yet problems of perishability, market price fluctuation and cost of cultivation blur the prospects. Supply chain management and market efficiency play a crucial role in this regard. It could be ascertained that widespread use of Information Communication and Technology (ICT) tools would improve market efficiency and work out the price spread of the produce in favour of the producers, thereby enabling fair trade for all members of the supply chain. The study suggests that widespread use of ICT tools in the development of tomato clusters would bring out not only horizontal integration of tomato growers but also vertical integration of all the members of the supply chain, leading to better prospects for farm profitability. Apart from checking asymmetricity in the market, mutual trust and cooperation among tomato farmers needs to be encouraged to make tomato clusters a reality. Modernizing the marketing system is of utmost priority. The retail chains need to be organized in such a way to integrate the supply chain through backward linkages with the farmers supported by pre-cooling facilities, refrigerated transportation, grading and standardization facilities and air-conditioned shelf space. Tomato clusters would also more possibly create spatial distribution of production, thereby ensuring sustainable remuneration and preventing possible gluts in the market.

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Table 1. Farm profitability of tomato crop in Tamil Nadu

Sl.No	Sl.No	Tomato
1	Yield (qtl./ ha.)	185.60
2	Price (Rs./ qtl.)	570.71
3	Gross returns (Rs./ ha.)	105923.78
4	Total variable costs (Rs./ ha.)	42038.40
5	Total costs (Rs./ ha.)	48951.43
6	Returns over variable costs (Rs./ ha.)	63885.38
7	Net returns (Rs./ ha.)	56972.35
8	Benefit-cost ratio	2.16

Note: Rs**.** is abbreviation for Indian rupee. qtl/ha – quintal/hectare
Source: Primary survey

Table 2. Marketing costs, margins and price spread for tomato (in Rs/qtl)

Sl.No.	Particulars	Channel I	Channel II	Channel III
Farmer				
1	Net price received by producer	426.32	607.26	678.56
Village trader				
2	Price paid by village trader	426.32	-	-
3	Marketing cost	37.42	-	-
4	Profit margin	227.63	-	-
5	Marketing margin	265.05	-	-
Wholesaler cum commission agent				
6	Price paid by wholesaler	691.37	607.26	-
7	Marketing cost	12.67	12.67	-
8	Profit margin	264.82	300.82	-
9	Marketing margin	277.49	313.49	-
Retailer				
10	Price paid by retailer	818.86	818.86	-
11	Marketing cost	22.41	22.41	-
12	Profit margin	271.37	271.37	-
13	Marketing margin	293.78	293.78	-
Consumer				
14	Price paid by consumer	1112.64	1112.64	678.56
15	Producer's share	38.31	54.50	-
16	Price spread	686.32	455.84	-
17	Shepherd's Index	1.22	1.73	-

Source: Primary survey
Note: Rs. – stands for Indian Rupee; qtl. stands for 'quintal'; Net price received by the farmer = (Gross price received/ unit) - (Average per unit cost incurred on marketing /unit); Producer's share = Net price received by producer / Consumer's price x 100;

Table 3. Marketing efficiency of tomato farmers

Particulars	Tomato	
	Co-efficient	Marginal value
Quantity marketed (in quintal), X_1	-0.016^{NS} (0.051)	-0.039
Distance travelled to the market (in km), X_2	0.089^{*} (0.067)	1.43
Labour involved in postharvest operation (in number of days), X_3	0.178^{**} (0.04)	0.16
Intercept	1.61	
R^2	0.72	

Note: *significant at 1 per cent level, ** significant at 5 per cent level
NS - not significant. Standard errors within parenthesis.
Source: Primary survey

Table 4. Constraints perceived by the sample tomato growers

Sl. No.	Constraints	Farm respondents (**n = 100)**	
		Garrett's Score	Rank
1	Price volatility	64.77	I
2	Lack of technical support	58.40	II
3	Escalating cost of cultivation	53.00	III
4	Non availability of labour	51.55	IV
5	Lack of awareness about ICT tools	46.76	V

Source: Primary survey

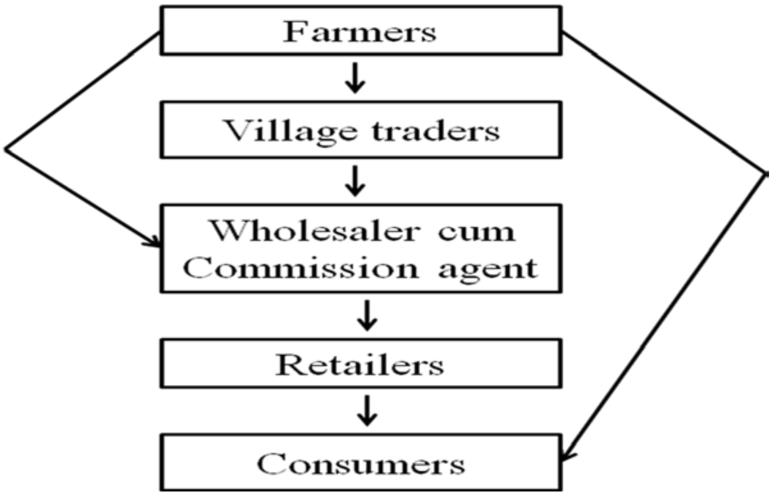


Figure 1. Disposal pattern of tomato among Trichy district farmers

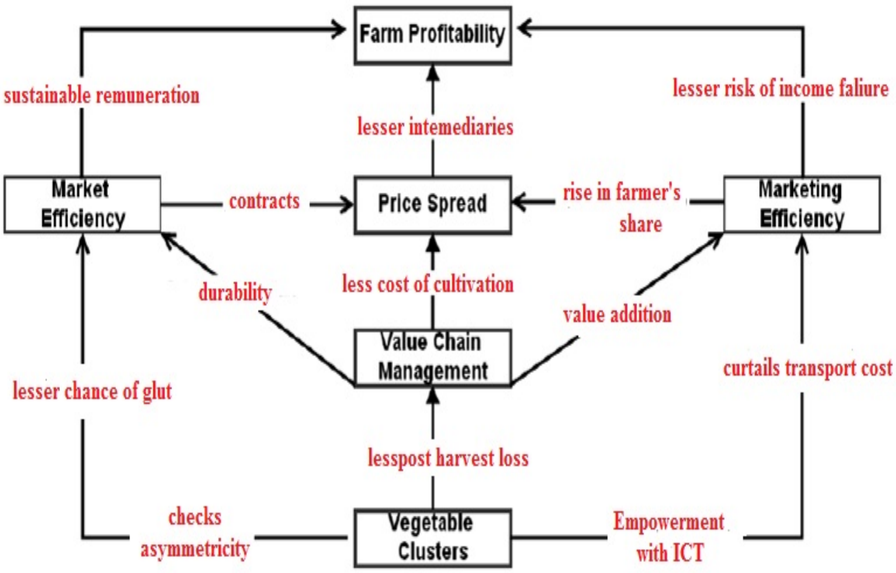
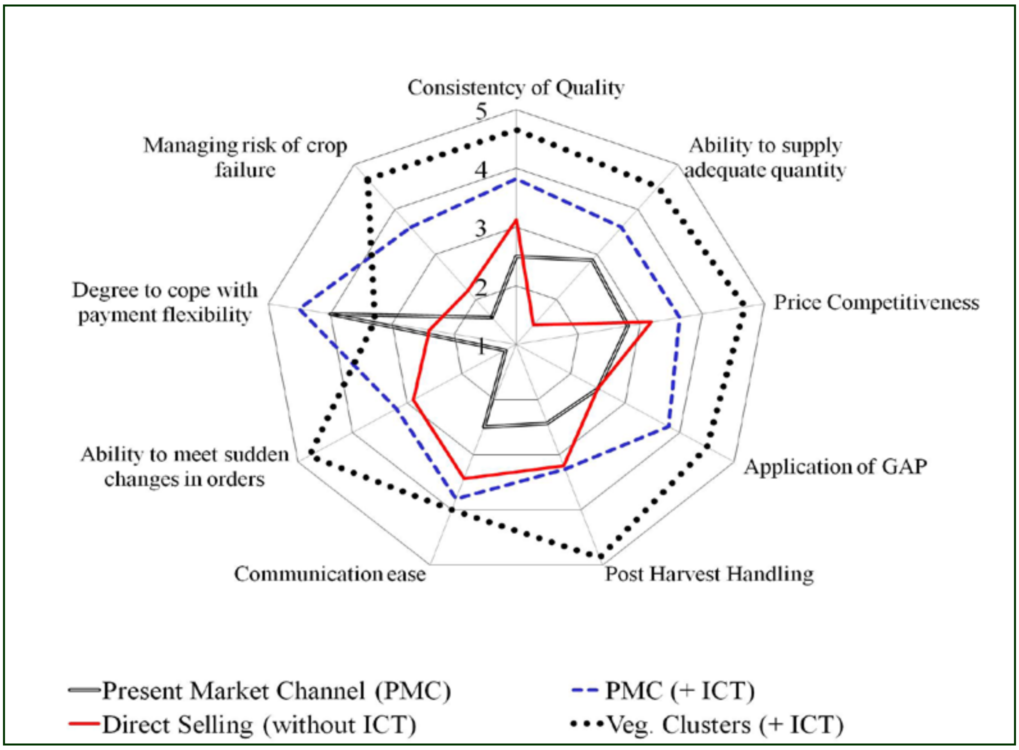


Figure 2. Importance of vegetable clusters for tomato crop in sustainaing farm profitablity



Note: Likert Scale of 1 to 5. GAP – Good Agricultural Practices

Figure 3. Farmers' perception of the supposed impact of tomato clusters

From harvest to table: enabling higher value production in vegetable supply chains through market-based interventions in the coastal chars of southern Bangladesh

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ABSTRACT

In the southern coastal chars of Bangladesh smallholder vegetable producers often have poor access to quality inputs and technical knowledge needed to increase their productivity and diversify into high value production. The Rural Enterprise Development (RED) Component of the Market Infrastructure Development in Charland Regions (MIDPCR), a project funded by IFAD, the Government of Bangladesh and the Government of Netherlands, aimed to develop national market linkages, add value to produce, and build capacity of smallholder farmers. Led by iDE, RED introduced new ways for producer groups, buyers of locally cultivated agricultural produce, and larger processing companies to do business with small producers in five coastal districts of southern Bangladesh.

The RED Component achieved significant impacts through facilitating commercial production and sales strategies for smallholders, and undertaking strategic interventions to improve the performance of vegetable supply chains. The commercial strategies included identifying and linking poor vegetable producers to productive opportunities in the vegetable sub-sector which significantly increased their incomes as they accessed high-value markets. Value chain interventions included improving the transportation system for tomato and cucumber supply in Bhola to accessing higher value markets by introducing plastic crates. RED achieved increased crop yields and increased farmer income through using quality inputs, technologies such as the sorgen method (a method of planting in ridges), services and linking farmers with markets. Each farmer increased vegetable cultivation areas from 17 to 26 decimals, providing additional income of some USD 280.

The data from RED suggests that market-based interventions enable smallholder producers to achieve productivity and income increases necessary in sustainable commercial production.

BACKGROUND

Food security is a pressing problem in Bangladesh, with around 26% of the Bangladeshi population chronically food insecure1. Primary producers at the Base of the Pyramid (BoP) often experience poor crop production and low quantity, quality and diversity levels. Land sizes are decreasing due to sub-division of land with each generation, leading to increasing pressures on land and a need for sustainable intensification of agricultural production. Around 70% of rural farmers hold access to less than one acre of land or are landless, with the majority of the remaining 30% with only up to 3 acres. Across a variety of horticultural and field crops, the yield gap for the typical farmer range from 29-53%[2] compare with existing and improve crop product practices.

Barisal, located in the southwest coastal part of Bangladesh used to be well known for its high productivity of rice cultivation, but overall the region has a low cropping intensity (average 183%[3]) due to rising salinity levels, drought, seasonally water-logged lands, and high prevalence of poverty. 40% of the regional GDP comes from agriculture, with 80% of the population employed in the sector[4]. The major crops are rain fed (amon) rice, mungbean, grass pea, lentil, soybean, ground nut, chili, watermelon, sweet gourd, okra, bean, hog palm, guava, and capture fish.

In the southern coastal chars[5] of Bangladesh smallholder vegetable producers often have poor access to quality inputs and technical knowledge needed to increase their productivity and diversify into high value production. The vast majority of farmers are unable to improve their production systems due to lack of knowledge and skills on new agronomic practices and access to production technologies as well as limited entrepreneurial capabilities. General constraints include: (i) lack of access to market information; (ii) poor access to quality inputs (especially seed, fingerlings, feed); (iii) weak distribution channels caused by low demand for quality inputs; (iv) low technical knowledge and lack of access to technical advice (with often weak government extension services at the rural level); (v) low levels of farmer organization.[6]

THEORETICAL CONTEXT

Increasingly it is being recognised that integration of low income populations into wider market systems is an effective means of achieving sustainable development. Approaches such as the Making Markets Work for the Poor (M4P)[7] and the

1 FAO Hunger Portal 2011, data for 2007-08

2 Drawn from numerous iDE-B reports and staff interviews. Sources include: Technical study report on crop production system and technology in the regions by identifying constraints and opportunities under MIDPCR, June 2008, iDE, “Agricultural Market Assessment Report: Barisal and Noakhali Region,” Rural Enterprise Development Project: 2010; iDE-B, “Collection Point: Linking Smallholders with Markets”: August 2010; Islam, Khairul, “Report on Horticultural Subsector Study in Charland of Noakhali and Barisal Regions,” Rural Enterprise Development Project (RED): 2009.

3 “DAE Annual Report, 2008, Agricultural Market Assessment Report: Barisal and Noakhali Region”. RED, MIDPCR, LGED, IDE-B.

4 “Agricultural Market Assessment Report: Barisal and Noakhali Region”. RED, MIDPCR, LGED, IDE-B.

5 Char is the Bangladeshi term for a river island.

6 Jun 2013. RED, MIDPCR Subsector Development Process

7 Making Markets work for the Poor (M4P). See: http://www.enterprise-development.org/page/m4p

Participatory Market Chain Approach (PMCA)[8], focus upon the integration of low-income communities into wider market systems. M4P promotes the analysis to identify interventions that support the development of private sector actors (PSAs) which provide key services upon which the target population's core commercial model depends. PMCA asserts that market access for low-income groups can be generated by generating collaboration amongst market chain actors. These approaches view low-income communities as Base of the Pyramid (BoP)[9] consumers to engage in formal markets as both producers and consumers. Also, they understand that as market competitiveness is dynamic and continuous adjustments are needed to sustain it, those involved need to have the capacity to constantly identify and take advantage of new market opportunities.

This contrasts with traditional agricultural livelihood programmes which, although often is effective at reaching the poorest and may realise gains during the project period, is often overly supply-driven and cast the project as a 'service provider' of agricultural inputs, circumventing and weakening the ancillary services upon which rural farm businesses depend. Such models, in the absence of a clear exit strategy and an evolution in programming from 'asset-transfer' towards sustainable technology and service provision, can undermine efforts to build the capacity of small-holders to engage effectively with market actors effectively. Such models render farmer groups as beneficiaries of 'aid' rather than autonomous consumers, as decision-making remains in the hands of external agencies. In this context, iDE deployed in the RED project an approach in which it sought to act as a facilitator and work through and strengthen wider market system actors rather than serve as a direct service provider, even in the context of weak service markets in the chars.

THE RURAL ENTERPRISE DEVELOPMENT (RED) PROJECT

Rural Enterprise Development (RED) component of MIDPCR – project targets

The goal of the RED component is to increase the income of 20,000 households (HHs) by USD200 within 5 years. This is achieved through enhanced capacity of 20,000 primary producers and trader in business planning, management and marketing and linked with higher markets, and enhanced capacity of 500 input service providers in providing quality goods and services to producers1. The project operated across 20 Upazilas of 5 Coastal districts - Barisal, Patuakhali, Bhola, Noakhali and Lakshimpur (Source: RED Project Brief). The Rural Enterprise Development (RED) project (2009- June 2013) was a component of the *Market Infrastructure Development in Charlands Region* (MIDPCR) Project, an international effort funded by IFAD, Government of Bangladesh and the Government of Netherlands. The wider MIDPCR sought "to improve the well-being and reduce the poverty of primary producers, char-based traders (both women and men), landless and single women and their households" through improvement in the facilities and terms of access of men and women to the market; increases in wage employment in project period for women; increases production and sales of products for the market; and movement of

8 Participatory Market Chain Approaches- User guide, International Potato Center, 2006

9 For a more in-depth understanding of BoP see: *Taking the Green Leap to the Base of the Pyramid* Stuart L. Hart, Johnson School of Management, Cornell University, in Next Generation Business Strategies for the Base of the Pyramid. Ted London, Stuart L. Hard (eds). FT Press, New Jersey. 2010.

primary producers up the value chain.[10] The aim of the RED component was to make market linkages work for primary producers by developing sustainable value chains in the coastal regions. RED was managed by iDE with the remit to focus on the development of linkages to buyers and markets beyond local markets in the project areas; the addition of value to the products sold by rural producers in project area; and, capacity building of the beneficiary groups (such as primary producers and small traders).[11]

RED APPROACH

In RED, iDE utilized its approach: Poverty reduction through enabling smallholder prosperity by integrating smallholders into sustainable and expanding agricultural markets (PRISM). PRISM is a set of tools that are used to develop an understanding of the situation of the rural poor and to create sustainable solutions to rural poverty. It creates sustainable opportunities through market-oriented interventions by: (i) creating networks of small enterprises to provide agricultural supplies needed by poor farmers; (ii) working with farmers to improve small farm productivity; and (iii) linking producers to markets for effective and sustainable poverty reduction[12].

Commercial strategies for primary producers

RED instigated market-based strategies for agricultural groups to improve the competitiveness of small farm businesses and facilitate their access to new markets. The project promoted farmer-led business planning through Production and Sales Planning Meetings (PSPMs), in which market information is provided by local private sector actors (PSAs), such as input and output traders and agro local service providers (LSPs). This demand-side market information informs the creation of Production and Sales Plans (PSPs) which act as micro-commercial strategies for the producer groups. These identify the rewards which can be realized should the farmers engage in higher risk strategies, such as changing from a traditional crop to an ‘off-season’ crop which they need to invest in additional inputs or acquire new skills to be able to cultivate. This creates demand for products and services from local PSAs (rather than the development initiative) and also reveals the constraints faced not only by farmers but also by the service providers. Additional activities could then be developed to strengthen the services identified through PSPMs as key to the producers’ strategies.

Value chain interventions for service market actors

10 2013. RED Project Brief.

11 2013. RED Project Brief.

12 RED Technical Approach and Methodology

RED identified four objectives for value chain interventions:

1. Make quality inputs and services available to the farmers (seeds, compost fertilizer micronutrients, compost, pesticides and irrigation) that can help improve yield and increase profitability;
2. Make the farmers capable for tapping the market opportunities through enhanced linkages with the private sector actors;
3. Link the farmers with the advanced technology service providers to promote sustainable cultivation practices;
4. Link the farmers to traders who can provide market information and help the producers reach high value end market players.

RED followed a market development approach in designing and implementing the interventions in the value chain. The project focused on identifying gaps in the market system and working through enhancing the provisions of services or products that could enhance the performance of the sub-sectors. Subsector studies were carried out to identify products, market opportunities, constraints and overall market dynamics of five selected subsectors on the basis of findings from the situation analysis[13]. These subsector studies provided detailed information on the existing market situation and prospects for economic opportunities for the smallholders operating in the project areas. More in-depth Value Chain (VC) studies were conducted to further understand the products in those sub sectors. This allowed for the identification of opportunities, constraints and specific intervention plans for developing the value chain of the specific products.[14] The identified vegetables were tomato, bitter gourd, cucumber, country bean and okra. Under each strategy a number of interventions were identified (total 15) which aimed to enhance the producers' access to quality inputs, technology and production information, and help them improve production and sales planning skills and access to higher value markets.

Engagement with lead firms

The RED team also engaged leading private sector companies to set up technology (product) demonstrations, provide training and supply inputs to the farmers. The RED team engaged lead input firms such as *Lal Teer Seed Ltd*., *ACI seed*, *ACME*, *Square*, and others who leveraged out of the RED networks and facilitation to reach down 'hard-to-reach' rural areas. To ensure quality of inputs and services, the RED team also collaborated with the government line agencies at regional and local levels. This collaborative approach ensured a comprehensive means of developing the market system to benefit farmers effectively. Through its market facilitation approach, the RED component was able to attract engagement of such PSAs with the Market Management Committees (MMCs), Collection Points (CPs) and Farmers Associations (FAs) that RED was supporting. Such engagement of the private sector actors with the local producers increased not only input sales but also substantially increased sales of local produce to local and outside markets.[15]

13 The five selected subsectors were: (i) horticulture; (ii) fish, (iii) pulses and oil; (iv) cereals; (v) livestock and poultry.

14 Jun 2013. RED, MIDPCR Subsector Development Process

15 Completion Report, RED Component Under Market Infrastructure Development Project in Charland Regions, LGED

Example of an intervention: Plastic crates for tomato transportation

The Horticulture sub sector study conducted by RED in 2009 identified the market access constraint being “Lack of proper packaging and handling both at the trader and farmer level resulting in large amount of wastage”. In late 2010, the RED team discussed the process with producers and buyers of tomato and cucumber in Charfession upazilla, Barisal. It was understood that the production volume is increasing and losses of transportation is high from the farm gate till they reach the high value distant markets. Particularly for tomato, the wastage was about 15-25% due to the poor packaging and transportation systems.

The team identified some key services which could be strengthened, these were: i) cleaning and grading of the vegetable; and ii) packaging and transportation of vegetables to distant markets. RED undertook some market research to compare the cost-benefit analysis of using plastic crates as opposed to traditional packaging and transportation methods. The project assisted the traders to engage in grading the tomatoes, through engagement with traders which demanded graded produce, and also to acquire low-cost plastic crates to support better postharvest handling (they bought used plastic crates from the fruit traders at the beginning, now they have their own stock of crates). It was seen, that by using plastic crates, a producer was able to reduce wastage by almost 8-10 kgs per 80 kg sack. The traders earned extra income of USD 0.028 per kg of tomatoes on delivery to the target market. Thus, value was created throughout the chain for both the producer and trader.

METHODS

The results for the RED project component are based upon two sources of information. Firstly, the comprehensive monitoring and evaluation (M&E) system set up to generate management information and provide LGED and IFAD with evidence of results and impact against both the log-frame and IFAD’s project indicators. This involved output, outcome and impact monitoring and IFAD conducted a baseline, mid-term review and an impact assessment after completion of the project to ensure a comprehensive appraisal of the MIDPCR project and its components, including RED. Secondly, Ad hoc studies conducted by the iDE M&E section and outside agencies on key subjects such as the participation and empowerment of women, markets and value chain development in various sub-sectors, and access to services[16.]

Although the final RED evaluation is not yet released, interim documents are available which provide official data on the results of the RED program.[17] Also the RED team conducted a baseline survey in 2010 and impact calculation survey in late 2012 of vegetable sub sector in general and of cucumber, country bean and bitter gourd in mid-2013. The M&E indicators were based on the indicators from the log-frame of the MIDPCR project design, including indicators for nutrition, food security and asset ownership of the households. The project staff collected this information

16 IFAD. Bangladesh: Char Development and Settlement Project Design Completion Report – Appraisal Main Report.

17 These include the November, 2012 and May, 2013 documents: *Annual Supervision Mission: Aide Memoire. IFAD. Bangladesh: Char Development and Settlement Project Design Completion Report – Appraisal Main Report*. This are the report documents of the IFAD missions which undertook annual supervision appraisals of the MIDPCR project in November 2012, and subsequently in May 2013.

from the field and shared with the team members on a regular basis as this formed the basis of regular reporting on quarterly and annual basis by the iDE.

RESULTS

The RED project realized substantial results during the period of the project. These include large numbers of indirect beneficiaries reached through value-chain interventions. RED reached some 71,275 beneficiaries: (i) 18,525 as *direct* beneficiaries from RED activities; and, (ii) 52,750 as *indirect* beneficiaries, either people from the same or different communities who have replicated techniques or improved inputs promoted by the project or people from the same or different communities who have integrated value chains and benefited from market or supply linkages supported by the project.

Notable outcomes of RED

1. Increased sustainable involvement of the private sector in the provision of services to farmers/producers (in total 41 companies regularly providing improved quality inputs, production advisory services, rural finance, six institutional buyers, and 176 inputs sellers implemented in/regularly visiting project-supported communities);

2. Four additional micro-finance institutions (MFIs) extending loans to project-supported farmers;

3. Incremental income of farmers/ producers has on average reached BDT 16,107 over a 4-year period (and BDT 22,147 per vegetable farmer over the same period);

4. Approximately 80% of trained people have adopted 31 technological innovations promoted by the project (with a large number of non-project-supported farmers having also adopted these technologies); and,

5. Yield increases as well as significant increase in area under production (approximately of 59 to 90 kg/decimal of land; pond size increased from 37 to 47 decimals)[18].

RED achieved improved food security of the target beneficiary households. The proportion of HHs experiencing one hungry season throughout the year preceding the survey fell from 57% to 35%, and those experiencing two hungry seasons fell from 21% to 15%. Levels of chronic malnutrition among children under 5, measured by the proportion of stunted children, remained about unchanged at around 50%. Indicators of acute malnutrition, the wasted and the underweight proportions, show and improvement as the proportion of wasted children fell from 16% to 8% and that of underweight fell from 40% to 34%. Also RED beneficiaries experienced increased

18 Compiled from different sources: Completion Report, RED Component Under Market Infrastructure Development Project in Charland Regions, LGED. Impact Report on Vegetable Subsector, October 2012, Impact Report on Cucumber Subsector, March 2013, Impact Study Report On Country Bean Subsector, June 2013, Bitter Gourd Subsector Impact Study Report, June 2013.

incomes as the project increased the income of direct project participants, with surveys from RED showing an average incremental income between 2010 and 2013 ranging from USD 196 (vegetable) to USD 271 (fish) with poultry having an increase of USD 219 per household[19.]

LEARNING POINTS

Some of the major learning from implementing RED and the processes that made the project effective can be highlighted as:

- Reorganizing groups according to their commercial potential, rather than exclusively on the poorest or marginalized groups, is effective in delivering results amongst large numbers of beneficiaries. Targeting only women and poor producers was less attractive to PSAs and hence their desire to engage in business was limited. Targeting productive households and selecting cluster based producers was much effective approach in terms of attracting the private sector investment and their participation in business transactions.[20] The role of Market Management Committees (MMCs) and Collection Points (CPs) was crucial for the farmers to access input supplies and interact with output buyers and perform business transactions.
- Building the capacities of existing market structures leads to more sustainable outcomes. Building upon existing structures was key as the RED component reorganized old producer groups of the project areas into new producer groups based on product cluster. RED also focused on building up the capacity of local producer groups and other PSAs. Farmer groups like Farmers Associations (FAs), Community Business Organizations (CBOs), Farmers Committees (FCs) and others were the organizations led by farmers that RED focused upon to develop their business capacity to deal with other market actors.[21]
- Aligning the incentives of each actor according to their relative strengths is vital. For example the project led on the identification of suitable technologies to enhance productivity and production volume. While the technology identification and promotion was done by the RED component as per the local need basis; the supply and sales of these technologies were carried out by PSAs on a commercial basis. Such a modality supported the producers to increase their production and sales volume leading to increased in-come and crucially also contributed towards business expansion for the private sector organizations engaged. It was seen that approximate sales of seed companies have increased by 10%.

CONCLUSION

RED facilitated market-based solutions to overcome constraints and increase the income of farmers and private sector actors through optimizing market opportunities. The project was successful in developing ‘bottom-up’ commercial strategies with smallholder producers which, through engagement with wider market actors, particularly output market actors, provided them with the information necessary to manage and overcome the risks in engaging in more lucrative production and sales

19 Market Infrastructure Development Project in Charland Regions – BD 681, Annual Supervision Mission: 2-16 May 2013.

20 Jun 2013. RED, MIDPCR Subsector Development Process

21 Jun 2013. RED, MIDPCR Subsector Development Process

strategies. This work proved to be highly effective when combined with interventions either to overcome constraints, or realize opportunities, in the market system. Other market-based interventions include attracting lead firms interested in expanding their market into rural areas and attracting them to invest resources on a commercial basis into the development of the target farmer groups. These combined interventions, based upon the market facilitation approach, enabled RED to contribute effectively to enable smallholder producers to achieve productivity and income increases necessary in sustaining the successful commercial vegetable production. The learning from RED suggests that the approach is potentially a highly effective, scalable, and transferable mean of tackling food security issues in the south of Bangladesh and potentially beyond.

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Vegetables Go to School in Southeast Asia and Africa: Training of Trainers workshop design and implementation

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Keywords

Bhutan, Burkina Faso, Indonesia, Nepal, Philippines, Tanzania, nutrition, health, schools, vegetables

ABSTRACT
AVRDC – The World Vegetable Center's 'Vegetables Go to School' project focuses on promoting school gardens and increasing children's consumption of fresh vegetables in Bhutan and Nepal in South Asia, Indonesia and the Philippines in Southeast Asia, and Burkina Faso and Tanzania in Africa. The project, conducted in collaboration with the Swiss Tropical and Public Health Institute and the University of Freiburg, Germany, is funded by the Swiss Agency for Development and Cooperation. Country managers and project collaborators were invited from the agriculture/horticulture, education, and health sectors of the participating countries to attend a four-week long training of trainers workshop to identify the current status of school gardens and ascertain specific needs in promoting food and nutrition security through school garden-based approaches. The workshop focused on criteria for the selection of schools, sampling procedures, garden design, crop selection, planting schedules and good agricultural/horticultural practices, data collection and management strategies. The participants engaged in hands-on capacity building activities at the Center's Demonstration Garden and research facilities. Action plans created by the respective country teams at the end of the workshop included objectives, garden design layout, implementation, promotion, management, expected outcomes and nutritional impact assessment strategies. Following the training workshop, a three-day policy workshop brought together country policy makers, management and project advisory committees to evaluate the action plans and chart a course forward for implementing school gardens and obtaining data for impact assessment.

INTRODUCTION
Malnutrition is a state of under- or over-nutrition caused by insufficient intake of macro- or micronutrients, as per the current recommended intake levels. Epidemiological surveys show developing countries that rank high in the prevalence of underweight also rank high in overweight populations. Globally, underweight prevalence is highest in South Asia (59 million) followed by sub-Saharan Africa (30 million); overweight prevalence is the highest in sub-Saharan Africa (10 million) followed by East Asia and the Pacific (7 million) (UNICEF, 2013). Malnourished populations are particularly susceptible to infection by disease-causing organisms such as bacteria, viruses, and parasites (Brown, 2003).

World food security takes into account food production and stabilization of food supplies, while food and nutrition security considers the crucial element of ensuring access by the poor to the food groups required for an active, productive and fulfilling life. Swaminathan (1986) defined food security as "physical, economic and social access to balanced diet, clean drinking water, environmental hygiene, primary health care and nutritional literacy." This definition includes three dimensions: availability, access and absorption. Availability refers to the physical availability of food in desired quantities; access is determined by physical and economic access to food and the opportunities open to achieve them; absorption is defined as the ability to biologically utilize the food consumed, which is closely related to the availability of safe drinking water, sanitation, a hygienic environment, primary healthcare and to nutritional knowledge and appropriate practices. Thus food and nutrition security brings into focus the linkage between food, nutrition and health.

In 1996 the World Food Summit defined food security as "when all people at all times have access to sufficient, safe, nutritious food to maintain a healthy and active life." This definition includes availability (sufficient quantities of food available consistently); access (having sufficient resources for a nutritious diet); and utilization (appropriate use based on knowledge of basic nutrition and safe water and sanitation).

Increasing agricultural production, productivity, or household income levels do not necessarily lead to improved food and nutrition security. However, there is evidence that targeted agricultural interventions, such as community, home and school vegetable gardens can result in healthier eating habits, including increased consumption of vegetables and fruits. Bhutta et al. (2013) drew attention to the fact that "schools offer an enormous opportunity for promotion of health and nutrition for older children and adolescents and could have an important role in their future." This opportunity is also apparent in the finding by Langellatto and Gupta (2011) that school vegetable gardens were associated with greater vegetable consumption; this was related to participation in gardening and not to nutrition education. Others concluded that children who are engaged in gardening activities are more likely to eat fruit and vegetables, and are more likely to continue healthy eating habits throughout their lives (Bell and Dyment 2008; Morris and Zidenberg-Cherr 2002). In an analysis of 53 community gardens in South Africa, Shisanya and Hendriks (2011) concluded that although the gardens contributed to increasing consumption of fruit and vegetables, gardens alone were unable to solve the problem of food insecurity, thus underscoring the need for an integrated approach including improved productivity and agricultural and nutritional advice. The presence of a vegetable garden in the school provides physical proximity to a garden for schoolchildren, with opportunities to learn about the importance of vegetables in the diet individually as well as in peer groups.

The nutritional benefits of a school vegetable garden program may be jeopardized if the school, community and household environment is not safe and appropriate sanitary and hygiene practices are not followed. The success of a school vegetable garden program will therefore depend on the safety of water, sanitation, and hygiene practices that are adopted by the participants.

AVRDC – The World Vegetable Center's 'Vegetables Go to School' project takes an integrated approach to promoting school gardens and increasing children's consumption of fresh vegetables in Bhutan and Nepal in South Asia, Indonesia and the Philippines in Southeast Asia, and Burkina Faso and Tanzania in Africa. The objective of the project is to contribute to improved nutritional security in the target countries through school vegetable gardens linked to other school-based health, nutrition and environmental initiatives with close participation of local communities. The project, funded by the Swiss Agency for Development for Cooperation (SDC), is being implemented in collaboration with the Swiss Tropical and Public Health Institute (STPH) to provide expertise in water, sanitation and hygiene practices in the project schools, and the Albert Ludwig University of Freiburg in Germany, which will set up a collaborative research environment for baseline and research data collection, analysis and management.

VEGETABLES GO TO SCHOOL

The project will be implemented in three phases: Phase I (2013-2015) focuses on research-for-development—building capacity in the target countries, establishing pilot school vegetable gardens, studying the impact pathways, and showing the evidence for impact. Phase II (2016-2018) will scale-out the implementation of school vegetable gardens in the target countries to increase the number of schools with school vegetable gardens. Finally, Phase III (2019-2020) will institutionalize the project benefits in the target countries.

The primary beneficiaries of the project are schoolchildren 6to 18 years old. These girls and boys are expected to receive benefits in terms of more knowledge about the importance of a diverse, balanced and nutritious diet. This is expected to lead to more balanced diets and an increase in the daily consumption of vegetables, which would eventually result in better health of the children as illustrated in Figure 1.

PROJECT IMPLEMENTATION STRATEGIES

During 2013, the project focused on building capacity and raising awareness about school vegetable gardens at various levels of government in target countries, establishing a national task force, and developing country-specific action plans for implementing school vegetable gardens in the project countries. The task force included a multidisciplinary panel of members comprised of senior officials from national ministries and departments of education, agriculture/horticulture, nutrition and health and a senior official at the national policy level. Vegetable gardens were designed and optimized for each specific country by selecting country-specific, nutritious and easy-to-grow vegetables with targeted cropping schedules, crop management technologies and protocols for ensuring seed supply for long-term sustainability.

CAPACITY BUILDING

To establish national task forces, a team of government officials from the ministries and departments of education, agriculture/horticulture, nutrition and health from each country were identified and invited to participate in a four-week Training of Trainers (ToT) workshop at AVRDC headquarters in Taiwan. The aim was to equip the task force members to return to their countries and train teachers and other key project participants to implement all aspects of the ‘Vegetables Go to School’ project. A senior official at the national policy level from each participating country was invited to participate in a three-day policy workshop held in conjunction with the ToT.

NATIONAL TASK FORCE

Each national task force is comprised of a team of multidisciplinary government officials of which one member assumed the role of the country manager, taking the responsibility of project implementation in their respective countries.

One government official each from the ministries/departments of Education, Agriculture and Health constitute a Country Team. Team members are senior officers with sufficient in-country experience to hold a senior position within the national governing system. The key incentives for country team members are; to derive satisfaction out of interesting, creative work that would improve the nutritional status of schoolchildren in their countries; and international exposure. The Country Manager is a member of the country team and has close connections to the lead implementing agency (the Ministry of Education or the Ministry of Agriculture/Horticulture) to be able to effectively implement the project in the country.

To ensure enough support for the implementation of the Vegetables Go to School Action Plan, one senior government officer was invited to Taiwan to attend a three-day policy workshop on school vegetable gardens. This person was a Principal, Permanent or Deputy Secretary or Director or Director General who can support and catalyze changes in policies to favor the project outcomes. During the workshop, they met their counterparts from other countries as well as government officials from Taiwan. The policy workshop highlighted the potential of school vegetable gardens by presenting success stories from the Philippines, Thailand, Taiwan and the United

States. The senior government officer is expected to work closely with his/her Country Team to adjust the action plan and develop a strategy for implementation, scaling-out and attracting additional resources.

TRAINING OF TRAINERS (TOT) WORKSHOP

The aim of this workshop was to provide hands-on training to the country teams on the best practices in design and implementation of school vegetable gardens. A detailed program was developed for the ToT workshop (Table 1). A manual was prepared to provide instructions in the layout and implementation of school vegetable gardens and contained general principles that set the framework for a successful project implementation locally. The team also visited local school gardens in Taiwan and interacted with the schoolchildren and staff in charge of the school gardens and the children.

SCHOOL VEGETABLE GARDEN IMPLEMENTATION

AVRDC staff trained the country teams on horticultural aspects including garden designs based on sound principles of crop rotation, choice of diverse vegetables, preparation and management of healthy seedlings, integrated crop management, identification of pests and natural enemies (predators, parasitoids and pathogens), soil health and fertility management, composting, integrated pest management, and best practices in seed saving. Many important issues for successful garden implementation were addressed. The country teams also received hands-on training at the AVRDC Demonstration Garden, and from the Nutrition and Genetic Resources and Seed groups at AVRDC headquarters in Taiwan. The AVRDC project team assisted the country teams in developing garden plans and practices specific to each country of implementation.

During the ToT, communication strategies suitable to various audiences including students, parents, colleagues and community to create awareness and generate interest about the school gardens were discussed. Topics of discussion included analyzing audiences and information; crafting and delivering messages, announcements and updates; and, planning garden tours and open houses for the parents and community.

The importance of experimental design, randomization, replication and control during the research phase (Phase-I) of the project was presented to the country teams. Target school selection criteria were discussed and the randomization procedure was explained to the team. Sampling and data collection strategies were discussed among the team members.

Project impact assessment strategies were discussed during the ToT workshop to assess the impact of vegetable gardens relative to the objectives. The outcome indicators of opinions/attitudes, preferences, awareness, knowledge, vegetable consumption patterns and nutritional status were discussed with each team. The country teams developed monitoring and evaluation schedules, tools and data collection protocols suitable to their countries.

NUTRITION

Training topics in nutrition included information about the food basics, role of macro- and micronutrients in human health, major food groups, sources, dietary reference intakes, the importance of a balanced diet, as well as the importance of vegetables as key sources of micronutrients and beneficial phyto-compounds as a substantial part of daily diets to meet the micronutrient needs. The team visited local schools in Tainan

County in Taiwan and interacted with the kitchen staff and the schoolchildren. The project team assisted the country teams in developing dietary assessment tools including 24-hour recalls and food diaries suitable to their countries. Possible case studies of interventions in the value chain were presented and discussed.

WATER, SANITATION, HYGIENE AND HEALTH (WASH)

The STPH team provided training on the importance of safe water, sanitation, hygiene and health in the target schools. Specific ways of ensuring a health-promoting and disease-preventing environment to minimize children's exposure to risk of injury, safe handling of food grown on the plots to keep the produce free of pathogens and chemicals, and maintaining a safe environment for children, teachers and parents were discussed.

COLLABORATIVE RESEARCH ENVIRONMENT (CRE)

The University of Freiburg (ALU) provided training on creating a collaborative research environment in a web-based platform to facilitate data collection, analysis, sharing, and archiving with appropriate web-based tools. The multiple benefits of CRE in a large project were presented to the country teams: it provides the same tools for all partners, ensures a common data structure, secures data management and archiving, allows for sharing of the data between partners as per the access rules agreed upon, and enables joint data analysis with standardized tools. The CRE can be used for effective communication among project partners and to disseminate project results. The team assisted the country teams in identifying and defining the variables that are suitable for their countries. A tentative draft list of required data including baseline and research data was developed during the ToT workshop. A core data set was drafted to describe the geographic location of schools, school gardens and schoolchildren for each country.

FIELD TRIPS AND SOCIALIZATION

Rapport and strong interpersonal relationships are crucial to the success of a project. Effective and successful socialization in capacity building ensures commitment of the team members to the successful implementation of the project and "elicits the best in an individual by breaking in." This was achieved during the ToT and policy workshop through ice breakers, informal discussions with the group, organized dinners and lunches with the AVRDC staff, research partner teams and sightseeing trips around Taiwan; informal coffee hours in the morning and the afternoons; visits to local vegetable markets and day/night markets; shopping trips; and visits to local temples. There were ample opportunities for socialization and building rapport between the country teams and the project team. The integrated and coordinated activities also allowed the country team members to mingle and interact among themselves, enabling strong networking opportunities.

PERFORMANCE MANAGEMENT SYSTEM FOR THE PROJECT AND THE COUNTRY TEAMS

To make sure that the project is piloted and rolled out successfully in the project countries, AVRDC has appointed a full-time Project Manager for the Vegetables Go to School Project. A project team consisting of five AVRDC scientists and research team members from the STPH and ALU was formed to advise the country teams and monitor progress.

Additionally assistant country managers will be appointed in each country who will be assigned the task of ensuring on-site implementation of the project and data collection as per the research protocol. The assistant country managers will work closely with the national teams and the AVRDC scientists in the successful implementation of project activities. Timely execution of activities will be monitored by regular on-site visits made by the AVRDC scientists, the Project Manager, and meetings with the country managers.

POLICY WORKSHOP

A policy workshop was conducted to bring awareness of the project to senior policy level officers from the project countries, so as to obtain their support in the implementation of the project. The policy level officials attended sessions during which country team members presented success stories with school vegetable gardens; they also participated in a panel discussion to share their expertise in school gardens, agriculture, nutrition and health. Each official worked with their respective country teams to finalize the country action plans for successful implementation. The policy-level team members serve as members of the project advisory council who will continue to advise and assist the national task force in project implementation.

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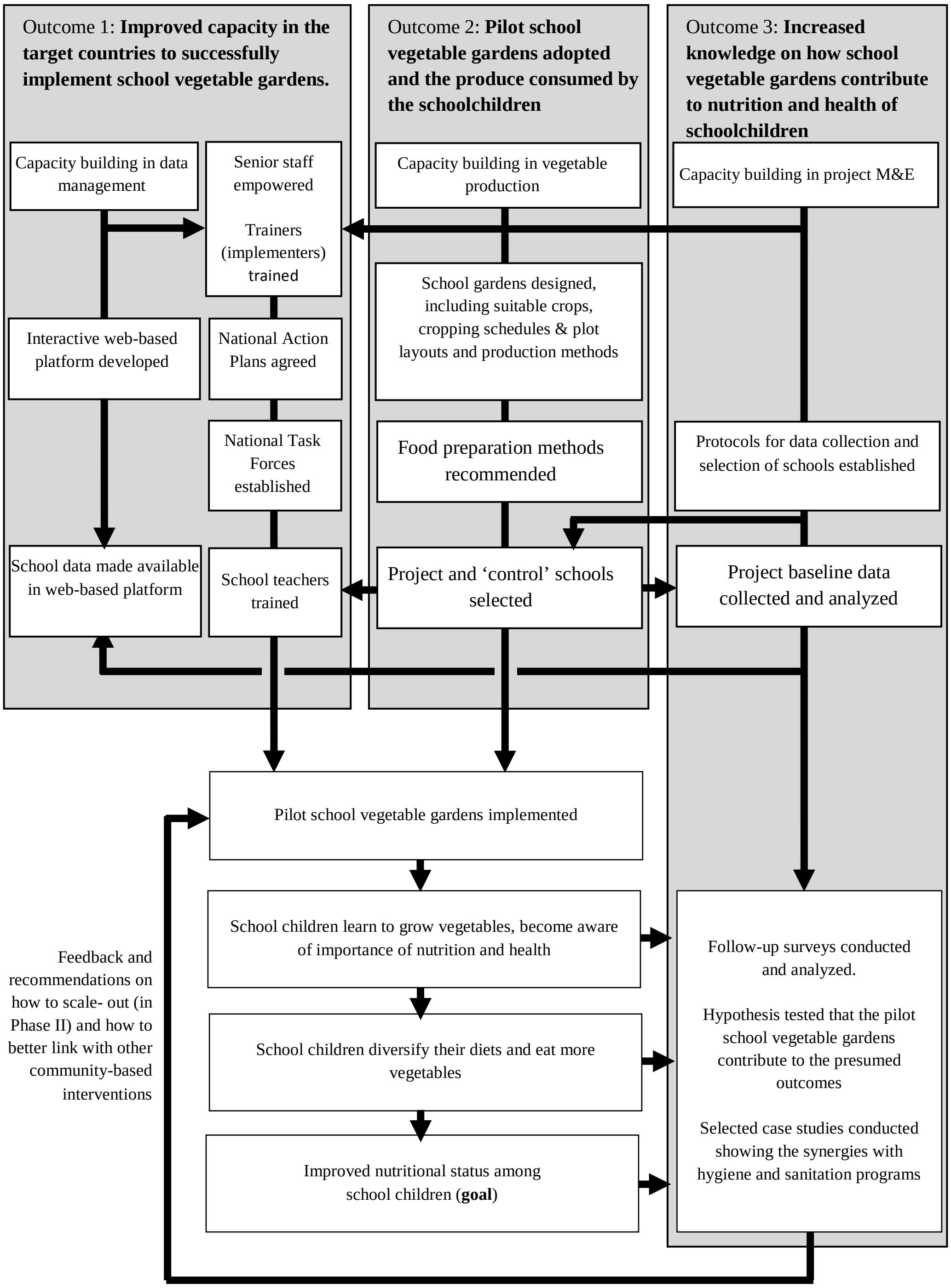

Figure 1.The impact pathway of the project around the three project outcomes leading to the overall impact goal: to contribute to improved nutritional security in the target countries through school vegetable gardens linked to other school-based health, nutrition and environmental initiatives with close participation of local communities.

Table 1. Vegetables Go to School project, Training of Trainers workshop program

Day	Activities
1	Welcome and icebreakers; presentations by the country teams on current status of school vegetable gardens in their respective countries
2	Visit to the AVRDC Demonstration Vegetable Garden followed by presentations on crop selection, cropping schedules, seedling preparation, integrated crop management (ICM), soil health and land/bed preparation; visit to the local night market
3	Transplanting, starter solution application and visiting composting heaps, integrated pest management (IPM); biological control with natural enemies; developing and finalizing the year-round planting schedule for school garden
4	Vegetable seed regeneration and quality preservation followed by visit to the AVRDC Germplasm facilities where the team learned to determine the seed quality
5	Group work on country action plans
6	Excursion to Tainan
7	Free day
8	Vegetable garden design and implementation; natural enemies and pests; field collection of insects and classification activity; IPM methods; appropriate stages for harvesting
9	Communication strategies: analyzing information, crafting and delivering messages
10	Proposed evaluation plans, data collection and analysis for impact assessment; group work and presentation of evaluation plans by the Country Teams
11	Visit Tzu-Lung elementary school and composting area; demonstration of compost making and liquid fertilizer preparation; participate in local food preparation and promotion activities
12	School garden programs in Tainan: Visit Guo Yi Elementary School, Liujia District, Tainan; Visit Andian Elementary School, Annan District, Tainan; visit to the Taiwan sugar factory
13	Work on country action plans
14	Free day
15	Presentations on school vegetable garden and nutrition, school lunch programs in Taiwan, nutritional practice and promotion in schools, evidence base interventions, program design and case studies
16	Functional properties of different vegetables; nutrition-sensitive postharvest handling of vegetables; vegetable preparation, recipes and cooking methods; cultural perspectives and eating habits; determinants of malnutrition in school children; methods of nutritional assessment
17	Synergies between agriculture, nutrition and health, monitoring and case studies
18	Collaborative research environment: target groups, benefits, structure, requirements and responsibilities for effective data flow; country specific data requirements
19	Work on country action plans
20	Excursion to Zhoumalai Farm, Taiwan
21	Free day
22	Welcome the senior policy level officers from the project countries; present an overview of the project and set expectations; share experiences with school vegetable gardens by the policy level officers in their respective countries
23	Presentations on topics of horticulture, nutrition and health; presentations of country action plans by the country managers; welcome dinner for the senior officers from the project countries
24	Presentation of action plans and panel discussion by the senior policy level officers from the project countries; discussion of follow up plans, way forward and concluding remarks

Moringa: An indigenous high value underutilized vegetable crop can play a great role in nutrition and poverty alleviation in Bangladesh

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ABSTRACT

Moringa (*Moringa* spp.) is one of the world's most beneficial trees. This fast growing plant is grown throughout the tropics for human food, medicine, livestock forage, dye and water purification. It can easily be grown in the homestead and along the roadsides. The climate of Bangladesh is favorable for moringa. The leaves and fruits of moringa contain high amount of beta-carotene, protein, vitamin C and iron. Both moringa species. *M. oleifera* (locally known as *Sajna,* fruiting in one season) and *Moringa stenopetala* (locally known as *Lajna*, fruiting year round) are most widely cultivated in Bangladesh. Malnutrition is a serious public health problem in the hunger prone northwestern region and saline-affected southern Bangladesh. Moringa plays a vital role to meet nutritional deficiency as well as to help to alleviate poverty mainly in the north-western region of Bangladesh. Research findings showed that *M. oleifera* and *M. stenopetala* both are well adapted to our northwestern region but in the southern saline and eastern wet areas only *M. oleifera* grows well. Compared to summer vegetables like cucurbits and amaranths, moringa fetches higher prices. In the northern part of Bangladesh about 20% of the population depends on moringa, but in saline and hilly areas only 2.5%. Moreover, moringa is used as a traditional remedy against smallpox and chicken pox.

INTRODUCTION

Moringa (*Moringa oleifera* and *M. stenopetala)* is one of the most important, useful and nutritious vegetable trees in Bangladesh (Fig. 1). It contains beta-carotene, protein, vitamin C, calcium, potassium and iron (Table 1). Different parts of the tree are utilized for food, medicine, perfume, oil, lubricants, etc (Rashid 1976; Rahim et al. 2013). It is considered a minor vegetable in Bangladesh. But demand for moringa is gradually increasing day by day. Consequently, the production of moringa is increasing (Fig. 2). Almost all part of the trees are usable (Fig. 3-8). Production area should be expanded and yield should be increased. Only a few scientists are concerned about the improvement of moringa in our country; research on moringa in Bangladesh is scant. Here we evaluate the present status of moringa and future plans for moringa cultivation.

Comparative nutrition of moringa leaves

In Southeast Asia and ASEAN countries moringa leaves are mostly used as vegetables. All moringa food products have a very high nutritional value compared to other foods. A nutritional comparison of moringa leaf with other food crops is shown in Figure 9.

Economic value

Moringa is a nutritious vegetable that can be grown with minimum cost and is available year-round. In Bangladesh, the average price of moringa is about 50Tk/kg. About 60-100 kg pods are produced by a moringa tree per year, resulting an income of about 3000-5000 Tk/plant/yr. By cultivating 5 plants per homestead a farmer can earn worth Tk 15000 to 25000 per year under Bangladesh conditions (Rahim et al. 2013). Moreover, the pruned parts of moringa can be used as fuel wood. Therefore, moringa has great economic value in our country. Moringa serves as a major vegetables during lean periods of vegetable production in Bangladesh (Fig. 10; Rahim et al. 2013). *Moringa oleifera* harvested during lean period I (March-May) and *M. stenopetala* produces fruits year-round, ensuring both lean periods (March-May and August-October) are covered (Fig. 10).

Poverty alleviation through moringa cultivation

In Bangladesh, vegetable consumption is about 120 g/person/day, which is far behind from the standard requirement of 200 g /persons/day. About 80% of the people in our country live below the poverty level. They have no ability to purchase major vegetables like tomato, cabbage, cauliflower, potato, etc. Hence, they can get some amount of nutritive values from moringa with minimum cost and effort. Moreover, if a farmer cultivated moringa in their homesteads, they can easily consume and sell moringa. As a result, malnutrition can be overcome as well as earning of money through moringa cultivation. A huge number of people depend on moringa cultivation, harvesting and marketing (Table 2).

Utilization

The “drumstick” fruit of moringa, including young seeds, are good for soup. Young leaves can either be fried with shrimp or added as a topping in fish soup. Moringa leaves in soup increases urination and thus benefit the kidneys. The leaves are widely used in traditional medicine. Moringa is considered one of the world’s most useful trees, as almost every part of the tree can be used for food or has some other beneficial properties. As a traditional food plant, this vegetable has potential to improve nutrition, boost up food security, foster rural development, and support sustainable land care. Almost every part of the plant has value as food. Seed is eaten like a peanut. Foliage is eaten as a cooked vegetable, in curries, as pickles and for seasoning. It is commonly planted as a living fence tree.

Moringa production methods

1. Propagation by stem cutting is best for production and true to type (Fig. 11).
2. Best planting time is April/May.
3. Pruning occurs in April/May.
4. Fertilizing: 10 t/ha organic matter, 250 kg Urea/ha, 200 kg TSP/ha and 200kg MoP/ha has been found to be the optimum dose, to be applied after pruning
5. Collection of egg masses, or hand killing of larvae clusters of hairy caterpillar can completely control the insect on moringa.

6. Irrigation during January/February and September/October produces better yield.

CONCLUSION

Moringa is a unique underutilized vegetable tree that has a huge nutritional and economic value. Its cultivation cost is very low compared to other vegetables. Necessary steps should to be taken in Bangladesh to implement the slogan “Every homestead should have at least one moringa tree for home consumption.” However, further market and economic analysis of moringa is needed to understand why it is not being adopted more widely in different regions of Bangladesh.

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Figure 1. ★ **= Indicates major moringa growing region of Bangladesh**

Figure 2. Production and yield of moringa in Bangladesh (Source: BBS 2010)

Figure 3. Young moringa seedling

Figure 4a. Moringa at vegetative growth stage

Figure 4b. Moringa

Figure 5a. Moringa flowers

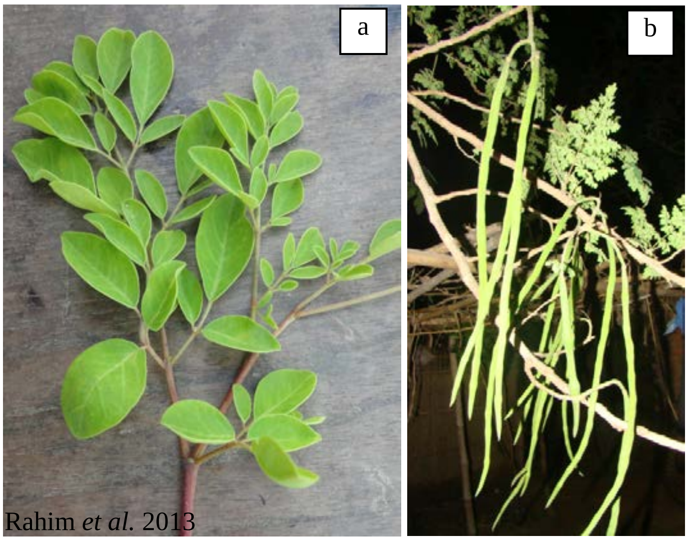

Figure 5a-b. Tender leaves and fruits of moringa

Figure 5c. Bundled leaves of moringa for marketing

Figure 5d. Moringa drumsticks

Figure 5e. Edible leaves

Figure 5f. Moringa at flowering and fruiting stage (Flowers and young fruits are edible)

Figure 6. Moringa at mature stage (fruits and seed edible)

Figure 7. Pods and seeds of drumstick

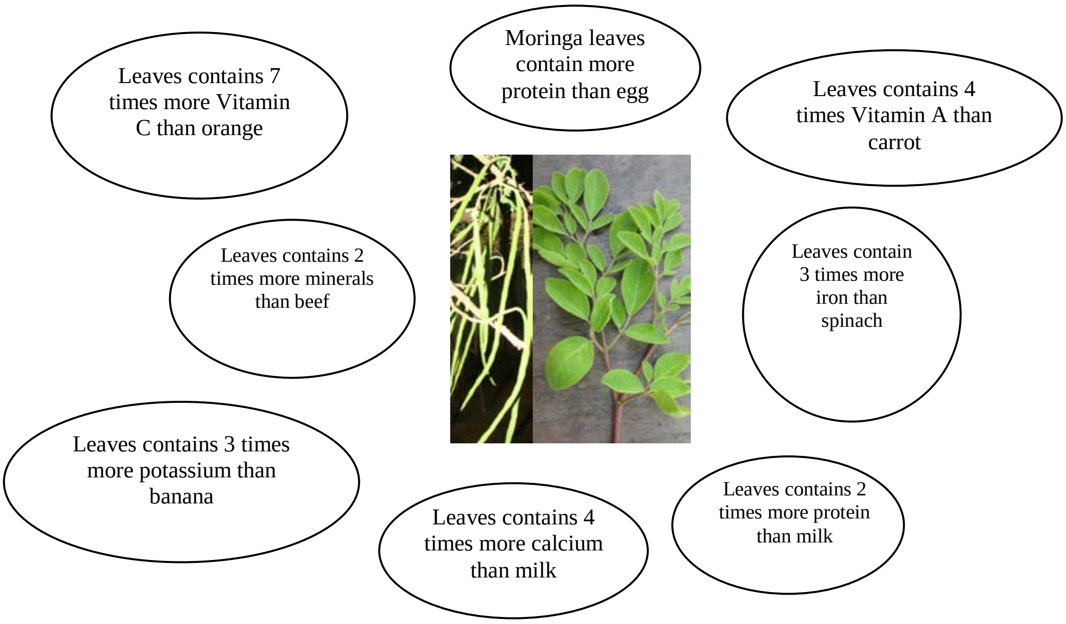

Figure 9. The comparison of nutritional value of moringa leaf with other foods.

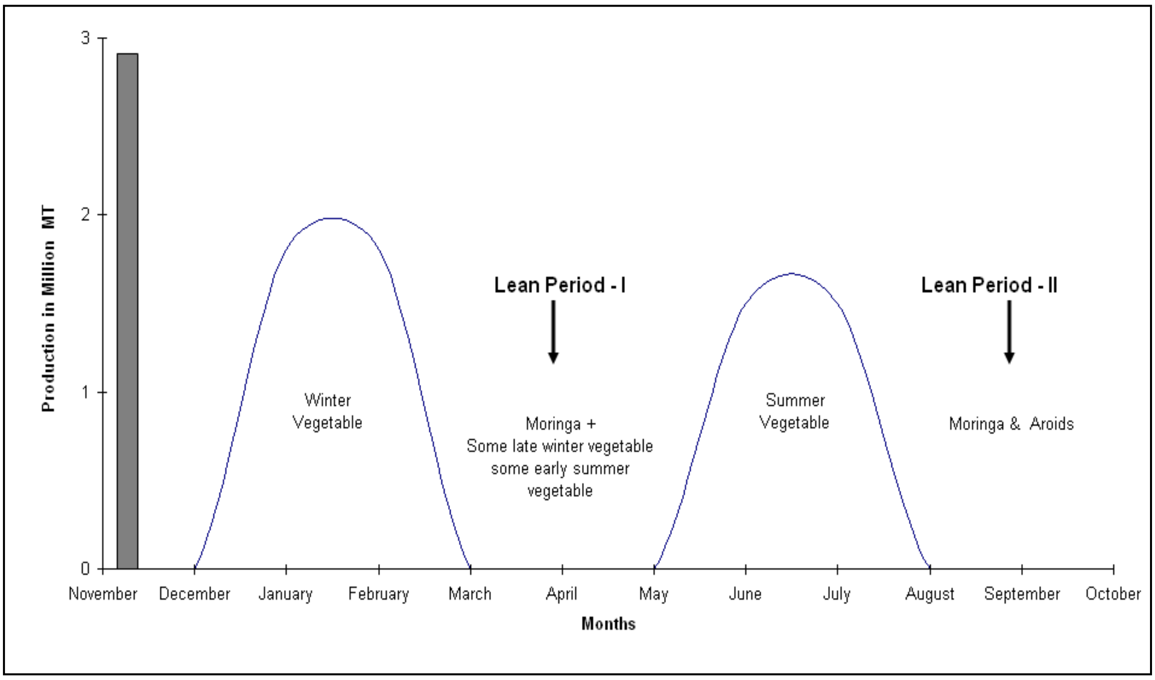

Figure 10. Role of moringa during lean period of vegetable production

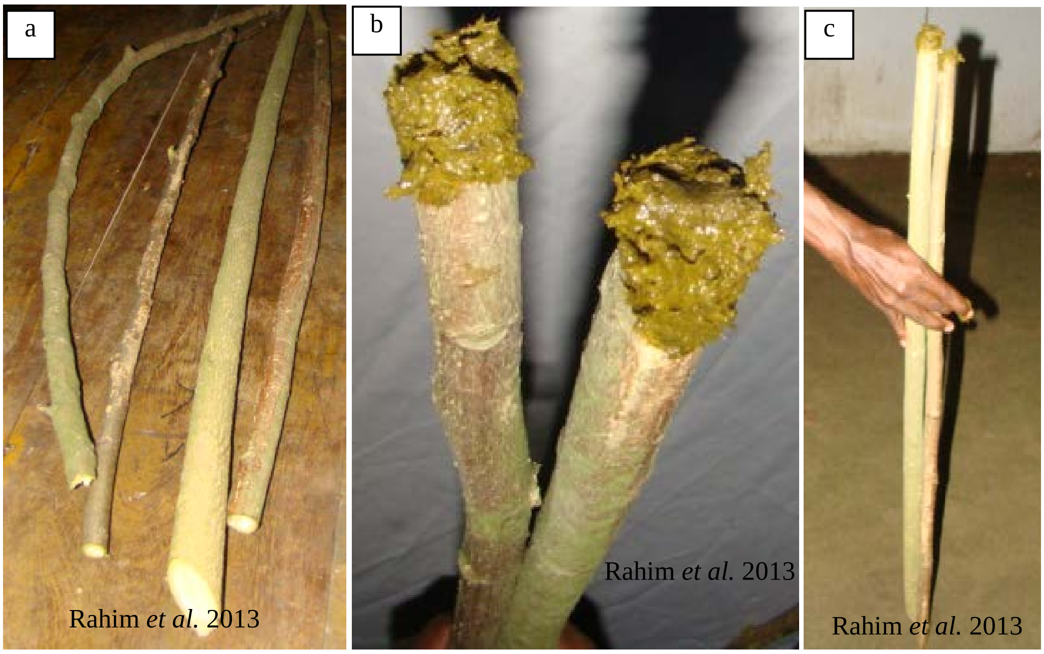

Figure 11a-c. Limb cuttings for propagation of drumstick

Table 1. Nutritive Value of moringa

Nutrition		Leaves	Fruit
Water	(%)	75	87
Protein	(g)	6.7	2.5
Carbohydrates	“	13.4	3.7
Fat	“	1.7	.1
Fiber	“	0.9	4.8
Calorie	K.Cal.	90	26
Carotene	(I.U.)	11300	180
Thiamin	(mg)	0.06	0.05
Riboflavin	“	0.05	0.07
Niacin	“	0.8	0.2
Vitamin-c	“	220	120
Calcium	“	440	30
Iron	“	7.0	5.3

Rashid, 1999; Rahim 2012

Table 2. Percent peoples' involvement with moringa

Activities	% peoples' involvement
Cultivation	40.00
Harvesting	30.00
Marketing	30.00

Lessons learned from implementing nutrition-sensitive agriculture as a platform to improve nutrition and household food security

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ABSTRACT

Although progress in development has reduced hunger and malnutrition since the 1990s, global food price volatility, social unrest and increasing inequity have resulted in a stagnation of progress (since the mid-2000) with too many people, particularly women and young children, still suffering from hunger, undernutrition and food insecurity. Children under the age of five and pregnant and lactating women are at highest risk of resultant vitamin and mineral deficiencies. For 25 years, Helen Keller International (HKI) has supported efforts to improve household nutrition through implementation of an enhanced homestead food production (EHFP) program that simultaneously promotes optimal nutrition practices and increases year-round availability and intake of diverse micronutrient rich foods among poor households. This paper aims to review the impact of HKI's EHFP program and identify core elements of the EHFP model and lessons learned for adaptation and replication. Evaluation results from five countries showed that HKI's food production program positively impacted poor households' year round food production and availability, particularly for women and children. EHFP improved household garden practices, food production, consumption and dietary diversity. The number of crop varieties consumed was significantly increased from a range of 2-3 to 8-9 between baseline and end line among program households. The change in proportion of households consuming eggs and/or liver was higher among program (24% to 46%) than comparison (12% to 18%) households. The median income earned from selling surplus EHFP produce increased from US$1 to $7 among all countries programs. Anemia prevalence was lower among children in the program households at end line compared to baseline. Preliminary results of a randomized control trial in Nepal showed that HKI's EHFP program can reduce anemia among children and women and can reduce underweight among women, but there is as of yet no demonstrated impact of the program on child growth although there were significant improvements in a range of maternal practices that are known to impact child growth. Key elements of successful EHFP programs include an evidence-based and participatory program design, practical training package for both agriculture and essential nutrition actions, established local resource centers, tested behavior change communication and advocacy strategy, gender analysis that informs the strategy, links with existing systems, continuous learning system through formative research and process monitoring, staffing that depends on program design, community/ local ownership, documentation, publication and dissemination, and minimum duration of technical inputs to ensure impact.

Abbreviations

AAMA: Action Against Malnutrition through Agriculture, HKI's EHFP Project in Nepal (*Aama* means 'mother' in Nepali)
AED: Academy for Educational Development
Ag: Agriculture
BCC: Behavior Change Communication
EHFP: Enhanced Homestead Food Production (Home gardening + small animal husbandry + essential nutrition actions for improved nutrition of women and young children)
ENA: Essential Nutrition Actions
FAO: Food and Agriculture Organization
FCHVs: Female Community Health Volunteers (in Nepal)
HKI: Helen Keller International
IFPRI: International Food Policy Research Institute
IQ: Intelligence Quotient
NCHS: National Center for Health Statistics
UNICEF: United Nations Children's Fund
USAID: United States Aid for International Development
VMF: Village Model Farm
WHO: World Health Organization

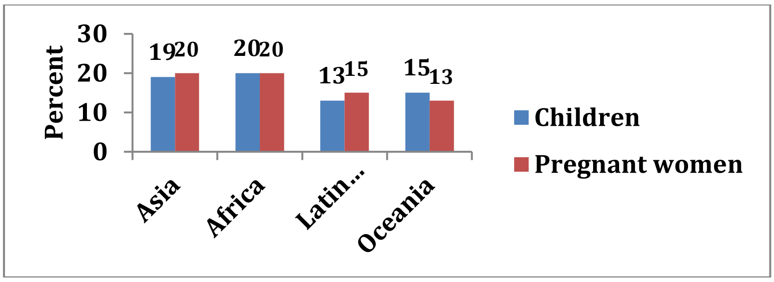
AIM

This paper aims to position nutrition-sensitive agriculture programs within the context of undernutrition in developing countries. It also reviews the impact of Helen Keller International's (HKI) enhanced homestead food production (EHFP) program on nutrition and food security and outlines lessons learned for adaptation and replication of the model.

BACKGROUND

Although progress made in development has reduced hunger and malnutrition since the 1990s, global food price volatility, social unrest and increasing inequity have resulted in a stagnation of progress (since the mid- 2000) with too many people, particularly women and young children, still suffering from hunger, malnutrition and household food insecurity. Statistics vary but according to the Food and Agriculture Organization (FAO), 842 million people in the world still do not have enough to eat, the vast majority (827 million) live in developing countries, with most of those living in Asia. Asia has the largest number of hungry people (over 50 million people) but sub-Saharan Africa has the highest prevalence (24.8% of population).[i]

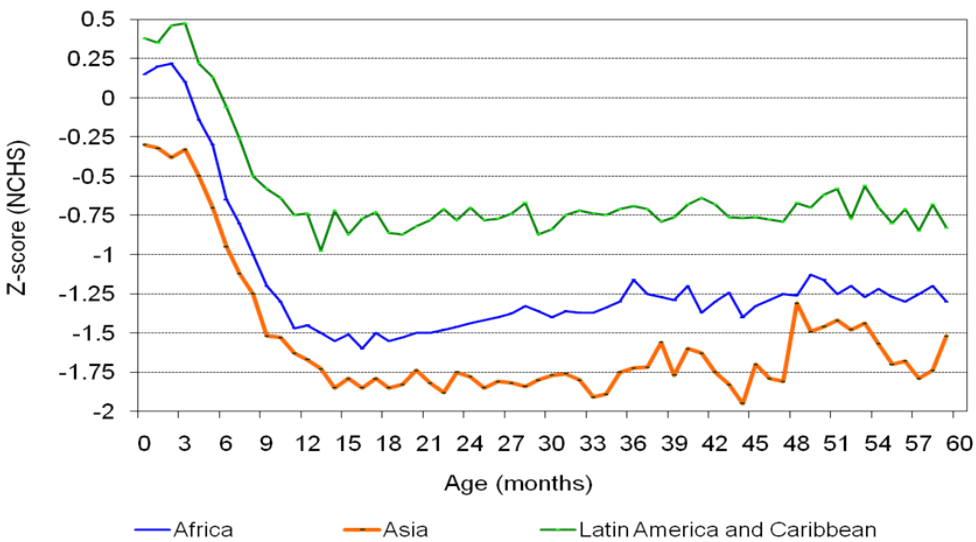
Women and children remain the most vulnerable to hunger and food insecurity. According to the World Health Organization (WHO) and as reported in a recent Lancet Series on nutrition, 165 million children under five (26%) are stunted (too short for their age) with 20% of stunting by 24 months due to being born Small for Gestational Age; 96 million are in Asia; 52 million children under five are wasted (too thin for their height); 100 million children are underweight (too thin for their age). 14.3% of the population is undernourished in developing countries. Undernutrition is responsible for 45% of all under five child deaths or 2.6 million child deaths each year. [ii], [iii]



UNICEF State of the World's Children

Hidden hunger is also still highly prevalent in Asia and has long-term developmental consequences contributing to the burden of premature death among young children, poor birth outcomes among mothers and lower productivity among people overall. Anemia remains highly prevalent in developing countries among young children under five years of age and pregnant women particularly with around 20% being anemic in Africa and Asia. Approximately one third of the developing world's children under the age of five suffer from vitamin A-deficiency. The consequences are devastating. Each year, about 670,000 children under the age of five die due to vitamin A deficiency and an estimated 350,000 children go blind as a result of this condition, representing 70% of all new cases of childhood blindness that occur annually[iv]. Tragically, blindness from vitamin A deficiency is unnecessary because it is treatable with vitamin A supplements.

As mentioned, stunting can begin before birth and most of the growth faltering happens well before the age of two years so it is imperative to focus programs to improve nutrition among pregnant women and young children – in the first 1000 days from conception through age two. Stunted children become stunted adults who will never realize their full developmental potential. Iron deficiency anemia lowers IQ by nine points. Severe stunting is associated with an IQ loss of 5-10 points. Low birth weight babies have IQs five points lower than non-low birth weight babies (various sources, Profiles/AED).



Weight for age, by region: illustrating growth faltering
From V Quinn Presentation

The 2013 Lancet Series[v],[vi] proposed ten interventions that if implemented at 90% coverage could prevent one million under five child deaths and avert 20% stunting. The below interventions have been categorized as nutrition-specific, with direct impact on nutrition, and nutrition-sensitive, with less direct impacts on nutritional status of children, but still critical to improving undernutrition among children. These are:

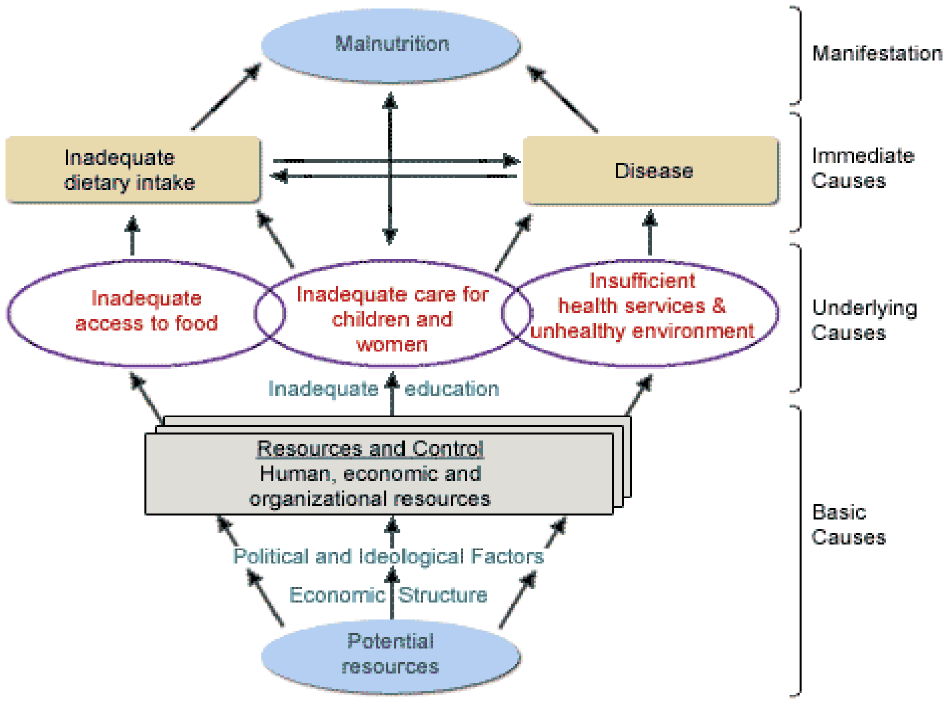
Nutrition Specific

- Promote appropriate breastfeeding and complementary feeding
- Micronutrient supplementation
- Management of acute malnutrition
- Balanced energy and protein supplements to women

Nutrition Sensitive

- Agriculture and food security
- Social safety nets
- Women's empowerment
- Water, sanitation & hygiene
- Health and family planning services;
- Early child development & child protection programs

For all programs with a goal to improve nutrition, it is important to address all three underlying causes of malnutrition – food, health and care – in order to maximize positive nutritional impacts. In reality, field programs rarely address all three and agriculture programs often focus only on food production and processing.



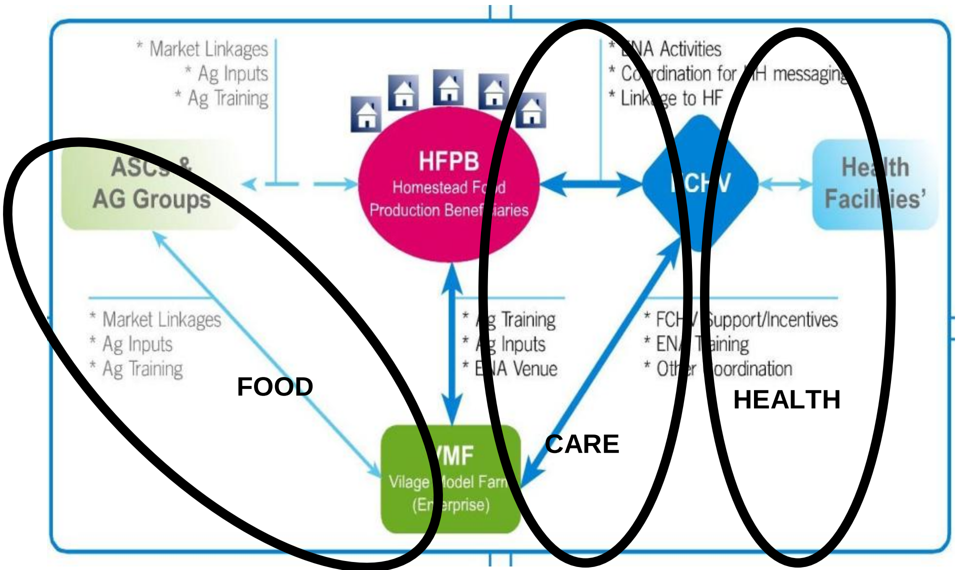
UNICEF basic determinants of malnutrition model

So what do we know about the impact of nutrition sensitive agriculture interventions on food and nutrition of families? To date a review of studies on nutrition-sensitive agriculture interventions have shown consistent improvement in the volume and diversity of vegetables and fruits produced, diversity of foods consumed, and women's involvement in family decision making.[vii], which we know is important for child health, but have shown inconsistent impact on nutritional status of children. Some reasons for this maybe that not much solid evidence exists as very few evaluations of agriculture programs have included nutritional indicators, and when they did, the evaluation designs have not often been rigorous enough to detect much change. In addition, targeting of interventions may have been suboptimal and programs many not have addressed all three determinants of malnutrition adequately, namely food, care and health (including adequate attention to ensuring clean water and proper sanitation and hygiene).

Description of an integrated nutrition-sensitive agriculture program model

Helen Keller International has developed an integrated nutrition-sensitive agriculture intervention that focuses on improving nutritional status of poor households and among the most vulnerable family members—young children and pregnant and lactating women. HKI's enhanced homestead food production (EHFP) program has evolved over 25 years and now addresses six of the ten Lancet Series nutrition specific and nutrition sensitive interventions through an integrated agriculture, nutrition, and health program strategy that simultaneously promotes optimal nutrition, care and health practices and establishes a system for year-round food availability and intake of diverse micronutrient rich foods among poor households. The model marries production of plant and animal source foods: home gardens, small animal rearing, and village model farms) with nutrition education for behavior change using the essential nutrition actions (ENA) framework, including promotion of optimal breastfeeding and complementary feeding.

HKI-EHFP Conceptual model: A program model that includes the food, health and care components with the goal to improve nutritional status of vulnerable members living in poor households, particularly young children and women.



AAMA Conceptual Program Model, HKI Nepal

The integrated model was expected to improve maternal and child nutritional outcomes through several pathways namely 1) increased access to and consumption of micronutrient-rich fruits, vegetables and poultry or small animal products, 2) improved breastfeeding and complementary feeding practices, 3) increased use of public health services by mothers and children, 4) increased income through the sale of surplus products from the home gardens and poultry, and 5) empowered mothers by improving their knowledge and skills and influence over household decision making. The model has added a sixth pathway in order to reduce infections (particularly diarrhea disease and intestinal worms) namely 6) improved water, sanitation and hygiene practices.

The basic characteristics of the HKI-EHFP have evolved through identifying gaps and testing new strategies to fill those gaps and include:

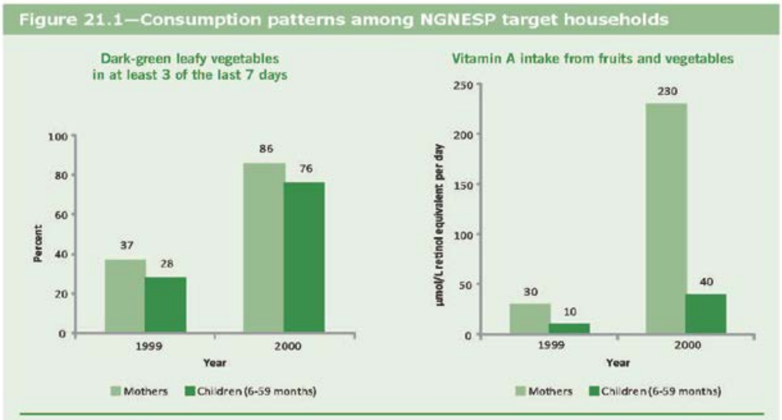
- Select pregnant women and women with children under two years of age from poor households as the beneficiaries of inputs and training on homestead farming and nutrition education. Targeting these women to receive benefits is important to focus attention on the critical 1000 days developmental window and to build their confidence and empower them to make good nutrition and health choices for their children and themselves.
- Engage influential members of the family (spouse, mother-in-law, etc.) for support to women beneficiaries.
- Establish model farms as private enterprise /community resources; and as a venue for women beneficiaries to meet.
- Work through local partners (communities, civil society, private sector, non-governmental and governmental organizations) to build their capacity to manage the program and provide ongoing support; and to ensure all aspects of the food, care and health determinants are being addressed according to the local context.
- Build linkages to the local health and agriculture systems for continued support.
- Build linkages to local markets for sale of excess produce and animal products for generation of a small amount of income, controlled by the women.
- Ensure year round production of micronutrient rich crops and animal source products (plus some high value plants for income generation) through crop planning and access to seeds, seedlings and saplings.
- Introduce improved local farming practices, including post-harvest.
- Promote optimal nutrition, food preparation and feeding practices through nutrition education at women's groups and behavior change communication messaging. Demonstrate use of HFP produce / products to improve children's and family diets.
- Have a defined program cycle and exit strategy. Provide initial agriculture inputs and training for up to 2 years

Impact of HKI's Enhanced Homestead Food Production

From HKI's initial home gardening pilot project done in 1990 in Bangladesh to improve dietary diversity and micronutrient status (particularly vitamin A), HKI has adapted and expanded the program to reach well over 1 million families in Asia (Bangladesh, Nepal, Cambodia, Indonesia, the Philippines and Vietnam) and has also recently adapted the EHFP model to several countries in Africa. A review of HKI-EHFP program evaluations in Bangladesh, Nepal, Cambodia, Indonesia, and the Philippines showed that HKI's EHFP has positively impacted poor households' year round food production and availability, particularly for women and young children (6-

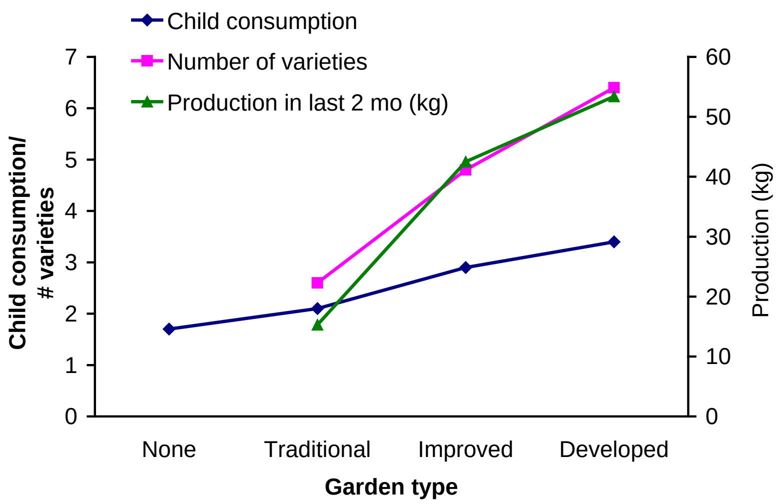
59 months of age). EHFP improved household garden and animal husbandry practices, food production, consumption and dietary diversity and reduced anemia and night blindness (vitamin A deficiency) prevalence among young children. The results also showed an increased women's level of influence in household decision-making along with an increased household income, controlled by women.[viii]

An external review of HKI's Bangladesh Program by the International Food Policy Research Institute[ix] showed the HKI's HFP programs increased diversity and quantities of food produced and consumed and also increased women's involvement in household decision making: "*…there is sufficient evidence to conclude that HFP is improving household food security, and in some cases nutrition and other intermediary outcomes.*"



HKI's EHFP also improved intake of vitamin A by families in Bangladesh
HKI Bangladesh

Intake of vitamin A rich fruits and vegetables by mothers and young children among poor families in Bangladesh improved substantially in just one year mostly because of the additional production that took place all year round, but also because of promotion and instruction of how to prepare the foods for children.



Production and consumption of vegetables by type of garden (n=10,107), Bangladesh

Other evaluation research by HKI showed that gardening practices improved (seen in the above graph as *type of garden*) and with that, production and diversity of vegetables increased as well as consumption of vegetables by children. The study also showed that[x]:

- the project resulted in more households having any kind of home garden;
- the number of varieties of foods produced was increased among beneficiary households;
- the quantities of foods produced increased including vegetable production increasing by greater than two fold (135 kg instead of 46 kg vegetables) in 3 months;
- that project households engaged in year-round gardening increased from 3% -33% by the end of the project;
- that the consumption of home grown vitamin A-rich foods increased including egg consumption by 48% and dark green leafy vegetable consumption among 6-59 month children and mothers from around 33% to 75%; and
- income opportunities were created with more than 60,000 women making income from EHFP. As 73% of the gardens were managed by women, they were also the main decision-maker for gardening practices and use of income earned from sale of excess produce.

An external evaluation of the Bangladesh homestead food production program by Bushamuka confirmed that women's influence in the household improved across all parameters as women got more power with increased knowledge and skills and also got control of a small amount of income from sale of excess HFP produce (after their own home consumption)[xi].

Women's influence level in household decision-making

Activity	Program Phase	Women Caretakers (%)					
		Influence level before program			Current level of influence		
		None	Some	Full	None	Some	Full
Participation in group meetings	Completed Active Control	66.8 89.7 83.6	24.6 8.3 12.4	8.6 2.0 4.0	16.6 3.8 57.6	32.2 63.4 24.0	51.2 32.8 18.3
How to use the land	Completed Active Control	44.3 62.5 66.1	45.1 33.7 26.9	10.6 3.8 7.0	7.8 13.2 43.2	57.6 59.9 40.8	34.5 26.9 16.0
Making small household purchases	Completed Active Control	24.9 35.0 40.0	61.0 58.3 52.4	14.1 6.7 7.6	2.2 5.4 16.9	48.7 52.9 61.3	49.1 41.7 21.8
Making large household purchases	Completed Active Control	47.7 59.0 68.3	41.2 35.2 25.2	11.1 5.8 6.5	16.1 21.9 52.5	60.6 58.4 35.2	23.3 22.7 12.3

Bushamuka, V. N. et. al. FNB 2005

HKI has also evaluated the impact of EHFP on children's nutrition (vitamin A and anemia). Although the results were not significant in all countries, anemia was reduced more in program households than control households among children.

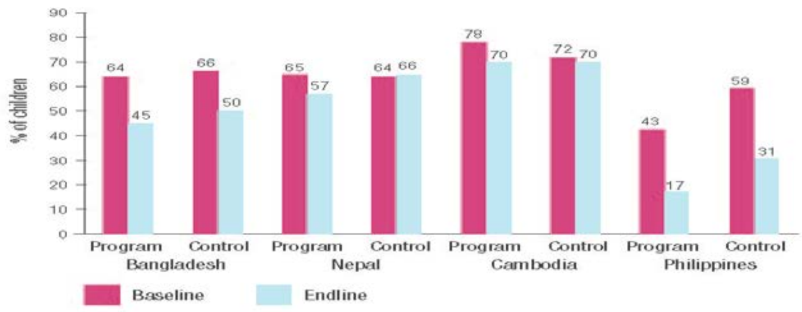


Figure 3. Anemia prevalence among children aged 6-59 months from HFP program and control households in Bangladesh, Cambodia, Nepal and the Philippines at baseline and endline (2003-2006).

EFHP program evaluations from 2003 - 2009.

Talukder, Haselow, et al, FACTS Report 2010 and Abstract MN Forum

HKI-EHFP program results have consistently shown:

- Increased year-round production and consumption of home produced micronutrient-rich vegetables and fruits and animal source foods (increased dietary diversity)
- Increased household income from the sale of production that can be used to purchase nutritious foods and other necessities
- Improved child nutrition, care and health practices through nutrition behavior change (e.g. ENA) and links to local health services
- Improved child care through the empowerment of participating women
- Reduced anemia prevalence among targeted children aged 6-59 months and non-pregnant women

However, because we have had no results on child growth, and there are very few, if any, well-designed studies that are set up to evaluate this for nutrition-sensitive agriculture interventions, HKI designeda study to test the impact of our EHFP model on child nutrition and growth (anthropometry), as well as women's nutritional status. The study also assessed impact on household food security, as well as agriculture production and consumption, women's empowerment and income. As part of a USAID-funded Child Survival Innovations Project, we implementaed two EHFP projects in Nepal from 2009 – 2012 that address the food, health and care causes of malnutrition in the area.[xii] The project, covering about 11,000 households, was an integrated EHFP model including home gardens, poultry-rearing, essential nutrition action behavior change communication led by community health workers and a hygiene component based on evidence and experience as to the importance of includig this. The main study was a cluster randomized controlled trial that assessed more than 2000 families with children 12 – 48 months of age at baseline and endline in equal number of intervention and control Village Development Committee areas.

The results of the main study will be submitted to a peer-reviewed journal soon once the manuscript is completed so will not be reported fully here.However, preliminary results of the study showed that there was a significant improvement in household food security (using the Household Food Insecurity Access Scale)[xiii] among intervention households compared to controls, with the greatest difference realized among severely food insecure households. This is the 'food' component. The EHFP also addressed the care component and showed an increase in early initiation of breastfeeding, exclusive breastfeeding and improved complementary feeding practices among intervention households compared to controls. EHFP improved hygiene practices of mother hand-washing with soap before and after key activities as well. The health component was also addressed with the intervention having a significant positive impact on children's/mother's participation in preventative health services. At end line, anemia was significantly lower among mothers and children in the intervention (EHFP) group compared to the control group and mothers participating in the EHFP were significantly less likely to be underweight (BMI < 18.5 kg/m2) then those who were not in the program. There was no impact on child anthropometry.[xiv]

The study showed an integrated agriculture sensitive intervention can play an important role in improving household food security, maternal hand washing and child feeding practices, as well as reducing anemia among women and children and decreasing maternal underweight. Although there were significant improvements in a range of maternal practices that are known to impact child growth, there was no demonstrated impact on child growth. Further research is needed to assess the impact of an integrated nutrition-sensitive agriculture intervention on child growth.

Lessons learned from implementing a nutrition-sensitive agriculture program model

1. Agriculture is critically important but it is not enough to improve nutrition of vulnerable populations. Food security at national or even local level does not equal nutrition security at household level. For agriculture interventions to improve and optimize nutrition outcomes of the most vulnerable, they should be designed through a nutrition lens, with nutrition indicators and address local food, care and health determinants of malnutrition. This does not mean doing everything yourself, but working with partners across sectors to ensure all aspects are adequately addressed.

2. In addition to the underlying premise of selecting and working with pregnant women or women with small children from poor households to improve their year round access to nutritious food during the important developmental period (1000 days), since women tend to make positive choices for family health, programs should be designed to enable women and give them more options. Design programs to empower women in their important role as the gatekeepers of household food security, food production, hygiene and child nutrition in order to maximize positive nutritional impact. This also means educating and enlisting other key influential members of the household, like mothers-in-law and husbands, to provide both emotional and physical support.

3. The design and adaption stage of the integrated project delivery model is critical and should be based on evidence regarding the food, care and health determinants of malnutrition in the project area.

4. A gender / social equity analysis should be done to inform the strategy and provide an understanding of the social dimensions, including gender roles, community and intra-household dynamics that must be addressed to implement equitable programs that reduce gender and social barriers and enable men and women to better access resources, livelihoods opportunities and improved nutrition and food security.

5. The behavior change communication and advocacy strategy should be based on formative research and tested to facilitate lasting change. The research should include an analysis of the barriers and facilitators of specific agriculture and nutrition actions, including the related social gender and equity norms. Key messages should be developed to share evidence-based information and knowledge, and promote doable

actions (such as in the seven priority doable action in Essential Nutrition Actions Framework) for positive change regarding agriculture, nutrition, health, sanitation and hygiene and livelihoods behaviors. The messages should be consistent and reinforced through multiple channels (interpersonal communication, community mobilization, mass media) at all levels.

6. A practical training package for agriculture, nutrition and health should be adapted to the local context and tested. Use of the evidence-based essential nutrition action package that promotes improved nutrition and health among women and children under two; and optimizes the benefit of increased production for the most vulnerable household members is recommended; along with the more recently developed essential hygiene actions package. The training content should be updated to include state of the art information and appropriate technology in nutrition, health, water and sanitation and agriculture that could be usable and available in the project area. Agriculture practices and planning should address climate change issues in the target area as well.

7. Have an entry and exit strategy. Participatory and learning methods should be used for community entry and to ensure full participation and ownership among all stakeholders. There should be an initial and ongoing support mechanism built into the program model with a qualified technical and management team available to build capacity of local resources for about two years in order to ensure households can receive the support they need, and be prepared to continue without much assistance.

8. A local source for continued agriculture inputs and support (Village Model Farm or another mechanism) is important for access (particularly in more remote areas), affordability and sustainability of the agriculture component. It is best when these are civic- minded, group-selected households that receive additional training and can establish a model farm as a private household enterprise.

9. Building multi-sector collaboration at national, regional and local level is important to maximize nutrition outcomes and use limited resources wisely. Locally, this also means that links to existing agriculture resources, both private and public sector, and to markets must be established in the project. Strong links to the existing health, nutrition, water, sanitation and hygiene resources should also be embedded in the project; as well as working closely with local authorities to support community improvements and leverage additional resources.

10. A monitoring and evaluation system that provides continuous learning is necessary when adapting the model successfully and sustainably to new areas, environments and cultures. Nutrition indicators should be included in any and all projects with the aim of improving nutrition, including agriculture projects. A rigorous evaluation designed specifically to assess impact on nutrition is important in order to build the evidence base for integrated nutrition-sensitive agriculture approaches.

11. Documentation, publication and dissemination are critical to advocate for policies that support nutrition-sensitive agriculture approaches and to compel donors to invest in these kind of interventions for poor communities.

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Strengthening market integration of smallholder farmers: A demand-driven approach to knowledge transfer in Myanmar

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ABSTRACT

The significance of vegetables as an engine for economic growth in rural areas has long been overshadowed by a predominant focus on rice. However with potential for growth and increasing demands for higher qualities, vegetables offer good opportunities to farming families, many of whom live under the national poverty line. Nevertheless, profitability for many smallholder farmers continues to be challenged by a predominantly supply-driven approach to production.

To embrace and benefit from a demand-driven approach, traditional farm practices, commonly used by many smallholders in less developed areas of Myanmar, need significant adaptations to bring in line with market requirements. However, multiple factors affect and hinder the adoption of improved practices which are needed for successful market integration. Alongside numerous institutional and policy constraints, the poor performance of many farmers can be largely attributed to limited access to knowledge and information along the value chain.

There is a general consensus in literature that through the failure to recognize market solutions, public extension in many countries has been ineffective, lacked sustainability and failed to offer the services needed to benefit the poor. These negative experiences have inspired considerable debate about the most effective way to provide and finance advisory services in the future. In Myanmar's challenging environment, pluralistic systems of extension which improve financial sustainability and align production to the needs of developing markets could provide the necessary incentives to drive productivity and upgrade qualities in remote rural communities.

Based on East-West Seed's experiences of engaging in extension services, this paper discusses how market based solutions which promote the adoption of improved practices and access to knowledge along the value chain, can make significant impacts towards market integration of smallholder farmers in Myanmar.

Keywords

Myanmar, vegetable seeds, vegetable value chain, demonstrations, peer learning.

INTRODUCTION

Benefiting from a wide range of agro-climatic zones and being strategically located near regional markets, Myanmar, one of the poorest countries in Southeast Asia, is the ideally suited for the cultivation of vegetables. But despite being an important source of nutrition, and having the potential to generate considerably higher incomes than field crops (Lumpkin et al. 2005), the significance of vegetables as an engine for economic growth in rural areas has long been overshadowed by a predominant focus on rice. With potential for growth in domestic and export markets, vegetables can however take a major role in improving the livelihood of Myanmar's farming families, 26% of whom live under the national poverty line (ABD 2010). Nevertheless, profitability for many smallholder vegetable farmers in Myanmar continues to be challenged as a result of a principally supply-driven approach to production, and with less attention from donors and government, the sector has so far remained relatively undeveloped.

SMALLHOLDERS AND VEGETABLE PRODUCTION IN MYANMAR

Vegetables, which are produced on 400,000 hectares (DOA 2011), offer an important source of income to an estimated 750,000 smallholders in Myanmar. A survey by LIFT (2012) indicates that for approximately 35% of these farmers, vegetables represent their primary source of family income. Although lacking in accurate data, it is assumed that the majority of other rural households also produce small amounts of vegetables for their home consumption. Given that there are over 8 million rural households in Myanmar, backyard cultivation of vegetables is an important source nutrition for many poor families.

Vegetable cultivation can be divided into three distinct groups; commercial smallholders who are the main suppliers of vegetables to the markets, backyard farmers who are numerous in number and commercial farms which are limited to only a few enterprises. Although large commercial farms, can offer some prospects for employment, it is widely accepted that small-scale farms in developing countries are able to achieve higher levels of productivity (Fan et al. 2013) and are in general more beneficial for economic development in rural areas. Through labor and cultivation on rented land, short duration vegetable crops also create opportunities for Myanmar's landless households, which are estimated make up 30 to 50% of the rural population (ADB 2012, Wilson and Wai 2013). With data from the Department of Agricultural Planning indicating that more than 75% of land awarded in concessions to agri-business remains unused, questions should be raised as to whether policies promoting larger scale agriculture would not be more effective re-focused to develop smallholder production systems. With growing markets and limited land requirements, there is no doubt that smallholder farming systems offer the greatest potential for pro-poor growth and the reduction of rural poverty in Myanmar. Although average landholdings in Myanmar are in the region of 2.5 ha (FAO 2010), the majority of vegetables are produced on smaller plots only about 0.25 ha (MSU/MDRI 2013). Even though small areas like these can be highly productive, with limited knowledge on improved technologies; deeply embedded perceptions and high aversion to risk, the profitability for many smallholders so far remains under exploited.

CHALLENGES TOWARDS MARKET INTEGRATION

Access to knowledge

To embrace and benefit from a demand-driven approach, significant adaptations are needed to the traditional practices commonly used by many smallholders in less developed areas of Myanmar. However, multiple factors challenge the adoption of improved practices needed to bring their products in line with consumer requirements and ensure successful market integration. Alongside numerous institutional and policy constraints, the poor performance of many smallholder farmers can be largely attributed to the exceptionally limited access to technical knowledge and market information along the value chain. In many developing countries, poor access to productivity enhancing technologies and advisory services is the main cause for farmers to continue to pursue traditional practices (Fan et al. 2013). The significance of extension services and appropriate technologies for smallholders in Myanmar cannot be overestimated, however to be effective, development must be in parallel with improving trust and linkages which is needed to overcome the market failures inherent in most traditional supply driven approaches.

Aligning production to the needs of the markets

With the greater part of production under traditional practices and the widespread use of farmer saved seed, qualities on the Myanmar's markets remain relatively poor. Few farmers have taken the opportunity to organize into groups and the low level of trust between farmers and collectors hinders the flow of vital market information. This fragmented flow of information results in farmers pushing products onto markets with little regard for the actual demands of the consumers. With a general lack of exposure to better quality products on the markets, insufficient premiums are paid by traders and consequently farmers have little incentive to upgrade qualities.

Despite growing opportunities for exports, the vast majority of production is presently geared towards domestic markets; which due to Myanmar's past isolation have so far faced little or no competition from imports. However, as in other developing economies, it is expected that there will be a significant shift towards higher quality and safer to eat vegetables in Myanmar. Although local farmers currently supply most of the country's fresh vegetables, with the opening of trade across borders there is no place for complacency in the Myanmar's vegetable sector and serious consideration needs to be given to upgrading qualities; targeting both existing domestic markets and potential export markets for the future.

OPPORTUNITIES TOWARDS A DEMAND DRIVEN APPROACH TO TECHNOLOGY ADOPTION

Better seeds to develop competitive markets

The majority of vegetables produced in Myanmar are from farmer self-saved seed (Phyu 2012). Common problems encountered by farmers include, low germination, incidence of disease, non-uniformity, poor year round performance, poor transportability and storage. Whilst self-saved seed may be appropriate for home consumption, farmers producing vegetables as their main livelihood are expected to face increasing difficulties to compete with the shifting demands on Myanmar's developing markets and as such the lack of good quality vegetable seeds, bred for specific markets and agronomic conditions, is considered a major bottleneck for growth of the sector.

With food security being a primary concern, public sector programs in the region have generally focused plant breeding towards the agronomic needs of smallholders, such as better yield, tolerance to stresses and diseases, etc. With minimal involvement of the private sector (IFPRA and DAR 2007), end users have rarely been the foremost consideration for agricultural research and development in Myanmar. However, with markets being the primary driver for agricultural development, there is a clear need for both customers and farmers to be at the centre of variety improvement. The private sector, with expertise, resources and commercial incentives, can assure the development of varieties more aligned to the changing demands of consumers, as well as the agronomic needs of the farmers.

Improved varieties alongside better farm practices are widely recognized as contributing towards food security, reducing poverty and bettering the livelihoods of smallholder farmers (Eaton and Wiersinga 2009, Dias 2010). Accordingly, market based plant breeding and the promotion of high quality commercial seeds will be major factor towards defining the future position of smallholder farmers on Myanmar's transforming markets.

Knowledge transfer to smallholders

With a large part of the decline in worldwide poverty attributed to technological innovation (OECD 2012), many developing countries have recognized the need to revive their agricultural advisory services. However there is a general consensus in literature that through a failure to recognize market signals, public extension in many developing countries has been ineffective, lacked sustainability and failed to offer the services needed to benefit the poor (Rivera 2009, FAO 2004, Feder et al. 2011, Christoplos 2010, Katz 2006). These negative experiences have inspired considerable debate about the most effective way to provide and finance advisory services.

In general, vegetable farmers in Myanmar have very poor access to market information and technical knowledge. Despite being one of the main employers in the Ministry of Agriculture and Irrigation, with a lack of resources, outreach from public extension is extremely limited (MSU and MDRI 2013). For most villages, advisory services targeting vegetable farmers, is either nonexistent or limited to irregular visits from promotional staff of agro-chemical companies. Low expenditure in extension and weak linkages to research (Vokes and Goletti 2013) is probably a major factor towards to the stagnation of productivity that has led to area expansion rather than quality improvement (Shwe 2011).

With virtually no external source of advice, most vegetable farmers in Myanmar depend predominantly on neighbors and inputs dealers for technical and marketing information. Although this creates potential opportunities, the current reality is that without objective advice from external sources, farmer-to-farmer knowledge transfer is often perpetuating poor practices. Advice provided by agro-input dealers, who are cited by farmers as the second most important source of information, is generally orientated to maximise sales and therefore rarely objective.

In this challenging environment where the majority of potential clients (smallholders) have little or no access to information and weak functioning of value chains are major barriers to the adoption of high quality seed and better technique, East-West Seed, has identified extension as a precondition for opening and sustaining markets. Although often assumed to be the responsibility of the public sector or NGOs, East-West Seed regards extension as a long-term business opportunity, which through upgrading on-farm practices, is expected to lay down the foundations for future seed sales. Since 2012, extension has been integrated as a fundamental part of the company's business strategy for Myanmar.

The primarily target of East-West Seed extension activities is poor smallholder farmers, who are the main suppliers of vegetables to the markets. To assure effective outreach, activities are targeted in areas of concentrated vegetable production, where the majority of farmers are using local or poor quality seed alongside traditional techniques. 'Backyard' farmers are also considered as a potential new target group, especially in view of the affordability of small seeds packages.

Despite obvious opportunities, the framework conditions in which East-West Seed operates remains challenging. High levels of corruption, poor infrastructure, unpredictable trade policies as well as undeveloped human resources on all levels are some of the major hurdles that the company has to overcome if extension activities are to be a success. In addition, where farmers have had little previous exposure to outside advice, receptiveness to change can be slow and demanding.

Peer managed demonstrations

With generations of experience and in-depth knowledge of local conditions, smallholders hold many of the solutions needed to improve the profitability and sustainability of vegetable production. In Myanmar, as in other developing countries, effective knowledge transfer in resource poor communities depends largely on trust and clear evidence of the profitability of technologies promoted.

Accordingly East-West Seed has adopted a peer learning approach whereby farmers are capacitated to establish demonstrations, which showcasing profitable and sustainable cultivation practices, act as a benchmark of success to neighbors. Increased levels of trust enabled through peer advice can lead to a greater ability to absorb knowledge than advice perceived to come from outside sources. East-West Seed supports key farmers throughout the cropping cycle, providing regular advice on all aspects of production from land preparation and seeding production through to transplanting, correct fertilizer use and safe pest management as well as post-harvest handling. Although demonstration farms are used to introduce new crops and varieties in accordance with market demand, advice from extension staff is predominantly technical. Simple and replicable technologies are the result of internal research as well as years of experience with smallholders in the region. Building-up on existing practices and introducing technology step-by-step, allows a steady transition towards improved practices; first on their own and later with neighboring farms. However, with ownership and all management decisions in the hands of key farmers, the rate of technology adoption can be a slow process. In general, East-West Seed supports key farmers for approximately three crop cycles. Over this period a gradual adoption of more sustainable and profitable practices takes place, eventually culminating in systems which benefit from:

- Improved varieties
- Better land and bed preparation
- Rice straw or plastic mulching
- Optimum spacing and field layout
- Production of healthy seedlings in nursery
- Timely weed control
- Judicious nutrient management
- Safe and effective pest and disease management
- Suitable trellising systems
- Appropriate irrigation
- Timely harvesting and improved postharvest handling

The dissemination of both technical and variety information is assured through the organization of multiple training events and field days which are open to the participation of farmers from within the village as well as from neighboring villages. As successful adoption depends on the value of the technology being promoted; whether financial or labor saving, a major part of field days center around the cost and return analysis of the crop. Sharing information with vegetable collectors and agro-input retailers as well as their inclusion (where practical) in field days, leverages business incentives to advocate varieties and techniques best adapted to meet the needs of their markets. As well as contributing to a sustainable source of information, facilitating improved dialogue between value chain actors improves trust, lowers transaction costs and ensures fairer sharing of value added to farmers.

Experience in Cambodia confirms that once capacitated, key farmers continue to function as an innovative source of advice and inspiration to their neighbors. As well as remaining a valuable source of technical information, they also provide opportunities for the promotion of new varieties and on-farm research for the company.

Although farmer-to-farmer knowledge transfer takes time to establish, replication rates are high and continuity is assured. An independent survey of a public private partnership between East-West Seed, GIZ and the Provincial Department of agriculture in Siem Reap (Cambodia) concluded that more than 80 per cent of farmers participating in trainings and field days adopted some level of improved technology (Tep and Tem 2012). The most common changes in practice observed have been the use of improved seeds, effective fertilizer use and the use of mulching. The consequential changes in yield and quality led on average to a 147 per cent increase in net income from vegetables, from USD 108 to USD 267. Trust in innovations is reflected by increased investment costs of farmers, which on average doubled between 2009 and 2011. In addition, a significant number of other farmers benefit through better access to quality inputs and information. Once a critical mass of farmers has made the transition from traditional to improved farm practices, with clear increases in income, the momentum of uptake continues. Although still early, trends in Myanmar where East-West Seed have a similar partnership with Swisscontact indicate that results will be comparable.

Embedded services through collectors and agro-input dealers

Embedded advisory services and the market pull created by traders can be a more pragmatic and sustainable solution for farming communities than some of the approaches promoted by some NGO’s which are often more aligned to principles of the institution rather than the realities of the market.

Although rarely acknowledged by institutions, vegetable collectors have an inherent business incentive to develop more mutually beneficial arrangements with their suppliers. Driven by an interest to secure more stable supplies, collectors can be capacitated to promote technical and market information, which enables farmers to become more responsive to consumer demands. Their incentive to advocate varieties better adapted for markets, transportation and shelf life, as well as disseminating basic technical information can provide the incentive needed to encourage productivity and upgrade qualities in remote rural communities. As collectors show preference to higher quality commercial varieties, the quantity and regularity of supply increases accordingly.

A study of the vegetable value chain in Siem Reap confirms that by advocating varieties and basic technical messages, collectors played a major role in stimulating productivity and increasing incomes of smallholder farmers (Morris et al. 2012). The increasing regularity of supply resulted in a 26 per cent increase in the amount of collectors stepping into business. With increased competition for better quality vegetables, farmers benefited though increased transparency of market prices.

Agro-input dealers are regarded by many farmers as the second most important source of advice after their neighbors. However with sales being their main incentive, advice given is rarely objective. Nevertheless there are good opportunities to benefit smallholders through upgrading the knowledge of agro-input dealers. As with collectors, it is unlikely that they will have the capacity (or incentive) to offer the wide range of technical advice needed by farmers, but despite their imperfections, with better understanding of the products they sell and by introducing new technologies which offer business potential such as seedling trays, plastic mulch and trellis netting, farmers can be better enabled to select appropriate products and to use them correctly. With input retailers all too often supplying varieties unsuitable for local conditions or markets, perhaps the most valuable information relates to products. Understanding disease tolerance, seasonal variability and marketable qualities are crucial considerations that enable farmers to select appropriate products and to use them correctly.

Although collectors and agro-input dealers can provide a valuable service, their limited capacities and specific incentives need acknowledging. Capacitating agro-input dealers and collectors in simple but practical technologies and supporting them with material such as planting guides, reference manuals, and product flyers has proved effective in disseminating information to a wide target group of farmers in Cambodia (Morris et al. 2012). This was further strengthened through meetings between agro-input dealers and producers, jointly organized by East-West Seed and District Offices of Agriculture, to improve availability of new agricultural inputs, showcase the use of technologies and enhance communication between dealers and their clients.

Public Private Partnerships

Pluralistic systems of knowledge transfer have become increasingly recognized as a means of the improving both efficiency and outreach of extension. By recognizing the comparative advantages of the diverse range of stakeholders and acknowledging producers as clients rather than beneficiaries, pluralistic systems offer considerable advantages over the “one size fits all” approach that has long dominated public extension (Anderson 2007). Private sector inclusion in advisory services has several advantages including; improving financial sustainability, providing incentive for higher quality services through return on investment and assuring alignment of products to market requirements (Neuchatel Group 2006). With high risk aversion being a common barrier, there is no simple correlation between “knowledge-in” and adaptation of skills amongst resource poor farmers. Increasing farm income depends as much on improved trust and flow of information as on technical innovation. East-West Seed recognizes that the company’s advisory services alone are not enough to change the deep-set perceptions of the farming community. Accordingly development projects and government agencies are seen as key partners towards upgrading qualities and inspiring innovation on the farm level.

Making use of complementary skills and resources, public private partnerships leverage East-West Seed’s long-term business interests, to accelerate changes in farming practices that contribute to rural development goals. Rather than being categorized as corporate social responsibility, East-West Seed acknowledges that the profit of the company and that of the farmers are interlinked and develop hand-in-hand. The key to a successful partnership lies in acknowledging returns on investment as an integral part of the incentive needed to ensure long-term sustainability (OECD, 2012).

Public private partnerships are not a means of subsidizing business activities that would anyway be undertaken by the company. Rather, combined skills and resources are a way to lower risks and foster results that could not be effectively achieved by either partner independently.

Improving farm practices is a slow process that requires long-term commitment. Although demonstrations use East-West Seed varieties, returns on investing into extension, which primarily disseminates technical information on improved cultivation techniques is not without risks. Promoting commercial varieties is an important component towards developing a market driven approach to enable farmers to be more responsive to consumer demands. However, public goods information promoted through planting guides, demonstrations, field days or training events can be used by farmers with any variety (local variety, East-West Seed variety or variety from competitive companies).

Investments into extension create opportunities for other seed companies as well as companies selling non-competitive agro-inputs. Though clearly contributing to the development of a more vibrant and competitive vegetable sector, it does not lead to direct financial gain for the company as is illustrated within a public private partnership with GIZ and the Provincial Department of Agriculture in Siem Reap. Prior to activities, only self-saved and poor quality commercial seed were being used by farmers. Within three years, through success of peer led demonstrations, a demand was created for high quality seed, which are now widely available across the province and being used by an estimated 70% better quality seeds being the result of East-West Seed extension activities, opportunities were created for other seed companies to enter the market. Although there is no doubt that this has empowered farmers with more choice and led to a more competitive seed market, from a commercial perspective it is difficult to justify without the cost sharing of partners. In addition to developing markets for competitors, practices promoted on demonstration farms have also led agro-input dealers to stock other new products such as trellis netting, plastic mulch, seedling trays as well as better quality and less hazardous pesticides.

With long term commitment needed to enable a transformation to better farm practices and with the unusually high costs attached to disseminating essentially “public goods” information, East-West Seed clearly needs to collaborate with professional partners who can reduce the investment risks to a more acceptable level. Although there is a clear public benefit, with limited resources government agencies are often difficult to partner with, however development agencies can substitute or complement their role with cost sharing and professional expertise.

Through partnerships with GIZ and CAVAC, East-West Seed has positive experience of working together with public extension in three provinces in Cambodia. Rather than direct implementation, provincial departments facilitated extension services provided by East-West Seed. Both sides have clear benefits in such collaboration. With close attention to market signals, this approach overcomes some of the issues of sustainability and market integration inherent in public extension. East-West Seed gains through ease of access to groups of farmers for training events. Through on-going discussions with the Department of Agriculture is hoped that a similar pilot project could also be developed within the framework of a public private partnership with Swisscontact in Myanmar.

Defining roles

To improve the effectiveness of extension and avoid interference with market development there is a clear need to define the roles of the private sector, the public sector and civil society in Myanmar’s vegetable sector. With many smallholders in Myanmar living in marginalized areas with poor connections to the markets, there is an urgent need to identify the most appropriate and sustainable forms of extension. To enable extension services to prosper, it is important that the public sector and NGO’s do not compete with private sector initiatives (Rivera 2011). Rather than engaging directly with the implementation of extension, effectiveness can be improved, where possible, through facilitating market-based services from qualified service providers such as East-West Seed. In such cases the government maintains critical regulatory functions to assure that services provided remain in public interest. In areas where there is no commercial incentive, or where the risks cannot be sufficiently reduced to promote private sector engagement, there are clear needs for public extension to make services more accessible to vegetable farmers.

Private sector expertise and resources are needed to develop locally focused breeding programs that can assure smallholder's better alignment to the changing needs of Myanmar's domestic and export markets. With 30 years' experience, East-West Seed has accumulated a wealth of knowledge on plant breeding, seed production and systems of quality assurance. Transferring such knowledge into Myanmar could act as a benchmark for higher quality; however, with the core of the business being breeding material, current investment laws do not provide the necessary security or incentives for large-scale investments into research and development.

With trust, transparency and clear communication being the cornerstones of a successful partnership, NGOs, can provide a valuable function brokering and aligning the objectives of the public and private partners. As well as substituting or complementing the role of the public sector with cost sharing and facilitation, development agencies have outstanding expertise in developing levels of social capital in farming communities. By improving levels of trust and making farmers more receptive to technical messages from public or private service providers, extension services can be made significantly more effective. Enhanced cooperation and dialogue between value chain actors is seen as a major factor that could enable smallholder farmers to act upon specific market signals needed to strengthen the competitiveness of their products and assure their integration into the supply chain.

Linking Education and Industry

For a country where agriculture provides livelihoods for 70% of the population and contributes to 40% of the country's GDP (ADB 2012), the lack of skilled personnel in the sector is regarded as a major challenge. If insufficient numbers of trained people are available in Myanmar, scaling-up knowledge transfer initiatives such as those being initiated by East-West Seed will be stopped dead in their tracks.

With markets rather than technologies being the primary driver for agricultural development, there is an urgent need for agricultural education to embrace closer links to industry. As well as being pools of future knowledge, universities also provide a potential venue for practical research and outreach programs. Since late 2012, East-West Seed has worked closely with Yezin Agricultural University to enable students to gain practical hands-on experience of improved production technology. In the long term it is hoped that by supporting technology trials and demonstrations as well as developing practical internship/scholarship programs, more skilled graduates will seek opportunities in the vegetable sector.

CONCLUSION

With recent political and economic changes, Myanmar's vegetable markets are likely to undergo significant changes. In order to remain competitive in the face of these changes, serious consideration should be given to upgrading qualities of smallholder farmers; targeting both existing domestic markets and potential export markets. Promoting commercial varieties alongside the use of better farm practices is an important component towards developing a market driven approach and through enabling farmers to be more responsive to consumer demands will define the future position of smallholder farmers on Myanmar's transforming markets. Showcasing profitable and sustainable innovations which offer the potential of higher incomes at an acceptable level of risk as well as leveraging the commercial incentive of collectors and input dealers can provide the inspiration needed for the widespread adoption of improved practices.

Private sector engagement in extension will be central in accelerating smallholder's access to knowledge and technology in Myanmar. Commercial incentives can improve financial sustainability and accountability as well as assuring closer alignment to market demands. However, with returns on investment being an essential incentive for commercial companies, greater public-private collaboration is needed to reduce the high risks of disseminating "public goods" information. With closer attention to market signals, pluralistic systems of knowledge transfer could help overcome issues of sustainability and market integration inherent in many public extension systems.

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Protected cropping of vegetables

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ABSTRACT
Currently 70% of the world's fresh water is used in agriculture, and not very efficiently. As the population increases (from the current 7 billion to a predicted 11 billion by 2050, and a possible 25 billion by 2150) greater demands will be placed on this limited resource by both industry and for domestic use, particularly with the trend towards larger and larger cities. It is essential that agriculture uses this resource efficiently, and in vegetable production, this will mean using protected cultivation and hydroponics. Fertilizer is another resource used inefficiently, and in the case of potassium and phosphorous are both non-renewable resources. Protected cultivation has a large number of advantages over field production, the major one being that the crop is insulated from extreme conditions, which maybe biotic, or may be climatic. For example in Morocco plastic greenhouses are covered in a very fine mesh which excludes most (if not all) insect pests. In other situations, protected cultivation may involve simple rain covers, which can reduce the incidence of disease. The result in both cases is an increase in productivity, with automatically an increase in yield per litre of irrigation water. Protected cropping also has the potential to direct the rain falling on the "greenhouse" into a reservoir for later use in irrigation. Urban and peri-urban agriculture has potential problems due to unsuitable soils within the urban area, or due to soil pollution from pesticides or heavy metals. Combining protected cultivation with hydroponics provides the opportunity to further increase productivity, with the added advantage of having a product which is much cleaner (lower microorganism count) than as oil grown product. By using a recirculating hydroponic system both water efficiency and fertilizer use efficiency is greatly enhanced, with minimal damage to the environment. The ultimate in protected cropping is the "plant factory", and this will be the subject of another presentation.

Keywords
Greenhouses, hydroponics, water efficiency, product quality

INTRODUCTION
The human population is projected to increase from the current 7 billion to 11 billion by 2050, and as high as 25 billion by 2150. This will put tremendous demands on limited resources, particularly as the increasing population will result in bigger and bigger cities, and the need for agriculture in general (and vegetable production in this specific context) to make efficient use of these resources.

These resources will include land, fresh water, and fertilizer. All of these are finite, and although water may be regarded as a renewable resource, the population increase will change the dynamics. Currently on a world scale most of the world's fresh water is used in agriculture, while industry and people use less than 20%. Clearly this will need to change with an increased population.

Superimposed on this is the fact that fresh water is not evenly distributed worldwide, and the fact that as populations increase, and cities become larger, then so the distance for vegetables to travel from the production areas to the cities will become longer. Vegetable production is "site specific" and crops cannot be grown anywhere, as they require appropriate soils and climate for efficient production.

Thus although water is a renewable resource it is likely to become a scarce resource in the future. Fertilizer is also a renewable resource, but the cycle for potassium and phosphorous is many millions of years, and we need to “conserve” both of these essential elements. Vegetable producers are major users of fertilizer (on a per hectare basis), and much of this ends up lost in to river systems and eventually into the oceans.

Protected cropping involves insulating the crop from the influence of the environment to ensure that higher productivity and/or a higher quality product can be grown efficiently, and (of course) economically, within the resource available in that particular geographic site.

Hudson (1961) in UK introduced the concept of the relationship between average crop yields, best farmer yields and record yields, in which he demonstrated how the best 10% of producers grew heavier crops because of adequate capital, correct choice of site, and knowledge. He also showed that the record crop (almost certainly by one of the better producers) was achieved only because of exceptional weather conditions. The importance of environment was clear because the record crop of greenhouse tomatoes (in a semi-controlled environment) was not excessively greater than the crops produced by the best growers, whereas the record crop for an outdoor crop of potatoes was considerably higher than that achieve by the better growers (Fig. 1). These are mid-1950 figures, and although there is no current information but it might be assumed that currently the greenhouse yields will show a 4X increase, and the outdoor crops only a 2x increase (Table 1). In fact, the paper by Ho (2004) (Fig. 2) demonstrates how productivity has increased in glasshouse tomato production in UK in recent years, and how this increase has been significantly greater where the environment has been more controlled compared with a soil based unheated greenhouse.

The question thus is not do we establish high-tech greenhouses everywhere, but what degree of environmental control is desirable to make efficient use of our resources at any particular site. This will involve not only a consideration of economics, but also the social aspects of any changes.

The plant environment

The environment in which we grow our crops varies from year to year/month to month/day to day/ hour-to-hour/minute-to-minute and second-to-second. The above-the-ground environment changes much more rapidly than the below-the-ground environment, but nevertheless both exert a major effect on vegetable crop productivity.

Hudson (1961) listed the major environmental factors, but also emphasized the importance of the genotype/environment interaction, and the fact that productivity is also a function of genotype, environment and management, and that management can play a major role in productivity.

Knowledge and capital play an important role in determining this productivity. It has been shown that for two crops (potatoes and greenhouse tomatoes) (Fig. 1) that control of environment plays a major role. (Hudson 1961; Ho 2004)

So productivity will depend on the knowledge of the individual farmers, the availability of capital, and the willingness to invest.

The level of investment will depend on the individuals.

Radiation

There are three factors that involve radiation, namely quantity, quality and duration. In nature there is little we can do to modify these factors, but the potential exists to increase the quantity of light by using supplementary lighting (usually either HPS lamps or LED lights) for high value greenhouse crops during the winter months. Day length can be more easily modified economically by extending the day length by means of tungsten bulbs, or by shortening the day length by means of blackout curtains.

Temperature

Temperature plays a major role in crop development. Within a greenhouse situation heating systems can be used to raise the ambient temperature, while cooling can be done by using ventilators. However, it is extremely difficult to reduce the greenhouse temperature below the outside ambient air temperature, even by means of evaporative cooling.

Humidity

Humidity plays a major role in disease control and in ensuring good pollination. Humidity can be reduced by heating the greenhouse, and slightly opening the ventilators. Humidity can be raised by misting with fine droplets of water.

Wind

At low speeds, wind can be considered as an advantage in crop production, as it moves carbon dioxide through the canopy, but as the wind speed increases it can cause increased water loss, and eventually a reduction in crop yield due to damage. Netting is (of course) the ideal method to limit wind damage, but natural windbreaks are generally preferred, as they are much cheaper

Composition of the atmosphere

Clearly from a plant growth view point the CO_2 level is the most important, but consideration should be noted to the potential importance of air pollutants such as ethylene, ozone, and oxides of nitrogen and of sulphur di-oxide. The relationship (between temperature, radiation and CO_2 level (as demonstrated by Gaastra (1959) some 50 years ago) is a key one (Fig. 2).

Precipitation

This is important mainly as a means to provide the roots with moisture, but it should also be noted that hail can be extremely damaging to crops, and that snow may provide a valuable insulation layer to dormant plants in extreme climates.

Asparagus is regarded as a high value, high labour input crop, but in the humid tropics it suffers major yield losses due to fern diseases such as *Phomopsis*. The disease is very prevalent during the “rainy season”, when any pesticide is rapidly washed off the plant, but during the “dry season” only the occasional spray (if any) is needed. Growing the plants under plastic rain shelters (in this case tunnel houses) has have a major effect on the disease and therefore crop productivity.

In New Zealand a disease of kiwi fruit is causing concern. PSA (caused by a bacterium *Pseudomonas syringae* pv. *actinidiae*) is spread by rain droplets, and it appears that even with a relatively low value (per hectare) crop such as kiwi fruit the economics of using rain covers appears promising.

Macro and microorganisms

Pests and diseases, and their predators are a major factor to consider in relation the plant environment, particularly in relation to the need to comply with GAP. The use of physical barriers (e.g. fine mesh over greenhouses to prevent whitefly entry) or similar netting over outdoor crops is an important consideration.

Nets are another method of reducing pathogen damage (in this case from insects). In the Cameron Highlands (Malaysia) nets have been used to reduce the damage to brassicas from diamondback moth, but of even more potential is the use of coloured netting (developed in Israel) with a mesh size far in excess of the insects size, which repels insects due to the transmitted colour of the netting Shahak (2008).

Below the ground environment

Temperature
On the soil surface the temperature fluctuates wildly, but the deeper one goes, the smaller the amplitude. In cold climates the soil temperature can be increased by low voltage electric cables. In hydroponic systems the solution may be heated to the optimum root temperature, but it is normal to be more concerned about the air temperature.

Nutrients
All crops require the right quantity and balance of nutrients if they are to produce heavy crops. The only way to ensure this is to use hydroponic systems (see soilless culture section).

Composition of the atmosphere
The deeper one goes into the soil the lower the oxygen content, and the higher the CO_2 levels. Other gases, e.g. ethylene may also have a detrimental influence on root action. The effect of soil depth on soil atmosphere composition will depend not only on the depth, but also on the soil type. Hydroponic systems tend to enhance aeration.

Moisture status
Adequate soil moisture in close proximity to the roots is an essential requirement for mineral uptake and optimum plant growth. Once again, hydroponics offers this potential.

Soil type and structure
Soil is not an ideal medium in which to grow crops. It can be either too wet (with consequent poor aeration) for a clay soil or too dry, (with poor water availability) for a sandy soil. This was identified many years ago, but commercial practices to overcome this did not become common until 40 years ago, with the acceptance of soilless culture in high value greenhouse crops. The potential rewards from this have been demonstrated by Professor Lim Ho (Fig. 2).

Macro and microorganisms
The soil can be a major source of disease and pests. Traditionally rotation was the only way to ensure that soil borne pathogens had only a minor effect on crop productivity, but isolation (using polythene film) and soilless culture systems offer ways of reducing such problems. Grafting onto disease/pest resistant rootstocks is another alternative for high value vegetables such as tomatoes or watermelons.

Controlled environment agriculture
The level of environmental control that is used in any specific situation will depend primarily on economics and knowledge. For example the traditional “Chinese” solar heated greenhouse with its solid wall to the north can never be as productive as a modern greenhouse (as used in the Netherlands), but has numerous advantages in

terms of price, and local experience. Over the past 100 years there have been huge improvements in the control of the plant environment, and the consequent increase in productivity will become a major factor in the future development of urban and per-urban vegetable production.

This may not necessarily mean the use of greenhouses, but many of the systems developed for intensive greenhouse production may be used in the outdoor situation where control of temperature etc. may not be critical.

Soilless culture

There is already serious consideration being given in the Netherlands to the production of vegetables outside using recirculating hydroponic systems in order to reduce water use, to improve fertilizer efficiency and reduce the pollution of waterways (deHaanetal, forthcoming). When combined with greenhouse production using moving gulley production systems the efficiency of land use is increased many fold. For example let us assume that lettuce takes 3 weeks to reach maturity from being transplanted. It is planted 20 cm apart in moveable gulleys, which in week 1 are spaced 10 cm apart. In week 2 they are moved to 20 cm apart, and in week 3 to 30 cm apart. Thus the yield from the cropping area is essentially doubled (Nichols 2011a).

Leeks are another similar example (Nichols 2011b). Field grown crops average about 35 t/ha, while hydroponic crops can be in excess of 100 t/ha, and with mobile gulleys could reach 200 t/ha. In a greenhouse 5 crops/year would not be impossible, and harvesting costs and washing would be low. Japanese bunching onions would have a similar cropping profile.

Where electricity is not available to run pumps etc., there are systems that do not require the nutrient solution to be moving (see Kratky 2004).

CONCLUSION

Protected cropping offers the opportunity to produce crops intensively, close to the centres of consumption in an environmentally friendly system, and by using soilless culture systems the uncertain status of the soil in an urban environment can be disregarded.

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Table 1. The effect of “environment” on crop productivity (t/ha) in 2010
In brackets 1950 yields (after Hudson 1961)

	National Average	Best Farmers	Record
Potato	40 (20)	50 (30)	100 (67)
G/HTomato	400 (100)	800 (200)	1000 (250)

Table 2. The plant environment

Above the ground	Below the ground
Radiation	
Temperature	Temperature
Wind	Soil type /structure
Humidity	Nutrients
Composition of Atmosphere	Composition of Atmosphere
Precipitation	Moisture status
Macro/Micro-organisms	Macro/Micro-organisms

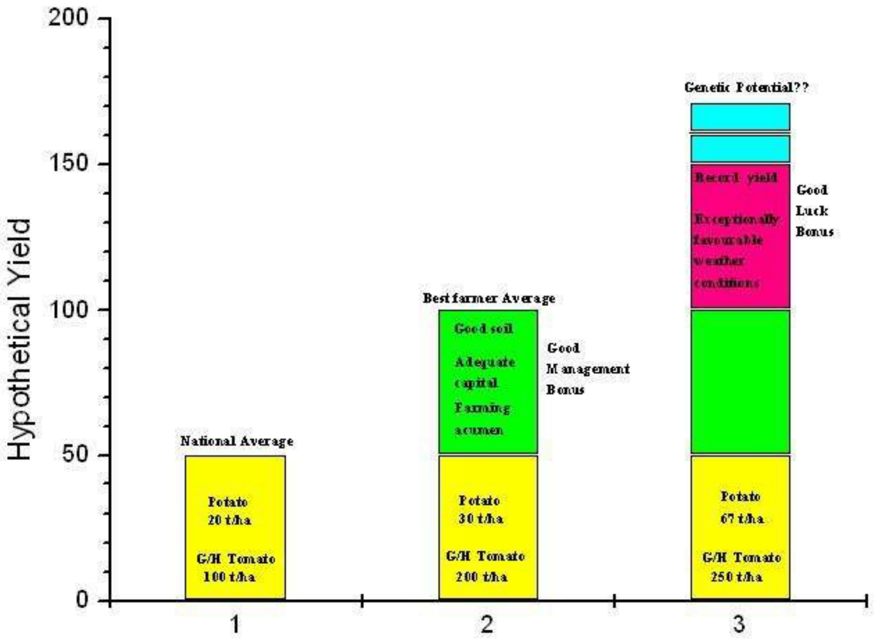

Figure 1. Average yield, yield from best growers, and record yield for potatoes and greenhouse tomatoes in UK (after Hudson 1961).

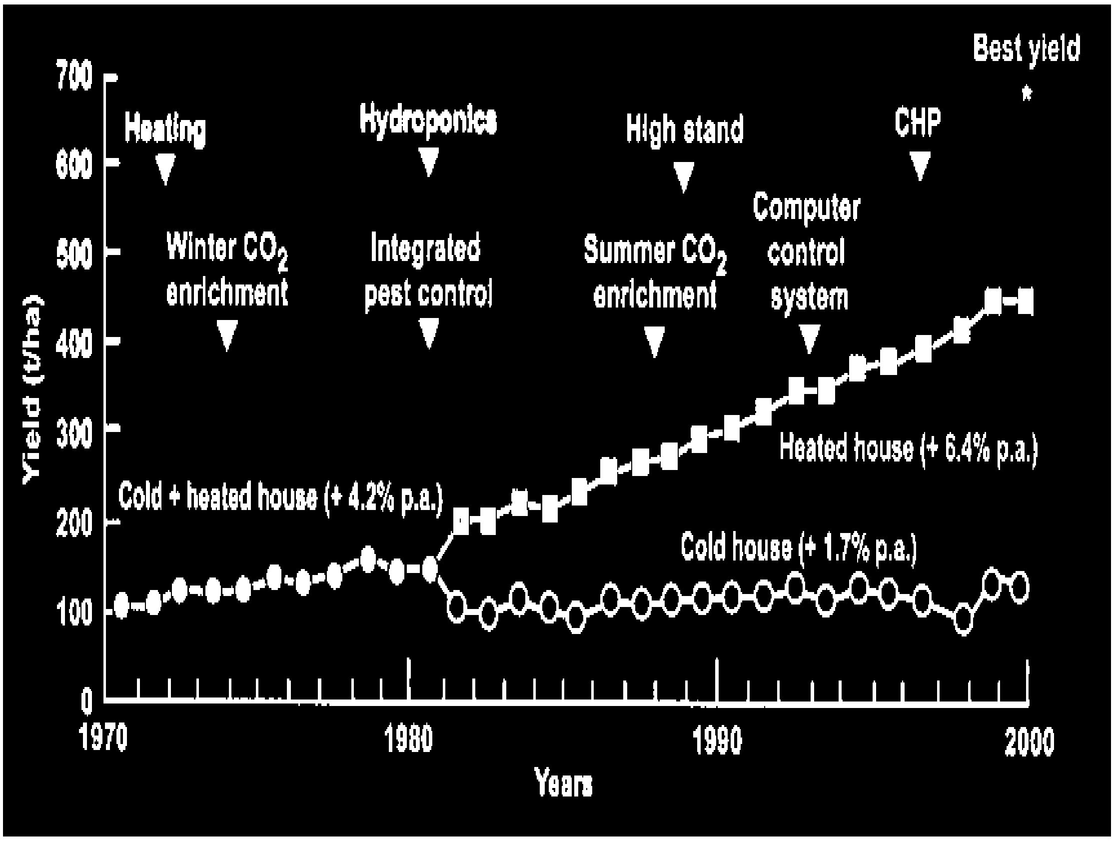

Figure 2. Yield of greenhouse tomatoes in soil and hydroponics in UK (Ho 2004)

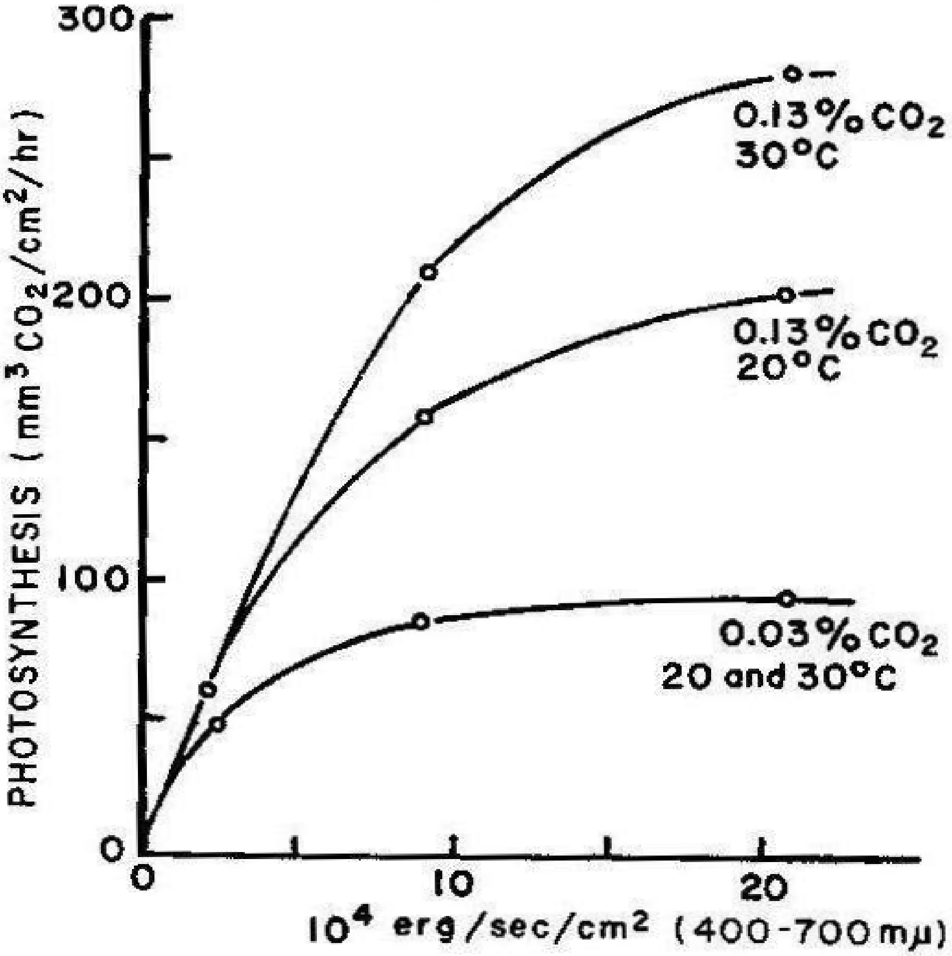

Figure 3. Effect of light intensity, temperature and CO_2 level on photosynthesis (after Gaastra 1959)

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ABSTRACT

The Research and Development Project on Selected Vegetables and Mushrooms was carried out during 2008-2011 at the Agricultural Research and Development Center (Chiang Mai, Pichit, Karnchanburi, Sisakat, Nan, Sukothai) under the Horticulture Research Institute, Thailand Department of Agriculture (DOA). The project is a continuation of previous DOA research and development projects, which are an ongoing, long-term effort. The studies focused on chili, okra, asparagus, ginger, potato, mushroom, Parkia and sweet potato. The general objective was to enhance the vegetable industry to contribute to food security as well as to promote Good Agricultural Practices (GAP). Specifically, the project aimed to: 1) generate new vegetable varieties; 2) improve crop cultural practices; 3) promote seed production technologies; and 4) improve postharvest and processing. Procedures to analyze experimental data used statistical procedures for agricultural research.

The project realized significant successes in developing new technology for selected vegetables that can be utilized in major production areas of the country. In terms of breeding programmes. e.g. for chili, the project released three new varieties that are highly productive with outstanding qualities, and built up populations for pure lines to be used in future breeding programmes. Similarly, a new variety of sweet potato containing high starch for industry suitable for ethanol production to combating the energy crisis was developed. The project also generated new varieties of mushroom suitable in different agro-ecological zones; okra resistant to *Okra yellow vein virus* (OYVV); and off-season Parkia (*Parkia speciosa*). Cultural practices on selected vegetable crops have been developed including tissue culture techniques for shoot and root formation in seedling production of asparagus. In potato, technology for production of certified seed (G_3) and improved cultural practices were made. Methods for ginger seedling production were developed. These practices minimize chemical use and help promote GAP. Technologies for on-farm trials for chili, potato and mushroom were evaluated, leading to increased income for vegetable farmers. A cultural practice for chili that can be applied in areas with serious root gall nematode outbreaks was adopted by farmers in Ubon Ratchathani province.

INTRODUCTION

Thailand’s gross domestic product (GDP) is approximately 6 trillion baht. The agricultural sector contributes 13% of the total GDP, with cropped areas of about 68%.

The agricultural sector employs about 56% of the country's population. From a total land area of 51.3 million ha, farm land is 21 million ha, consisting of 5.67 million farms, with an average farm size of 3.7 ha. In 2013, the export value of agricultural products was 1,128,060.6 million baht, which ranks sixth in the world, while import values were 456,708.4 million baht. Vegetable production is an important contributor to Thailand's exports and income. During 2012-2013, horticultural exports were valued between 101,422-113,584 baht per year. The export value and volume increased around 14% per year, but only 10.29-15.41% of products were exported.

Vegetables are high-value crops useful for improving incomes of small farmers. The value of exported vegetable and the products of Thailand was 300,914.10 metric tons with a value of 9,874.45 million baht. In terms of domestic consumption, the value is difficult to estimate, since many vegetables are both exported and imported. Due to daily consumption, and typically included in every meal of the household, vegetables play an important role in the economy and have a direct effect on health. Thai vegetable production is variable. Most of the acreage is devoted to chili production followed by baby corn (Table 1). Future trends in vegetable consumption will focus on nutrition and health; people are increasingly concerned about their health, and organic vegetable production is becoming popular.

Farm sizes in Thailand are relatively small. On average, a farmer in Thailand cultivates about 3.5 hectares of land per household (Saenjan 2009). Vegetable farms required more intensive work, and are smaller in size comparable to fruit orchards. The export value of Thailand's fruit and vegetable crop was 70,347 million baht. The important exporting fruits and vegetables are longan, durian, asparagus and baby corn with the export values of 2,193, 2,227, 1,796 and 1,675 million baht, respectively. The export value of fruits is usually higher than that of vegetables, more than 15-fold. However, discussions with exporters revealed that vegetable values will likely double or triple over time. Therefore, Good Agricultural Practices (GAP) are needed for practical application to support government policy.

As mentioned above, Thai vegetable products over the next decade should focus on quality and consumer health to increase the quantity of fresh, frozen, processed, minimally processed and ready-to-consume vegetables. The potential vegetable types in Thailand are baby corn, tomato, garlic, shallot, potato, okra, asparagus, leafy vegetable, eggplant and ginger. The maximum residue limits (MRLs) in vegetables and herbs for certification should also be taken into consideration to satisfy quality standards for ASEAN, UNECE and Codex (Sarikaputi 2004).

Indigenous vegetables are grown by about 70% of Thai farmers, who typically grow the vegetables in their backyards. Over the past three decades, farmers have been selecting and collecting indigenous vegetables that perform well. There is still a large and very valuable genetic pool of plant species available in rural areas; fortunately, many of them originated from seed. New varieties were developed, and now a wide range of species and varieties exist.

Vegetable production in the country can be divided as follows:

Leafy vegetables: edible amaranth, Oriental celery, garland chrysanthemum (Shingiku), Japanese greens, herbs, Chinese kale (kai lam), komatsuna, lettuce, Malabar spinach, Oriental mustard, bunching onion, yuchoy (edible rape), Oriental spinach, hon-tsai-tai, Chinese cabbage (white petiole small cabbage, green petiole small cabbage), white Large Pak Choy, heading Napa Cabbage, semi-heading Chinese cabbage.

Herbs: Chinese leek (Chinese chives), Thai basil, coriander (Chinese parsley), mint, perilla (Japanese Shi-So), watercress.

Fruit/gourd vegetables: Oriental cucumber, Oriental eggplant, bitter gourd (bitter melon), winter melon (wax gourd), calabash (OPO), maoqwa (hairy gourd), snake gourd, edible luffa, Oriental melon, pickling melon, Oriental sweet pepper, hot pepper, Oriental squash, tomato, watermelon.

Root vegetables: Edible burdock (gobo), carrot, Oriental radish (daikon), turnip.

Flower vegetables: Broccoli, cauliflower, flowering Chinese cabbage, Chinese leek flower, white choy sum, green choy sum.

Others: Baby corn, kohlrabi, okra, sesame.

Chili: Production in Thailand is expected to go up by 10-15% owing to the increase in acreage. Farmers prefer to use high yielding F1 hybrids of chili varieties. Chili is the largest spice exported and imported by Thailand by volume and occupies the second position in terms of value. Consumption of chili is increasing substantially with branded powder sales growing at a compound annual growth rate of 11%. The growing trend of hot cuisine will lead to an increase in chili demand. Chili production in European countries is declining. In China, chili output has been fluctuating because of erratic weather.

Potato was introduced during the late 19th century to the tribes of Northern Thailand either from Myanmar (at that time a British colony) or from Yunnan Province, China. There is a story that potato was introduced in Thailand by a Chinese hill tribe known as the Jeanhore. The term “alu” (sometimes spelled “alou”) is a local generic term applied to local varieties that have been grown by the hill tribes for many years; they are valued for their disease and drought resistance, but have small tubers, a bitter taste and dark color when fried. The term is also the same as the Hindi term for potato. In Thai, potato is “manfarang” (foreign tuber). Eighty percent of yearly demand of potato in Thailand is for processing. In 2015, the demand will double, increasing up to 2,000,000 metric tons for industrialization.

Asparagus was introduced to farmers in 1973 under the Royal Initiative Project implemented in HupKraphong Cooperatives, Petchaburi Province in the central region. Production of asparagus rapidly increased for export as fresh and canned vegetables. Japan and Taiwan are the main asparagus-importing countries. The asparagus supply chain, especially logistics, plays a significant role. At 12 times the cost of production, asparagus results in great impact on farmers in terms of production area and sources of planting material.

Okra: This vegetable has potential to improve nutrition, boost food security, foster rural development, and support sustainable landcare initiatives. The products of the plant are mucilaginous, resulting in the characteristic slime when the seed pods are cooked; the mucilage contains a usable form of soluble fiber. While many people enjoy okra cooked this way, others prefer less sliminess; keeping the pods intact and cooking quickly help to achieve this. To avoid sliminess, okra pods are often briefly stir-fried, or cooked with acidic ingredients such as citrus, tomatoes, or vinegar. Alternatively the pods can be sliced thinly and cooked for a long time, so that the mucilage dissolves, as in gumbo. The cooked leaves can also be used as a soup thickener.

In 2004, the Thai government declared the country as the “Kitchen of the World.” To further enhance the image of Thailand’s food supply, the government also launched a food safety programme (Anonymous, 2004) based on four strategies: 1) controlling quality of agricultural inputs and raw materials; 2) standardization of farming through by GAP certification; 3) standardization of GMP & HACCP certified factories, packing houses, SO_2, fumigated plants, and methyl bromide fumigated plants; and 4) controlling quality of produces and products for export.

The general objective of the project is to enhance the vegetable industry for food security as well as to promote GAP. The project aims to: 1) generate new vegetable varieties; 2) improve crop cultural practices; 3) promote crop care/ protection; 4) promote seed production technologies; and 5) improve postharvest and processing. The project consisted of 136 experiments.

Table 1. Vegetable acreage of different types, showing plantation area, damage area, harvest and yield.

Vegetables	Plantation Area[2/] (rai[3/])	Damage (rai)	Harvest (rai)	Yield (Metric Ton)	Yield/rai (kg/rai)
Chili	493,324.50	8,699.00	220,734.00	353,992.46	1,603.70
Sweet Corn	263,900.00	6,515.00	180,362.00	299,082.53	1,658.23
Baby Corn	181,302.00	609	167,217.00	222,994.42	1,333.56
Watermelon	146,113.50	9,915.00	71,525.00	169,401.91	2,368.43
Shallot	130,833.00	1,573.00	92,650.00	253,576.30	2,736.93
Mushroom	107,027.00	0	104,884.00	567.57	5.41
Cabbage	83,996.00	51	71,681.00	936,474.07	13,064.47
Garlic	72,965.50	455	40,887.00	63,847.99	1,561.57
Yard-long Bean	71,915.50	2,747.00	67,239.50	82,310.65	1,224.14
Eggplant	68,202.00	805	37,756.00	44,234.15	1,171.58
Others	741,172.25	24,202.00	524,456.75	968,652.04	-

Source of data: Office of Agricultural Economics (2012/13)

VEGETABLE AND MUSHROOM IMPROVEMENT

DOA's breeding programme was continuously carried out from a previous project using selected parental materials from the germplasm collection. The project released new chili varieties suitable for different agroecological zones, and developed populations for pure line selection to be used in further breeding programmes. Similarly, a new variety of sweet potato containing high starch for industry as well as for ethanol production was developed. The projects generated a new variety of mushroom suitable for different agro-ecological zones, okra that is resistant to *Okra yellow vein virus* (OYVV), and off-season Parkia.

Chili: Improvement for higher productivity and quality

The YodSon (Sisakat (2-1-59 variety has yield potential of 1,800 kg/rai (fresh) and the first harvest begins at 75-80 days after sowing. This variety is well adapted to medium elevations. Further development of YodSon (Sisakat 59-1-2) is expected to increase chili production. This high yielding, higher capsaicinoids (100,000 Scoville Heat Units) variety can be perceived as an alternative for farmers who seek an early

[2/] Vegetables and products	2,360,751.25	55,571.00	1,579,392.25	3,395,134.09	2,149.65

Survey was made in the year before planting year

[3/] 1 hectare is 6.25 rai

maturing chili with high productivity. Seed of this variety is expected to be developed by seed growers or the seed industry.

The Jinda F1-Hybrid chili (super hot) yields up to 2,000 kg/rai for a one-time harvest. The first harvest begins at 80 days after sowing. This improved variety is well adapted at medium elevations. Along with early maturity and high productivity, this variety is also suited for hydroponic culture. Further development of this variety requires high quality seed in sufficient quantities (Fig. 1).

The Pichit No.1 chili yields up to 378 kg/rai (dried) and can be harvested at 78 days after sowing; last harvest is at 150 days. This improved variety has the proportion at 4.5:1 of fresh to dry, and it is adapted well to medium elevations. Pichit No. 1 is expected to be widely adopted by farmers to increase the national production of red chilis for making chili powder. Further development of this variety requires support from seed growers or the seed company/industries (Racharourn and Amaramorn 2011).

The breeding projects were undertaken in normal field conditions. Insect and disease resistance were taken in to account in the selection process, especially for bacterial wilt and root gall nematode, Growers producing these three new chili varieties should follow a general pest control programme.

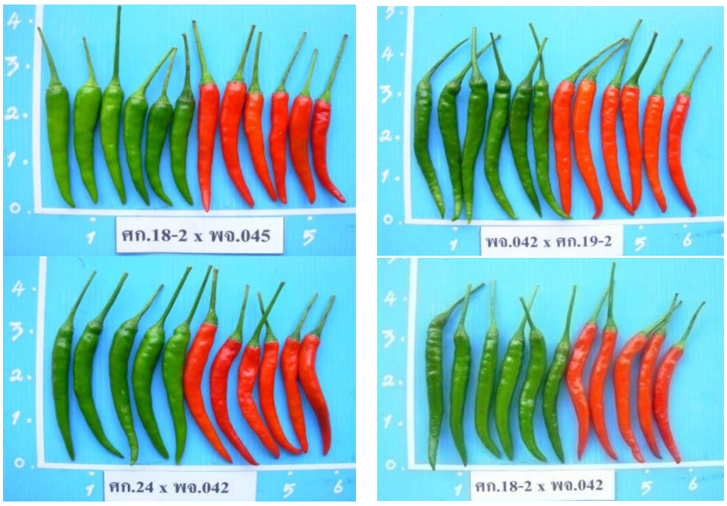


Figure 1. Jinda F1-Hybrid showing fruit characteristics (top left).

Potato: Selection for disease resistance

To screen for late blight resistance, 14 selected clones of variety Atlantic were evaluated on reaction to late blight compared to normal Atlantic. Results showed that the disease incidence of selected clones had significantly lower severity comparable to normal Atlantic and almost all selected clones gave higher yield than that of normal Atlantic. A study of the genetic relationship of the selected clones was conducted using inter simple sequence repeat (ISSR) markers (Touchdom PCR). A phylogenetic tree was constructed based on 209 polymorphic loci amplified from 24 random primers. According to cluster analysis, the accessions could be classified into two major groups, with a mean Jaccard index of genetic similarity (0.74) 74% to (1.0) 100%.

Sweet potato: Improvement for fresh consumption and industrial use

Forty sweet potatoes were selected for fresh consumption and suitability for starch production. All were placed in multilocation varietal yield trials from 2009-2010. The result showed four prominent varieties for fresh consumption and two for starch production.

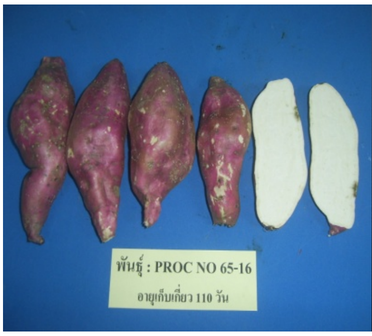
Three hundred fifty lines were studied for plant characteristics and clonal selection. Trials were carried out at different bio-physical locations from uplands to lowlands, and in areas with socioeconomic differences. Sweet potato grew well and gave higher fresh yield of 2,361 kg/rai in Pichit province, located in the upper central plain of Thailand. In terms of fresh yield for consumption, Pichit 265-1 (yellow color), Pichit 292-15 (purple color), T101 (orange), and PROC. No. 65-16 (white) expressed significantly prominent desirable traits (Table 2). Two lines, Taiwan #1 and PROC No. 65-16, expressed desirable traits for the starch industry or ethanol production (Table 3 and Fig. 3). On-farm trials will be conducted before releasing to farmers. Other lines collected will be used as parental materials for further breeding programmes.

Table 2. Fresh yield of sweet potato for fresh consumption (kg/rai) from varietal trial at different locations during 2009-2010.

Lines	Pichit	Pechaboon	Sisakat	Ayuthaya	Nakhon Si-thamarat	Mean
Pichit 189-257	943	533	717	701	298	638.40
Pichit 290-9	1,423	1,800	736	1,630	458	1209.40
Pichit 292-15	2,920	2,214	996	2,470	1,112	1942.40
Pichit 226-31	2,063	1,280	514	1,630	497	1196.80
Pichit 265-1	2,810	2,107	914	1,367	222	1484.00
FM37-LINNIDOK-3	3,640	2,294	911	2,360	1,258	2092.60
PROC.No.65-16	2,311	2,187	978	2,701	1,293	1894.00
Pichit 166-5	2,391	1,800	707	967	629	1298.80
Pichit 166-6	3,010	2,600	1,020	2,736	490	1971.20
Pichit 283-31	3,330	2,067	581	1,610	3,159	2149.40
T 101	3,596	3,400	839	2,167	1,458	2292.00
Pichit 227-6	2,747	3,600	1,293	1,773	1,376	2157.80
Okut	400	880	601	840	359	616.00
Mae jo	1,467	467	615	775	249	714.60
Mean	**2360.79**	**1944.93**	**815.86**	**1694.79**	**918.43**	

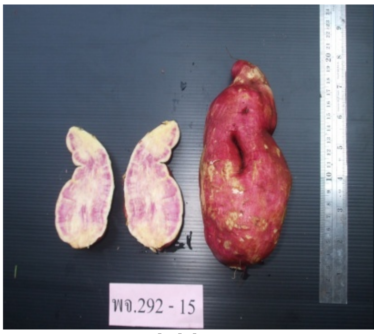
Table 3. Fresh yield sweet potato (kg/rai) for starch industry or ethanol from varietal trials at different locations during 2009-2010.

Lines	Sweet potato yield (kg/rai)				
	Pichit	Kanchanaburi	Sisakat	Khonkhen	Mean
Pichit 5-166	2283.0,	2,474.3	1,782.0	1,245.0	1,946.0
PROC.No.65-16	2,440.8	3,587.7	2,519.3	1,865.0	2,603.0
Pichit 6-129	2,538.6	3,876.1	2,360.3	1,664.0	2,610.0
PROC.OPS-101-R89-3	1,459.1	2,155.7	1,499.3	978	1,523.0
China No1	2,900.5	3,554.3	2,172.5	2,126.0	2,688.0
Taiwan No1	3,575.9	5,081.1	3,004.3	2,738.0	3,600.0
Mae Jo	934.8	1,432.1	712.0	537.0	904.0
Mean	2,305.0	3,166.0	2,007.0	1,593.0	

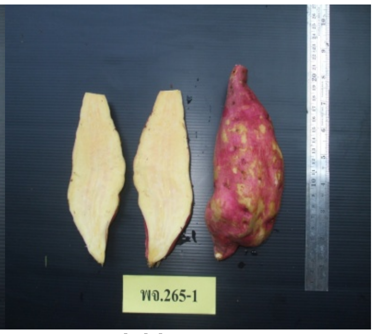


PROC.No.65-16

T101

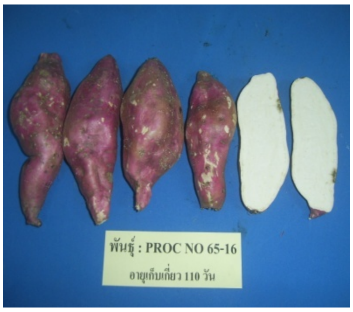


Pichit 15-292



Pichit1-265

Figure 2. Sweet potato selected for fresh consumption showing different colors



PROC NO 65-16: Harvest at 110 days after planting

Taiwan #1: Harvest at 110 days after planting

F1 hybrid Sukothai 3 x Pichit 226-24 (orange and purple fresh color)

F1 hybrid Sukothai 3 x FM 37 LINIDOK-3

Figure 3. Sweet potato selected for starch industry (ethanol).

Parkia: Off-season production variety selection

Parkia for off-season production has been selected from germplasm collection field at Trang province in southern Thailand. Trang #093, Trang #099 and Trang #075 expressed superior characteristics. However, further data collection is needed (Fig. 4).

Figure 4. *(left)* **Parkia silique showing good characteristics.**
(right) **Off-season Parkia tree at Trang Horticulture Research Center, Trang province.**

Okra: Advances in breeding of YVMD-resistant okra in Thailand

After yellow vein mosaic virus disease (YVMD) became a serious problem in Thailand, groups of government and private sector representatives were established to resolve the problem. Three government sectors including Department of Agriculture (DOA), Department of Agriculture and Extension (DOAE), and Mae-jo University, in collaboration with some seed companies and okra exporters, have searched for suitable cultivars with YVMD resistance and other desired attributes to substitute the Japanese cultivars for export. Exotic cultivars were introduced from India, Taiwan, and some other countries to test for disease resistance and agricultural performance. Most appropriate cultivars were introduced from India, and Thailand must now import the resistant cultivars from India. However, pods of Indian okra cultivars were too long, thin and light green in color, which are not desirable. Another major disadvantage is that the plants usually are too high and can be easily damaged by wind. In addition, YVMD resistance does not last long because the virus pathogen continually develops new biotypes. Okra improvement is an ongoing activity at many agencies. DOA has been concerned about YVMD since .1997A research project launched by the Plant Pathology Research Group, Plant Protection Research and Development Office and Phichit Horticultural Research Center, Horticulture Research Institute, has been set up. The research goal at the beginning was to obtain an open pollinated resistant cultivar. The pedigree selection method was applied with specific Indian cultivars, both in the screenhouse and in the field, and three promising lines were achieved as the project outcome. A few years later in 2007-2006, those lines were tested in farmers' fields in Kanchanaburi province. They provided good yield and resisted YVMD in the first year, but the resistance declined during the second year. Resistance instability also occurred with commercial cultivars grown as control (Adthalungrong and Buara 2008). Research work emphasized improvement of disease resistance and agronomic characteristics by hybridization. Studies on virus isolates and their interaction with the cultivars has been carried out. Currently, research on a comparison of eight promising lines that resist the Kanchanaburi virus isolate are on-going and selected lines will be released to farmers soon. However, the improvement of YVMD resistance and agronomic characteristics must be done continually. Therefore, a new base population of okra was created at Phichit Agricultural Research and Development Center. Apart from the cultivar improvement by DOA, research on breeding by other agencies, seed companies and okra exporters continue, and they have distributed seeds to farmers or contractors. East West Seed Company, Ltd. has a project on YVMD resistance development and released 'Green Star 691' to the market. However, the variety failed to succeed because of its small pod size of about 5-25 g/pod, while the standard size is about 10 g/pod. The pod color is light green, which is undesirable. Currently, an improved cultivar ‘Green Star 695’ has been marketed. The Uniseeds Co. Ltd., in collaboration with National Science and Technology Development Agency has developed the YVMD resistance F1-hybrid okra. Six F1-hybrid cultivars revealed good performance and high resistance to YVMD when testing in farmers’ fields in 2007 (BIOTEC). Maejo University also created an okra breeding project using a conventional method to develop an OP cultivar. They now release the okra cultivars named ‘Maejo49’ and ‘Maejo70’ to market. Lampang Rajabhat University conducts okra research. The Thailand Institute of Nuclear Technology (TINT) has conducted an okra-breeding project using a mutation breeding method; okra seeds are exposed to gamma rays to induce the mutation and okra varieties are selected using a pedigree selection method. TINT successfully obtained one resistant line (Phadvibulya et al. 2009). The resistance characteristic is controlled by and incomplete dominant gene and it is unstable (Boonsirichai et al. 2009). Although the research was not very successful, the method can be another strategy to gain new sources of YVMD-resistance in okra.

Mushrooms: Varieties for different locations

The *Lentinus squarrosulus* mushrooms (Fig. 5) were generated for different locations e.g. Northeast, Central and Southern part of Thailand namely L1, L5. The native mushrooms known as DOA 1, 3, 4, 5, 7 and 10 were developed for Central and Northeast Thailand. Similarly, shiitake mushroom No. 7, oyster mushroom No. 17 and No. 18 (Fig. 6) were developed for upper North Thailand. Abalone mushrooms (Poa Hue, P43-012, Oyster P9, Shiitake No. L1) were developed for Southern Thailand, and the native Het Hom for Northeast Thailand. Other natives, Tong Fone and *Oudemansiella,* were selected for high productivity and market demand.

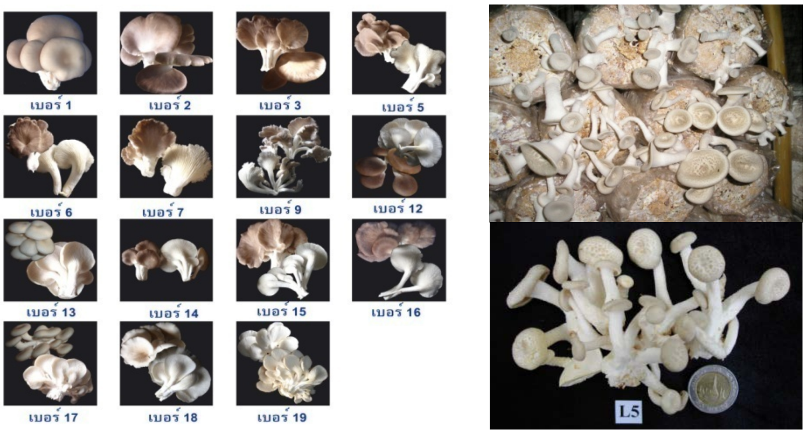
New mushroom lines were kept in DOA’s germplasm collection for further release to natural reforestation. The *Oudemansiella* were developed for use as a bio-substance.

***Lentinus giganteus* Berk**

***Macrocybe crassa* (Berk.) Pegler & Lodge**

Phaeogyroporus portentosus

Figure 5. *Lentinus giganteus, Macrocybe crassa* and *Phaeogyroporus portentosus*.



Oyster for North (No. 17 and No. 18)

***Lentinus* L1 for Central, NEL5 for South and NE**

Figure 6. Oyster mushrooms No. 17 and No. 18; *Lentinus* mushrooms

CULTURAL PRACTICES

The research project showed significant success in new technology generation and verification of vegetables that can be used in major production areas of the country.

On the other hand, cultural practices for selected crops has begun—for instance, tissue culture techniques for seedling production in asparagus. In potato, technology for the production of certified seed (G_3) and cultural practices for reducing hollow bulb were made. Technologies on seed production for chili, ginger, and potato as well as postharvest processing/handling for those vegetables are being developed, including capsaicin extraction methods and methods to keep chili free of chemical residues. These practices minimize use of chemicals and promote GAP in general. Technologies for on-farm trials of chili, potato and mushroom were also carried out, leading to increased income for potato farmers. Cultural practices for chili production that allow the crop to be grown in areas with serious root gall nematodes were adopted by farmers in Ubon Ratchathani province.

Asparagus: Tissue culture technique for seedling production

Asparagus production in Thailand is mostly by contract farming. Export companies normally provide agricultural inputs e.g. seedling, fertilizer and chemicals for pest control to control the quality of the produce. In the past five years, however, disease problems have been on the rise, brought about because famers were continuously using late maturing asparagus seedlings. This led to an abrupt decrease in plantation area and a lack of good quality seedlings. Technologies for asparagus seedling production were developed, such as a root and shoot induction media using MS (Murashiki and Skook) +0.04 ppm NAA0.1+ ppm Kinetin. As for multiplying seedlings, this was done by using MS+0.04 ppm NAA0.1+ ppm Kinetin together with MS+3% sucrose. For root induction media, the MS+3% sucrose was developed accordingly (Fig. 7). Likewise, callus induction media for anther culture was also generated by using MS+ Casein hydrolysate 500 mg/l+glutamine 800 mg/l2+ ppm NAA+1 ppm BA+sucrose+% 2phytagel %2. Shoot induction in the media of MS+glutamine 800 mg/l+inositol 100 mg/l+sucrose +% 3phytagel 3g, MS+0.04 ppm NAA 0.1+ppm Kinetin and MS+ %3sucrose was further developed.

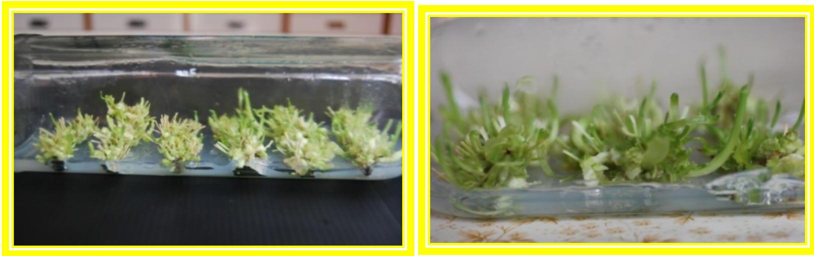


Figure 7. Callus formation and shoot and root induction in asparagus is developed for coping up lack of seedlings for asparagus production. MS+ 2ppm NAA+ 1ppm BA+ %3sucrose used as callus formation media *(left)*; **too much moisture results in less callus formation** *(right).*

Potato: Production and seed potato production

Due to high production costs, high cost of imported seed, and low productivity in the rainy season, there is an inadequate supply of potato for processing companies in Thailand. Studies were conducted to develop potato production technology for both seed and tubers, for high productivity, good quality, high efficiency, and safety of pest management control.

As per technology for rainy season production and pest and disease management, studies were conducted from October 2006 to September 2010. Comparison of substrate for pre-basic G_0 production showed that peat moss gave the highest vegetative growth and yield; however, costs were high. Mixtures of soil, sand, rice husk, rice burned husk and coconut coir dust were considered suitable substrates for growth and yield performance of potato and gave the lowest production cost.

A study of pre-basic seed production by aeroponic culture showed that the number of mini-tubers per plant in an aeroponic system was higher than that of a substrate culture, but the yield per square meter in substrate culture was higher because of the higher percentage survival of plants than in an aeroponic culture. In the efficiency seed production study in farmers' field, the pre-basic seed (G_0) was produced at the Research Center of the Department of Agriculture and distributed to farmers for three generations of basic seed production G_1-G_3 in their own fields. Farmers obtained yield of G_1, G_2 and G_3 seed at an average of 688.5, 709.7 and 936.9 kg/400 square meter, respectively. The production costs for G_1, G_2 and G_3 seed were 28.61, 16.30 and 11.84 baht per kilogram of seed, respectively. Compared to the price of imported seed, which can be as high as 30 baht per kilogram, farmers could reduce seed cost bt 4.63, 45.67 and 60.53% with G_1 , G_2 and G_3 seed, respectively.

A study was conducted to determine the effect of PVY infection on yield of seed potato. PVY infected seed at 0%, 10%, 20% and 30% was planted to compare with 100% PVY infected seed. Experimental findings showed that the yield was not statistically significantly different among treatments, but the 100% PVY infected seed gave smaller tubers than those from other treatments.

In a study of potato production technology during the rainy season, the effect of spacing and cutting seed was investigated on potato variety Atlantic. Results showed that close spacing at 15 x 15 cm gave higher yield than spacing of 20 and 25 cm, but not a significant difference. Planting potato by using whole seed gave higher yield than cut seed by 17.5 – 43.6%, and incidence of hollow heart in tubers was lower by 6.2 - 17.6% in the rainy season, but in the cool season were was no incidence of hollow heart.

In the fertilizer management study, a trial was conducted to determine the effect of foliar fertilizers on quality of Atlantic. The application of foliar fertilizer magnesium with calcium boron gave the highest potato yield and higher proportion of larger tubers than those from other foliar fertilizers treatments. In pest management studies, a trial was carried out to determine the integrated control of bacterial wilt caused by *Ralstonia solanacearum*. The trial demonstrated that the seed treated with antagonist DOA – WB4 *Bacillus subtillis* (before planting and subsequent soil treated with this antagonist at 10, 20 and 30 days after planting showed effective control comparable to other control methods such as crop rotation, drying, heating soil, and using medicinal plant extractions. The integrated control treatments significantly reduced the incidence of bacterial wilt by 2.8 – 5.1 % compared to the untreated control with 58% of bacterial wilt. The instant kit of antagonist DOA – WB4 for bacterial wilt control was developed and used in the farmers' fields on a total area of 1200 rai in 7 provinces. Results demonstrated that the application of the instant kit effectively controlled bacterial wilt and reduced the incidence up to 80%. In the potato root-knot nematode control, the efficiency of abamectin was also tested. The results showed that the soil application at 1.8% EC abamectin or seed treated before planting effectively reduced the incidence of root-knot nematode on potato variety Atlantic. Nematode multiplication was reduced only in the pot trial; it was not effective in the field trial. Control of root-knot nematode with abamectin may be extremely costly due to the high rate of application. However, seed treated with abamectin before planting may be appropriate but must be used together with other methods.

The effect of fungus *Paecilomyces lilacinus* on controlling root-knot nematode was studied. The results indicated that the application of the fungus *P. lilacinus* on commercial bioproduct Laicinus in the formulation of wetable powder at the rate of 3 g per hill as basal dressing before planting effectively reduced the incidence of root-knot nematode and gall on tubers of potato variety Atlantic.

In the potato virus study, a survey to monitor and identify potato viruses PVS, PVX and PLRV was carried out in farmers' fields in Chiang Mai, Lampang and Tak provinces. Results of the NCM-ELISA test of leaves revealed that the infection of PLRV was widespread in potato planting areas at Chaiprakarn, Mae-ai and Sansei districts in Chiang Mai province, but PVS and PVX were not detected in all farmers' fields. Several insecticides were tested to control insect transmission of potato virus. The results indicated that spraying of cabosulfan and abamectin gave more effective reduction of aphid population than the application of petroleum oil, white oil, azadizachtin and carbofuran, but did not prevent infection from the virus.

Ginger: Disease free planting material

Thailand produces around 170,125 metric tons of ginger annually, mainly for export to Europe, Japan, Pakistan and Saudi Arabia. In 2012-2013, the export value of ginger was 801 - 1,168 million baht (Custom Department 2013). A major production constraint is that the crop cannot be grown repeatedly in the same area or in subsequent cropping seasons. Due to a disease that causes the rhizomes to rot in the soil, the plant is considered by some to be harmful to the environment. Thailand Department of Agriculture set up a project on disease-free planting material to produce good quality ginger seed for farmers, to minimize rotation planting. A study on liquid media and bio-reactor for producing seed ginger showed 10-15 times higher production of plantlets than Potato Dextrose Agar (PDA) media. However, MS+ 2 mg/lBA+ 4% Sucrose + 0.8% Agar induced ginger shoots. After G_0 was transplanting in the soil, seed ginger was planted at 25 x 25 cm. Moreover, G_1 seed ginger production in a single row without a ridge, covered by plastic sheet, and with fertigation gave better rhizome yield at 3,051 - 7,251 kg/rai, respectively.

CONCLUSION

The projects generated new varieties to support the government policy of making Thailand the "Kitchen of the World" and released them to farmers in different agro-ecological zones from 2009-2011. New three varieties of chili YodSon (Sisakat -1-59 (2, Jinda F1-Hybrid, and Pichit No.1 were developed. The project produced new varieties of sweet potato for fresh consumption—Pichit 265-1 (yellow color), Pichit 292-15 (purple), T101 (orange) and PROC. No. 65-16 (white). Taiwan #1 and PROC No. 65-16 expressed desirable traits for the starch industry and ethanol production. Parkia for off-season production has been selected, inlcuidng such as Trang #093, Trang #099 and Trang #075; however, on-farm trials are needed. Okra with resistance to YVMD is needed as the disease has developed a new biotype. Similarly, 14 mushrooms varieties were released to different locations throughout the country.

Tissue culture techniques for asparagus seedling production were initiated in the laboratory. Developing good agriculture practices for potato production and management including cheaper seed potato G_{0-3} to minimize seed potato imports is an ongoing effort. Development of disease-free ginger planting material was investigated.

Some of the technologies mentioned in this paper have been transferred to farmers. Other lines than those will be kept for increasing the population of material for use in DOA breeding programmes. Information has been collected and will be available to improve GAP documentation, to support Thailand's claim as "Kitchen of the World".

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Rural Bio-Resource Complex Project: A model integrated agricultural development leads to economic growth

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ABSTRACT
The mandate of the Rural Bio-Resource Complex (RBRC) project implemented by the University of Agricultural Sciences, Bangalore, India from April 2005 to March 2010 covering 8340 rural households in Bangalore Rural District of Karnataka was to enhance income and living standards of rural people, particularly small and marginal farmers. Initially a five-pronged strategy was adopted, namely promotion of 20 capsules of profitable and appropriate technologies; provision of effective information support system; provision of quality critical inputs within the easy reach of the farmers including providing farm machinery on hire services; ensuring effective functional linkages; and arranging forward market linkages. Subsequently, commodity-based associations were established based on the need for organized markets to facilitate a large number of small and marginal farmers to ensure profitable prices for the produce.

In a span of five years, the project activities were able to bring about significant impact in terms of a shift in cropping pattern, added net income, employment generation and improved socio-economic status of the stakeholders. The stakeholders were able to realize threefold increase in income, 11% annual growth rate in agriculture, 2.52 lakh additional employment generation annually and improvement in livelihoods besides retaining a majority of youth. The Integrated Farming System (IFS) validated in this project is being replicated in all the districts of Karnataka state covering 1.25 lakh families. The model holds promise for sustaining livelihoods through increased employment opportunities.

One of the main interventions of RBRC activities was the promotion of improved varieties of vegetable crops to replace less profitable field crops. To facilitate growers to realize better prices, a Fruits and Vegetable Growers' Association was established at a strategic place to strengthen forward market linkages. The project provided skills to these growers that helped them in production and marketing and also improved the leadership qualities. Besides substantially improving the productivity and production of vegetables, the role of middlemen was minimized and overhead costs were reduced. The intervention was able to improve livelihoods of small and marginal farmers, enhancing their competitiveness and increasing their share of the consumer payment by around 60%. The RBRC model continues to evolve since its inception and remains to be self-sustained and driven by the effective participation of stakeholders. This diversifies agricultural entrepreneurship to generate employment and retain rural youth to practice agriculture.

Keywords
Rural Bio-Resource Complex (RBRC), agricultural development, Integrated Farming System (IFS), commodity based associations, socio-economic profile.

STATUS AND CHALLENGES OF AGRICULTURE IN ASIAN COUNTRIES

The Asia-Pacific region accounts for nearly half the world's population. India and China together are home to 70% of the region's population. More than 2.2 billion people in the region depend on agriculture for their livelihoods. Agriculture continues to be the engine of economic growth in most developing countries of the region. Increasing demographic pressure has led to declining per capita availability of land. Asia and the Pacific region has the smallest size of holdings in the world. The number of small and marginal farmers is on the rise. It is estimated that about 87% of the world's 500 million small farms (less than 2 ha) are in Asia and the Pacific region. Agriculture in Asia is characterized by smallholders cultivating on small land holdings. The average size of operational holdings is only 0.5 hectares in Bangladesh, 0.8 hectares in Nepal and Sri Lanka, 1.4 hectares in India and 3.0 hectares in Pakistan. About 81% of farms in India have land holdings of less than 2 hectares, whereas their share in total cultivated area is about 44%. The situation is similar in many other countries of Asia. In China 95% of farms are smaller than 2 hectares. Smallholders' contribution to the total value of agricultural output is significant in many countries of the region. For example, in India their contribution to total farm output exceeds 50% although they cultivate only 44% of land. Another feature of agricultural holdings in Asia is that these are often fragmented. The average number of parcels per holding in Asia is 3.2.

From the mid-1960s Indian agriculture experienced the Green Revolution, which transformed the scenario of food deficiency into one of self-sufficiency. In addition to food grains, production of oilseeds, fruits, vegetables, sugarcane, milk, fisheries and poultry recorded impressive growth. The success of the Green Revolution was also experienced by several Asian countries where the rapid adoption of modern agricultural technologies resulted in dramatic gains in productivity.

Despite significant achievements in food production, problems of food and nutrition security, poverty alleviation and regional imbalances still persist. Moreover, the effects of the intensive application of the seed-fertilizer-irrigation technology began to manifest themselves in rising soil salinity and toxicity, water pollution and nutrient imbalances, almost negating the beneficial effects of the technology. It is noteworthy that agricultural growth which accrued as a result of the Green Revolution was restricted largely to the irrigated and well-endowed regions. A major portion of cropland continues to be dependent on rains. Besides, small farms have been able to achieve some measure of economic viability in irrigated areas, while they remain bereft of the benefits of modern agricultural technology in rainfed areas.

The biggest challenge Asia faces in near future is the food security and rural poverty. There are many factors contributing to food security in the region. The major factors are constant decline in per capita land holdings, division and fragmentation of holdings, poor fertility of soil, shrinking water resources, impact due to climate change, poor marketing linkages, indiscriminate increase in cost of production and decline in profit margin from farming, as well as the emerging problem of youth losing interest in agriculture and migration of youth from rural areas to urban areas. The extent of migration in India is around 50% while in China it is 90% according 2011-12 figures.

Reviving and making agricultural professions profitable is the need of the hour. Emphasis on increasing productivity through restoration of soil health, increasing the knowledge level of farmers on improved technologies, market linkage, postharvest, processing, rural infrastructure, credit and insurance support are some of the areas that need to be strengthened for sustaining agriculture production and productivity in Asian countries. The trend in India more or less corroborates with the prevailing situation in many Asian countries. The situation may go from bad to worse in view of democracy and associated policy, namely right to inheritance of property by every sibling, and in the process, indiscriminate division and fragmentation. Therefore more serious measures/strategies are required to address emerging challenges in India.

RBRC PROJECT: TO REBUILD CONFIDENCE AMONG FARMERS

A comprehensive programme aiming to provide the most appropriate technologies based on resource endowment backed up by constant information, infrastructure and market support involving multi-level and multi-institutional systems are likely to have far reaching impact in improving standards of living for rural people, thereby contributing to overall growth. In this backdrop, the research project Rural Bio-Resource Complex (RBRC) was conceptualized during 2004 by a team of interdisciplinary scientists of the University of Agricultural Sciences, Bangalore with a view to revisit the unsustainable agricultural system and to promote confidence among farmers.

The project was implemented on a pilot scale with financial assistance from Department of Biotechnology, Government of India in Tubagere Hobli of Bangalore Rural District, in Karnataka State, covering 75 villages from April 2005 to March 2010. The project was implemented with six factors to enhance income and standard of living of farmers, viz., promotion of capsule of technologies; ensuring required information support system; providing quality critical inputs and custom hire services of agricultural machineries; effective functional linkage with related institutions; market empowerment; and establishment of Commodity Based Associations.

Promotion of capsule of technologies

Identification, validation and promotion of suitable technological packages comprised of different agricultural and allied enterprises were developed, in consultation with target groups and involving an interdisciplinary team of scientists from the university. The components included Integrated Farming System Modules (IFS), processing and value addition, seed production with an emphasis on good agricultural practices, climate resilient agricultural practices, and efficient natural resource management. The technologies promoted were:

- Field crops
    - Finger Millet
    - Maize
    - Pigeon Pea
    - Sunflower
    - Sweet corn
    - Pop corn
    - Baby corn

- Horticultural crops
    - Improved cultivation practices in banana

- Moringa (Drumstick)
- Improved French bean
- Open field rose cultivation

- Animal Based Enterprises
  - Fish culture
  - Sheep rearing
  - Backyard poultry

- Natural Resource Conservation and Management
  - Biofuels
  - Organic farming
  - Water use efficiency
  - Integrated farming system

- Seed Production activities
- Sericulture and Chawki Rearing Centre
- Value added products in finger millet, pigeon pea and jackfruit

Ensuring effective information support system

Due to a decline in the presence of the public extension system, the rural sector in general and agricultural sector in particular are almost impoverished in both knowledge and skills required for synthesizing the information and technological application required for the farm growth. The success of any technology promoted depends on availability of accurate and timely information. Efforts were made under this project to empower farmers and landless families with opportunities and new knowledge. Farmers were constantly supported by providing relevant information in support of technologies promoted and other related issues. The empowerment activities included training, demonstrations, field visits, teleconferences, agromet advisories, field day, participation in Krishi Mela, study tours and campaigns.

Providing quality critical inputs and custom hire services of agricultural machinery

Availability and affordability of critical inputs are major factors that bear on agricultural production and thereby rural economies. Apart from cost of inputs, quality, easy and timely access, overhead charges also play an important role in minimizing the cost of production and increasing profit margins by farming communities. An effective input management systems is essential in bridging the gap in agricultural production. The project aimed to empower farmers to get access to quality inputs by developing an effective input management system.

Effective functional linkage with related institutions

Promotion of technology per se cannot help farmers towards economic security unless other backward and forward linkages are adequately addressed. Thus critical gaps in input supply, access to credits, marketing, end user linkage and value addition, access to various services and resources are crucial to make farming a profitable venture. The project envisaged utilizing the services of other organizations including financial, development departments, input agencies, marketing organizations, local institutions and NGOs functioning in the area. The project worked towards the convergence of socio-economic, agricultural and other cross-sectorial developmental activities for overall development of farm families.

Market empowerment

Indian agriculture has seen phenomenal changes during the past few decades from subsistence agriculture to commercial agriculture. Unfortunately, marketing networks continue to be a weak link creating hardships for farming communities. Farming enterprises suffer from lack of proper market linkages with consumers and agro-industries. Several thousands of tons of fruits, vegetables and food grains are lost every year due to lack of such linkages. The project took the initiative to empower the farming community on market-related issues through continuous capacity building, knowledge and skill-imparting activities. More emphasis was given to value addition, grading, processing, packing and branding of agricultural produce for maximum profit and livelihood opportunities. The project provided special attention towards establishing a marketing linkage for farm produce to marketing organizations and industries.

Establishment of Commodity Based Associations (CBAs)

As a part of its strategy, RBRC actively promoted farmers' associations as a means of strengthening backward and forward linkages with a special focus to ensure profitable sale of farm produce with at least overhead charges. These associations are built around a group of farmers/farm women, which have proven to be reliable vehicles for participatory and sustainable rural development.

Organizing rural people into useful groups is an important activity that was undertaken by the project. The necessity of CBAs have become important now more than ever before in view of the breakdown of the joint family system, fragmentation and division of land holdings, uneconomic size of land holdings, inadequate availability of inputs, difficulty in availing and using improved implements, poor marketing arrangements, inadequate transport facilities, lack of local markets for produce, problems of factions, and associated social issues. Profitable marketing of produce of farmers is given top-most priority through organized arrangements. The continuation of the interventions introduced during the project period greatly depends upon active involvement of stakeholders, which was possible due to the start of various associations.

CBAs are platforms where farmers share knowledge on the use of appropriate and affordable technologies aimed at increasing their agricultural produce. They help in establishment of strong forward and backward linkages between farmers and service delivery institutions. CBAs enjoy similar status as that cooperatives in terms of legal / administrative procedures, but enjoy autonomy as that of SHGs and they are free from rigidities associated with contact farming as decisions are made by members of CBA from time to time.

The rate of success of these organizations is determined by their capacity to arrange for major investments and a continuous flow of raw materials. CBAs require a high caliber of representative and enlightened leadership from among the grower members. The competent management team had to man these CBAs, laying equal emphasis on both enterprise-related and member-related aspects. The profits generated are used to provide supplementary and supportive services at reduced cost to encourage members to utilize them.

Efforts were made in the RBRC project to start the following ten associations with active participation of the stakeholders.

- Rural Biofuel Growers Association, Hadonahalli
- Chawki Rearing Centres (Two Numbers)- Hegdehalli and Gangasandra
- Organic Farming Farmers Association, Karnala
- Jack Growers Association, Hadonahalli
- Federation of Women SHGs, Tubagere
- Fish Farmers Association, Tubagere
- Flower Growers Association, Hadonahalli
- Corn Growers Association, Hadonahalli
- Fruits & Vegetables Growers Association, Hadonahalli
- Agro Processing Centre, Melekote

These ten commodity based associations were established in strategic places of the project area. Creation of community/common infrastructural facility for the benefit of small and marginal farmers was especially encouraged. The most innovative aspect of the model is the use of the underutilized Milk Producers Co-operative Societies (MPCS) in each village as the base for the procurement of the village produce, namely, bio-fuel seeds, fruits and vegetables, vermicompost, manure and a range of other products, as well as for storage of critical inputs for timely distribution and easy access of stakeholders.

Benefits of CBAs

- ✓ Autonomy, flexibility and transparency in the system
- ✓ Registered bodies under the Registrar of Firms & Societies
- ✓ Strengthens backward and forward linkages
- ✓ Promotes division of labour and specialization
- ✓ Resource sharing including machinery and infrastructure
- ✓ Provide equal opportunities for all sections of rural society

ACHIEVEMENTS OF RBRC PROJECT

The farming community in the project area realized higher net income from increased productivity of the existing crops. They shifted from subsistence agriculture to seed production and nursery multiplication, took up new crops like roses, sweet corn, baby corn, increased the area under mulberry, and were introducted to tissue culture for banana and subsidiary rural enterprises like sheep, fish farming, vermicompost, and value addition to agricultural based products (VAPs). Further, introduction of integrated farming system demonstrations, improving water use efficiency measures, cultivation of biofuels in non-arable land, promotion of custom hire services of tractors and improved agricultural implements and start of 10 different commodity based associations had cumulative impact on enhancing the income of stakeholders.

The stakeholders showed increased interest in the project due to increase in the farm income and sustenance of the productivity. The net income generated during year 2007-08 in project area was Rs.101.6 million, and during the subsequent year (2008-09) it showed increased trend with net income of Rs.156.5 million and by the end of project period it rose to Rs. 182.2 million as against Rs.39.6 million during the benchmark year (2004). The project implementation resulted in direct employment generation of 2.52 lakh days per annum during 2007-08 with sustained increase in subsequent years. An overall assessment indicated that project was able to realize 1% growth rate in agriculture. It was an encouraging outcome, which provided confidence to the project team. The project amply proved that with the promotion of aforesaid factors it was possible to sustain the growth of agriculture and rural economy.

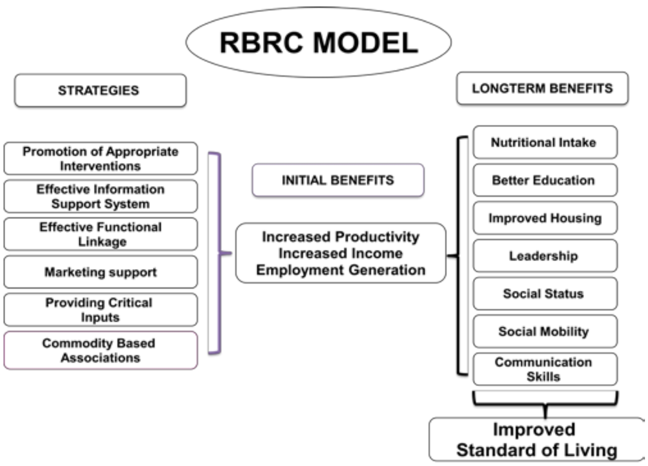
The RBRC model in a span of five years of its implementation provided direct benefits to the stakeholders through sustained agricultural growth and income. Besides direct benefits many indirect benefits accrued were: improved soil fertility, soil moisture conservation, decrease in cost of production, reduction in overhead charges, improved environmental conditions, decline in migration especially farm youth, enhanced food and nutritional security, improved leadership qualities, and higher confidence among farmers, particularly farm youth and women. All the RBRC beneficiaries were satisfied about the benefits derived from the project. The coverage in mass media, opportunity to share their experiences in various media and public events had improved their confidence level. Further, the recognitions and awards for achievements by the farmers had helped them to derive greater satisfaction in their vocations. The project has impacted positively in terms of sustained adoption of technologies, effective functioning of local institutions, and farmer-to-farmer knowledge sharing, realizable even after completion of project. It stands as testimony and demonstrates the resilience, sustainability of the project elements, and robustness of the project concept as a pilot model.

MAJOR OUTCOME

- Improved productivity and profitability to stakeholders
- Achieving 11% agriculture growth rate
- Establishing the forward market linkages for agricultural produce
- Increased employment generation
- Minimization of migration of rural youth
- The project had attracted delegates from different countries, states, and institutions
- Ensuring the sustenance of the achieved growth rate

CONCLUSION

At a time when the country is struggling hard to achieve a 2% growth rate in agriculture, this model has demonstrated 11% growth and could be replicated across the country as well as other Asian countries with suitable refinement to suit different agro-climatic zones. Sustainable development rests with mobilizing local people to take responsibility for continuous adoption and adaption of technology, as well as undertaking value addition and processing to realize the best price for their produce, which was effectively addressed through the start of commodity-based associations.



Good Agricultural Practices for sustainable vegetable production in the humid tropics

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ABSTRACT

Good Agricultural Practices (GAPs) depend on enhancement and sustainability of natural resources and maintenance of viable farming enterprises that contribute to sustainable livelihoods. Adoption of suitable cropping patterns, cultural practices that maintain soil structure and application of adequate doses of manures and fertilizers to restore soil organic matter are some of the GAPs related to vegetable production. In India, cropping systems are usually based on cereal or vegetable crops. Balanced dose of NPK, organic sources of nutrients and biofertilizers have proved superior with respect to yield, quality and nutrient uptake in vegetable crops.

In the humid tropics of Kerala, the important vegetable crops grown are cucurbits, solanaceous vegetables, leguminous vegetables, okra and amaranthus. Experiments were conducted on vegetable based cropping systems and good agricultural practices for vegetable production at All India Coordinated Research Project (Vegetable Crops), College of Horticulture, Kerala Agricultural University, located at $10^{0}31'$N latitude and $76^{0}13'$E longitude. During growing seasons from April-August, September-December and January-April, the vegetable based cropping system studies were compared with farmers' practices. The cropping sequences cowpea-tomato-bitter gourd, okra-pumpkin-brinjal, and ash gourd-bitter gourd-bottle gourd were found remunerative, giving higher net returns.

Integration of organic amendments and biofertilizers reduce the requirement for NPK and improve soil health and plant nutrient availability resulting in enhanced yields. Results of IPNM studies on the cropping sequence okra-tomato-cowpea revealed that application of FYM at 20 t/ha in okra and FYM at 20 t/ha along with AMF, *Pseudomonas*, *Trichoderma* and *Azotobacter*, each at 5 kg/ha in tomato gave significantly higher yields. Residual nutrients from the treatment FYM 20 t/ha along with AMF, *Pseudomonas*, *Trichoderma* and *Azotobacter* each at 5 kg/ha gave highest yield in cowpea where no fertilizers/manures/biofertlizers/were added.

Application of NPK at 110:35:70 kg/ha along with Vermiwash soil application at 1 l/bed and 3 foliar sprays at 1l in 10 l water at one week intervals starting 30 days after sowing gave significantly higher yield of 12.3 t/ha in okra. In cowpea FYM at 20 t/ha and in cucumber FYM at 10 t/ha along with vermicompost at 2 t/ha resulted in higher yields of 10.3 t/ha and 23.5 t/ha respectively. In amaranth variety Arun, application of 20 t/ha FYM resulted in significantly higher yield of 16.7 t/ha. Use of inorganic fertilizers in conjunction with organic manures and biofertilizers is essential for sustainable and profitable vegetable production

Keywords: Cropping system, GAP, IPNM, sustainability, nutrient uptake

INTRODUCTION

In Kerala, the important vegetable crops grown are cucurbits, solanaceous vegetables, leguminous vegetables, okra and amaranth. The crop management practices were standardized using inorganic sources of nutrients. Organic agriculture considers medium- and long-term effects of agricultural interventions on the agroecosystem. Experiments were conducted on vegetable based cropping systems and good agricultural practices for vegetable production at All India Coordinated Research Project (Vegetable Crops), College of Horticulture, Kerala Agricultural University, located at $10^{0}31'$N latitude and $76^{0}13'$E longitude.

VEGETABLE BASED CROPPING SYSTEM

The vegetable based cropping system studies were conducted during growing seasons from April-August, September-December and January-April. Farmers in Kerala cultivate paddy in the first season, followed by vegetables like cowpea in the second season and cucumber in the third season. This was compared with the other cropping sequences involving vegetables alone to understand the most profitable crop sequence for the region. The treatment combinations were ash gourd-bitter gourd-bottle gourd, chili-ash gourd-cowpea, okra-pumpkin-brinjal, cowpea-tomato-bitter gourd and amaranth-snake gourd-cowpea. The experiment was laid out in a randomized block design with three replications in plots of size 3.6 x 3.6 m during 2007-08 to 2010-11. The results (Table 1) revealed that the cropping sequences cowpea-tomato-bitter gourd, okra-pumpkin-brinjal and ash gourd-bitter gourd-bottle gourd were remunerative, giving higher net returns. The market price of each crop during the growing seasons was used to calculate the gross income. Among the different vegetable crops, cowpea, okra and cucurbits like bitter gourd, ash gourd, and pumpkin fetch premium prices in the markets in Kerala, which is evident from BC ratio of the cropping sequences involving these crops.

GOOD AGRICULTURAL PRACTISES (GAP)

Good agricultural practices involve adoption of cultural practices that maintain soil structure and application of adequate doses of inorganic fertilizers, manures and biofertilizers to restore soil organic matter content

Integrated plant nutrient management (IPNM)

Effects of integrated plant nutrient management (IPNM) and organic amendments along with biofertilizers and studies were conducted in okra, amaranth and in the cropping sequence involving okra-tomato-cowpea. In okra variety Arka Anamika, the effect of soil and foliar application of Vermiwash along with recommended dose of NPK on yield and quality was studied. The treatments were NPK+ Vermiwash 1 spray30 days after sowing (das), NPK + Vermiwash 2 sprays at 1 week interval starting 30 das, NPK + Vermiwash 3 sprays at 1 week interval starting 30 das, NPK+ Vermiwash 4 sprays at 1 week interval starting 30 das, NPK+ Vermiwash 5 sprays at 1 week interval starting 30 das, Vermicompost 5 t/ha+ vermiwash 1 spray, Vermicompost 5 t/ha+ vermiwash 2 sprays, Vermicompost 5 t/ha+ vermiwash 3 sprays, Vermicompost 5 t/ha+ Vermiwash 4 sprays, Vermicompost 5 t/ha+ vermiwash 5 sprays, NPK +Vermiwash soil treatment + vermiwash 3 sprays , Vermicompost 5 t/ha + Vermiwash (soil treatment)+ vermiwash 3 sprays and NPK (110:35:70 kg/ha). It was found that application of NPK @110:35:70 kg/ha along with Vermiwash soil application at 1 l/bed and 3 foliar sprays at 1l in 10 l water at one week interval starting 30 days after sowing gave significantly higher yield of 12.3 t/ha in okra (Table.1, Fig.1). The benefit cost (BC\) ratio was 1.9. The higher yield obtained in application of NPK + Vermiwash soil treatment + Vermiwash 3 spray may be due to the increased vegetative growth and fruit characters. Chattoo et al. (2009) reported that okra improvement in seed yield and related attributes due to integration of manures may be due to balanced CN ratio, organic matter build up and sustained availability of nutrients, which enhanced photosynthetic rate and resultant yield. Singh (2011) also reported enhanced yield due to applicatiion of vermicompost and farm yard manure in okra.

The effect of application of organic amendments along with biofertilisers on yield and quality of red-leaved amaranth variety Arun revealed that application of 20 t/ha FYM gave significantly higher yield of 16.7 t/ha and high BC ratio of 2.0 (Table 2; Fig.2).The protein content of leaves was highest (3.2%) when FYM and Neemcake were applied either alone or along with Azospirillum and PSB each at 5 kg/ha. The highest crude fibre (2.1%) and iron content (7.7 mg/100 g) were also obtained when Neem cake was applied at 2 t/ha. The vitamin C content of leaves was highest when FYM was applied either alone or along with Azospirillum and PSB each at 5 kg/ha. Significantly higher quantity of oxalates were observed when FYM was applied either alone 20 t/ha or in combination with Azospirillum and PSB each 5 kg/ha. High amounts of nitrates observed in the leaves when FYM and Neemcake were applied either alone or along with Azospirillum and PSB (Table 3). The protein content of leaves was also high in these treatments.

The effects of organic manures integrated with biofertisers were studied in the cropping sequence of okra-tomato-cowpea. There were eleven treatments as FYM 20 at t/ha, Vermicompost at 5 t/ha, Neemcake 2 at t/ha, FYM at 10 t/ha + Vermicompost at 2.5 t/ha, FYM at 10 t/ha + Neemcake at 1 t/ha, FYM at 10 t/ha + Poultry manure at 2.5 t/ha, Vermicompost at 2.5 t/ha + Neemcake at 1 t/ha, Vermicompost at 2.5 t/ha + AMF + *Pseudomonas+Trichoderma+Azotobacter,* Neemcake at 1 t/ha + AMF + *Pseudomonas+Trichoderma+Azotobacter* and FYM at 20 t/ha + AMF + *Pseudomonas+Trichoderma+Azotobacter* along with the recommended dose of NPK as check for okra (110:35:70 kg/ha) and tomato (75:40:25). The experiment was laid out in same plots of size 3.6 x3.6 m. The varieties used were Arka Anamika (okra), Anagha (tomato) and Kashi Kanchan (cowpea). The treatments were imposed only in okra and tomato and cowpea was grown as catch crop. The results (Table 5) showed that integration of organic amendments and biofertilisers reduce the requirement for NPK and improve soil health and plant nutrient availability resulting in enhanced yields. Results of IPNM studies on the cropping sequence okra-tomato-cowpea revealed that application of FYM at 20 t/ha in okra (12.1 t/ha) and FYM at 20 t/ha along with AMF, *Pseudomonas*, *Trichoderma* and *Azotobacter* each at 5 kg/ha in tomato gave significantly higher yield (18.3 t/ha) (Fig. 3 and 4). Residual nutrients from the treatment FYM at 20 t/ha along with AMF, *Pseudomonas*, *Trichoderma* and *Azotobacter* each at 5 kg/ha gave highest yield in cowpea (8.2 t/ha) where no fertilzers/ manures/ biofertlizers/ were added. The BC ratio was 1.9, 2.3 and 1.8 for okra, tomato and cowpea, respectively. The increased population of microorganisms in soil might have been responsible for the release of nutrients and plant growth promoting substances, thereby increasing yields and high net returns. Similar results were also reported by Smitha (2012) in tomato.

Use of inorganic fertilizers in conjunction with organic manures and biofertilisers is essential for sustainable and profitable vegetable production.

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Table 1. Mean yield and benefit cost ratio of cropping sequences

Cropping sequence			Mean yield t/ha			BC ratio
Season I	Season II	Season III	Season I	Season II	Season III	
Paddy	Cowpea	Cucumber	3.2	9.1	31.5	1.3
Ash gourd	Bitter gourd	Bottle gourd	20.6	19.6	20.7	2.8
Chilli	Ash gourd	Cowpea	11.9	16.4	13.9	2.3
Okra	Pumpkin	Brinjal	12.1	23.6	22.9	2.9
Cowpea	Tomato	Bitter gourd	61.6	25.6	16.9	3.3
Amaranthus	Snake gourd	Cowpea	14.3	35.3	90.9	2.3

Table 2. Response of okra to IPNM

Treatments	Yield t/ha	Plant height (m)	No.of branches	Days to flowering	Fruit length (cm)	Fruit girth (cm)	Av. Fruit weight (g)	BC ratio
T_1 NPK+ Vermiwash 1spray 30das	9.9	0.8	2.3	37.4	14.5	6.2	15.6	1.1
T_2 NPK + Vermiwash 2 sprays at 1 week interval starting 30das	9.6	0.9	3.3	35.6	13.2	6.6	16.4	1.1
T_3 NPK + Vermiwash3 sprays at 1 week interval starting 30das	10.8	1.2	4.7	35.8	16.4	6.2	16.2	1.3
T_4 NPK + Vermiwash 4 sprays at 1 week interval starting 30das	10.4	1.6	6.3	34.2	15.8	7.4	17.4	1.2
T_5 NPK + Vermiwash 5 sprays at 1 week interval starting 30das	8.5	1.2	5.3	34.4	14.7	6.6	15.8	0.8
T_6 Vermicompost 5t/ha+ vermiwash 1spray	11.1	1.6	6.3	37.2	17.2	6.8	17.4	1.5
T_7 Vermicompost 5t/ha+ vermiwash 2spray	11.5	1.2	5.7	35.6	16.8	7.3	18.6	1.6
T_8 Vermicompost 5t/ha+ vermiwash 3spray	12.1	0.9	6.3	34.8	18.6	7.2	17.9	1.8
T_9 Vermicompost 5t/ha+ vermiwash 4spray	8.9	1.2	5.3	35.6	12.8	6.7	15.4	0.8
T_{10} Vermicompost 5t/ha+ vermiwash 5spray	9.2	1.0	4.3	36.2	11.5	6.8	16.6	0.8
T_{11} NPK +Vermiwash soil treatment + vermiwash 3sprays	12.3	1.8	6.7	37.9	19.4	7.6	17.8	1.9
T_{12} Vermicompost 5t/ha + vermiwash (soil treatment)+ vermiwash 3 sprays	10.4	1.6	7.3	38.2	15.5	6.8	16.4	1.4
T_{13} NPK @110:35:70kg/ha	10.4	1.2	6.7	38.6	14.6	7.1	15.8	1.2

Treatments	Plant height (cm)	Mean t/ha	BC ratio
T_1 NPK (50:50:50kg/ha)	61.9^{d}	14.7	1.5
T_2 (Vermicompost@5t/ha)	71.4^{c}	6.2	0.9
T_3 FYM@20t/ha	12.1^{b}	16.7	2.0
T_4 Neemcake@2t/ha	66.9^{cd}	5.3	0.8
T_5 Vermicompost@5t/ha+ PSB+ Azospirillum @5kg/ha	76.1^{c}	5.8	1.1
T_6FYM @20t/ha+ PSB+ Azospirillum @5kg/ha	103.8^{e}	16.5	1.8
T_7 Neemcake@2t/ha+ PSB+ Azospirillum @5kg/ha	69.1^{c}	6.2	1.0

Table 3. Performance of amaranth as influenced by organic amendments and biofertilizers

Table 4. Effect of organic amendments and biofertilizers on quality of amaranth

Treatments	Protein (%)	Crude fibre (%)	Vit.C (mg)	β carotene (µg)	Iron (mg)	Anthocyanin (mg)	Oxalate (g)	Nitrate (g)
T_1 NPK (50:50:50kg/ha)	2.0^{d}	1.0^{b}	71.3^{b}	2282.5^{b}	3.3^{e}	25.3^{c}	$0.\ 7^{b}$	0.2^{c}
T_2 (Vermicompost@5t/ha)	1.3^{c}	1.3^{b}	78.8^{ab}	3055.7^{a}	4.2^{d}	$26.\ 3^{b}$	0.6^{c}	0.2^{c}
T_3 FYM@20t/ha	3.2^{b}	1.6^{ab}	95.0^{a}	3009.7^{a}	5.8^{c}	28.3^{a}	0.8^{a}	0.4^{b}
T_4 Neemcake@2t/ha	3.1^{b}	2.1^{a}	85.0^{ab}	3043.0^{a}	7.7^{b}	27.9^{a}	0.5^{d}	0.4^{b}
T_5 Vermicompost @5t/ha+PSB+Azospirillum @5kg/ha	2.7d	1.2b	78.9^{ab}	3061.8^{c}	4.2^{d}	26.6^{b}	0.6^{c}	0.2^{c}
T_6 FYM @20t/ha+ PSB+ Azospirillum @5kg/ha	3.2^{b}	1.7^{ab}	94.8^{a}	3023.1^{d}	5.8^{c}	29.3^{d}	0.8^{a}	0.4^{b}
T_7Neemcake@2t/ha+PSB+ Azospirillum @5kg/ha	3.2^{b}	2.1^{a}	85.1^{ab}	3048.3^{a}	6.7^{f}	27.8^{a}	0.5^{d}	0.4^{b}

Table 5. Effect of organic farming in okra-tomato-cowpea cropping sequence

Treatments	Okra		Tomato		Cowpea	
	t/ha	BC ratio	t/ha	BC ratio	t/ha	BC ratio
T_1 – FYM @20t/ha	12.1	1.9	16.0	1.6	7.3	1.6
T_2 – Vermicompost @5t/ha	8.4	0.9	14.1	1.3	6.3	1.0
T_3 – Neem cake@2t/ha	8.1	1.2	14.7	1.5	6.5	1.1
T_4 – FYM @10t/ha + Vermi compost @2.5t/ha	9.4	1.2	17.3	1.2	6.9	1.5
T_5 - FYM @10t/ha + Neem cake@1t/ha	8.5	1.0	13.9	1.6	5.8	1.7
T_6 – FYM @10t/ha+ Poultry manure@2.5t/ha	9.2	1.6	14.5	1.9	5.3	1.7
T_7 – Vermi compost@2.5t/ha + Nee cake@1t/ha	10.3	1.2	16.7	1.1	7.2	1.2
T_8–Vermicompost@2.5t/ha+ AMF+*Pseudomonas*+ *Trichoderma*+*Azotobacter*	8.1	0.9	14.7	1.4	5.2	1.6
T_9-Neemcake@1t/ha+ AMF+ *Pseudomonas*+*Trichoderma*+*Azotobacter*	11.0	1.5	17.3	2.0	7.1	1.5
T_{10}-FYM@20t/ha+ AMF+ *Pseudomonas*+*Trichoderma*+*Azotobacter*	11.1	1.1	18.3	2.3	8.2	1.8
T_{11}-Recommended dose of NPK	9.5	1.0	10.9	1.5	6.9	1.5

Okra CD(treatment) -- 1.5 : CD(years) –1.02 : CD(interaction) –3.3 Tomato CD treatment) --3.9: CD (years) –2.6 : CD (interaction) –8.6
Cowpea CD(years) –0.75 : CD(interaction) – 2.5

Figure 1. IPNM Inokra

Figure 2. Effect of organic manures and biofertilizers on field performance of amaranth.

Figure 3. Organic okra

Figure 4. Organic tomato

Vegetable consumption at household level and its implication on vegetable farming development in Indonesia

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ABSTRACT
The objective of this study was to analyze vegetable consumption at household level and suggest some strategies in vegetable development in Indonesia. Descriptive analysis was employed using secondary data from BPS-Statistics Indonesia and Ministry of Agriculture. In spite of the importance of consuming adequate vegetables for health, nationally representative data showed that vegetable consumption at household level in Indonesia was only 51.19 kg/cap/year in 2008 and during the period 2008-2013 tended to decline. In 2013, data showed that vegetable consumption was only around 40.66 kg/cap/year; much lower than FAO recommendation, i.e., 73 kg per capita/ year. During the same period, vegetable production, on the other hand, showed positive growth, resulting in per capita vegetable production that was higher than per capita vegetable consumption, i.e., 52.74 kg/cap/year in 2012. However, for some vegetables such as spinach, water spinach, string bean, cucumber, and garlic, per capita production was lower than their per capita consumption. Until recently, Indonesia is still a net importer for vegetables, especially for garlic, shallot, and onion. In spite of some problems and constraints it faces, Indonesia has big potential, especially in terms of land and human resource availability, and a good prospect to develop vegetable agribusiness. Some strategies in vegetable development implemented in Indonesia should be directed to efforts to develop production in accordance with needs, increase competitiveness, increase human resource capability, strengthen farmer institutions, and optimize sustainable land use. More investments in infrastructure development and improvement of marketing systems are also needed and interregional cooperation and coordination should be strengthened.

Keywords
Vegetable, consumption, farming development, Indonesia

INTRODUCTION
It is widely accepted that fruits and vegetables are important components of a healthy diet, and that their consumption in sufficient amounts could help prevent a wide range of diseases, including major diseases such as cardiovascular diseases (CVDs) and certain cancers (WHO 2005; Agudo 2005). According to *The World Health Report 2002*, low fruit and vegetable intake is estimated to cause about 31% of ischaemic heart disease and 11% of stroke worldwide (WHO 2002). Overall it is estimated that up to 2.7 million lives could potentially be saved each year if fruit and vegetable consumption was sufficiently increased. Due to the importance of fruits and vegetables for health, FAO/WHO recommends the intake of a minimum of 400 g (or

equivalent to 146 kg per capita per year) of fruit and vegetables per day (excluding potatoes and other starchy tubers) for the prevention of chronic diseases such as heart disease, cancer, diabetes and obesity as well as for the prevention and alleviation of several micronutrient deficiencies, especially in less developed countries (WHO 2003).

In Indonesia, fruit and vegetable are important in supporting national food security. These commodities have a wide diversity and play role as sources of carbohydrate, protein, fiber, vitamin, and mineral. According to Saptana et al. (2005), domestic demand for vegetables has been continuously increasing, in the form of both fresh and processed vegetables, as a result of the increase in population and household income, as well as the development of industry and tourism centers. However, this paper only aimed to assess consumption of vegetables at household level and its implication on vegetable farming development in Indonesia.

Vegetable consumption

Data on vegetable consumption were derived from the SUSENAS (National Survey on Socio-Economy) data published by BPS-Statistics Indonesia (2008-2013), which include the value of purchases, home consumption, and in-kind transfers over a given reference period. Spinach, kangkong, cabbage, petsai, caysim, green bean, string bean, tomatoes, carrot, cucumber, cassava leaf, eggplant, bean sprout, chayote, young jackfruit, baby corn, mushroom, young papaya, shallot/onion, garlic, and chili are among the plants or edible parts of plants classified as vegetable. These vegetables are commonly consumed by Indonesian people. However, only information on vegetable consumption at home was available in the surveys; no information was available on vegetable consumed outside the home. Table 1 summarizes vegetable consumption patterns in Indonesia from 2008 to 2013. Total expenditure and food budget shares are also presented.

Households in Indonesia on average spent a large percentage of their income on food and it ranged from 49.45% to 51.43% during the period 2008-2013. However, Table 1 shows that vegetable expenditure was only a small portion of food budget, ranging from 7.40% to 8.74% during the period 2008-2013. In spite of the increase in the per capita total expenditure, there was a general negative trend of vegetable consumption during the period 2008-2013, from 51.19 kg/cap/year in 2008 to 40.66 kg/cap/year. This negative trend widens the gap between the current vegetable consumption and the WHO/FAO recommendation to consume a minimum vegetable consumption of 73 kg/cap/year (or equivalent to 200 g/cap/day).

Many factors were responsible for this low vegetable consumption in Indonesia. One of them was that the households more focused on meeting the needs of food sources of carbohydrates than vegetables. In Table 1 it is clearly shown that expenditure for cereals and tubers had much larger share of food budget than vegetables, ranging from 16.27% to 19.08% during the period 2008-2013. The data show that cereals and tubers still play important roles as a source of carbohydrates for Indonesian people.

Another factor was the high price of vegetables. During the period 2008-2013, vegetable prices showed a positive trend. This reflects the increase in vegetable price during the corresponding period. The high price of vegetables limited per capita consumption of vegetable products for low-income households and consumption level of horticulture products tends to increase as income increases as reported by Rachman (1997). Higher income associated with the awareness of the nutritional value of vegetables made the consumption level of vegetables higher for the high-income household as presented in Figure 1. However, even the highest-income household consumed vegetables less than the quantity recommended.

On the other hand, since the data used only represent vegetable consumption at home, it is estimated that the actual vegetable consumption is higher than the figures presented in Table 1. This argument is supported by current lifestyle that makes eating outside home more popular. The declining trend of vegetable consumption at home can also be explained by the increase in the budget share of prepared food and beverages during the period 2008-2013 from 22.80% to 25.88%.

Shallots, garlic, chili, kangkong, spinach, string bean, and tomatoes are popular vegetables that are consumed by more than 40% of population of Indonesia. However, Table 2 presents per capita consumption of some important vegetables, wherein all kinds of vegetables show negative growth.

Vegetable production

Data on vegetable production was derived from the Ministry of Agriculture (2013). Table 3 summarizes area harvested, production, and productivity of vegetables in Indonesia, and covers 24 types of commercial vegetables. It shows that vegetable production tended to increase during the period 2008-2012 with average annual growth rate at 3.73% per year. The increase of vegetable production was due to the increase in both area harvested and productivity. However, according to the data, per capita vegetable production in Indonesia was still low, much lower than the recommended vegetable consumption of 73 kg/cap/year.

Table 4 presents production of some important vegetables in Indonesia during the period 2008-2013. While spinach and cucumber showed negative growth during that period, all other vegetables showed positive growth. For some vegetables, the increase in production was determined more by the increase in planted/harvested area. However, for some others, such as shallot, petsai, and cucumber, the increase in production was due to the impact of farming technology implementation. Implementation of farming technology for introduction vegetables or upland vegetables such as cabbage and tomato grew rapidly since 1980 and the highest adoption level was experienced in the 1990s. But farming technology for tropical vegetables or lowland vegetables has been left behind, although some indigenous vegetables such as cucumber and string bean were widely adopted and consumed.

According to Saptana et al. (2005) the vegetable production and marketing system in Indonesia is characterized by the following: (1) small business scale and small capital; (2) farming technology implementation was not optimal; (3) overuse of pesticides; (4) lack of quality seed, which affected the quality of both raw materials and products; (5) high postharvest loss, not only in farming, but also in marketing stages; (6) production arrangement not based on the balance of supply and demand; (6) inefficient product marketing, wherein price was more determined by traders. The results of the production system were low productivity, high yield loss, substandard vegetable quality, seasonal production, highly fluctuating prices, and unguaranteed food safety (Saptana et al. 2005). In this matter, government policy toward provision of adequate infrastructure will support vegetable development in Indonesia.

Matching consumption with production

Figure 2 shows that while per capita consumption of vegetables declined, per capita production increased during the period 2008-2013. As a result, since 2008 vegetable production exceeded consumption. However, even though per capita production of vegetables has exceeded its per capita consumption, it was still fall short of the

FAO/WHO recommendation in the quantity of vegetables consumed, not to mention if we take into account the losses due to the highly perishable characteristics of vegetables. As a consequence, Indonesia has been a net importer of vegetables, as presented in Figure 3 (BPS-Statistics Indonesia 2013c), especially for garlic, shallots, onion, potatoes, and peas. Meanwhile, Indonesia is a net exporter for tomato, cabbage, cauliflower, broccoli, and eggplant. However, as a whole, due to a large import volume of garlic, Indonesia is clearly a net importer of vegetable commodities.

Table 5 shows per capita production for some important vegetables during the period 2008-2012. This table reveals that per capita production of cabbage was much larger than their per capita consumption. Other vegetables such as tomato, cucumber, and chili also showed similar conditions. Meanwhile, per capita production of spinach, kangkong, string bean, eggplant, and garlic were smaller than their per capita consumption.

Problems and constraints in vegetable agribusiness development

In general, problems faced in the development of vegetable agribusiness in Indonesia are mainly discrepancy between vegetable production and market demand or consumer preferences in terms of variety, quality, quantity, and continuity. These problems are related to some constraints as follows: (1) small-scale and spreading vegetable farms, lack of development zones, and sporadic farming system; (2) lack of capital; (3) low technology adoption in nursery, farming, and postharvest handling, which causes productivity and product quality that cannot meet standards; (4) no balance between vegetable production in producing centers and demand in consuming centers; highly fluctuating prices due to seasonal harvest, intrinsic characteristics of vegetables (perishable), and inappropriate postharvest handling; (5) inefficient product marketing, low farmers' share, and long marketing chain; (6) lack of conducive government policies and strategies which cause disincentive for farmers and other marketing actors; and (7) regional government policies to produce various vegetables in order to be self-sufficient, which is less favorable from the point of view of regional economy development (Saptana et al. 2005).

Development strategies of vegetable agribusiness in Indonesia

Indonesia has an abundance of vegetable germplasm and land. On the production side, the potential of vegetable development can still be increased, in terms of farming, postharvest, and processing technology. Based on the result of identification done by Directorate General of Horticulture in 2001, land potential for horticulture development, including vegetable, covered 5.33 million hectares of backyard land, 11.61 million hectares of dry land, 7.58 million hectares of temporary abandoned land, and 9.13 million hectares of forest land (Saptana et al. 2005).

Based on the potentials and also the problems and constraints faced, the strategies of vegetable development should be directed to the efforts to develop production in accordance with needs, create planting/production patterns throughout the year, increase competitiveness, strengthen research and development, capacity building, capital and marketing, as well as optimize sustainable land use and infrastructure supports (Saptana et al. 2005; Sutrisno 2003). The goal is compliance of vegetable production with standards of quality and nutrition, vegetables that are safe to consume, and vegetable production that is competitive and environmentally friendly. Development of vegetable agribusiness should be directed toward increasing farmers' income. However, it should also be directed toward producing vegetables at affordable prices.

According to Saragih (1998), in the future vegetable agribusiness should be market-oriented because consumers demand more details and complete attributes of agricultural products. Vegetable agribusiness development should be done by considering potential of land resources and the agro-ecosystem through a resource-based approach and integrated regional planning. Therefore, a right and well-planned strategy should be arranged to help vegetable development in Indonesia make a significant contribution to national economic development.

CONCLUSION

Average per capita vegetable consumption at the household level in Indonesia is still much lower than the recommended consumption level due to lack of availability, high price, low household income, and the lack of awareness of nutritional value of vegetables. Hence, there is a need to increase the availability of vegetables at an affordable price on the supply side, and to promote the awareness of the benefit of vegetables for health and efforts to increase household income on the demand side. In order to be able to move on all these sides, significant investment in strengthening research and development, capacity building, and advocacy and education are needed. More investment in infrastructure development and marketing systems is needed. Interregional cooperation and coordination should be strengthened.

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Table 1. Summary of vegetable consumption patterns in Indonesia

Description	2008	2009	2010	2011	2012	2013
Household total expenditure (IDR/cap/month)	386,370	398,489	429,922	498,668	511,641	536,771
Food share (%)	50.17	50.62	51.43	49.45	51.08	50.66
Percentage of food budget						
- Cereals and tubers	19.08	17.52	17.30	15.14	17.91	16.27
- Vegetables	8.02	7.72	7.46	8.71	7.40	8.74
- Prepared food and beverages	22.80	24.95	24.87	27.77	24.42	25.88
Quantity (kg/cap/y)	51.19	45.25	44.59	43.88	42.90	40.66
Price (IDR/kg)	3,691	4,190	4,504	5,954	5,489	7,115

[1]The rupiah figures are deflated to 2008 prices using national CPI
Source of data: BPS-Statistics Indonesia 2009-2013a and 2013b

Table 2. Per capita consumption of some important vegetables

	Commodities	2008	2009	2010	2011	2012	2013	Growth[a]
1	Spinach	4.02	3.75	3.96	3.81	3.65	3.49	-2.66
2	Kangkong	4.80	4.43	4.59	4.33	4.22	3.96	-3.67
3	Cabbage	1.93	1.56	1.62	1.83	1.46	1.25	-7.39
4	String bean	3.81	3.49	3.65	3.44	3.08	3.02	-4.35
5	Tomatoes	2.23	1.97	1.93	2.09	1.88	1.72	-4.86
6	Cucumber	2.09	1.83	1.72	1.77	1.56	1.56	-5.39
7	Cassava leaf	5.16	4.12	3.70	3.60	3.23	3.34	-8.01
8	Eggplant	2.92	2.45	2.56	2.56	2.40	2.50	-2.72
9	Shallots	2.74	2.52	2.53	2.36	2.76	2.06	-4.53
10	Garlic	1.72	1.35	1.36	1.35	1.60	1.20	-5.50
11	Chili	3.26	3.05	3.08	2.97	3.27	2.89	-2.07

[a]Average annual growth rate during the 2008-2013 period (%/y)
Source of data: BPS-Statistics Indonesia 2009-2013a and 2013b

Table 3. Area harvested, production, and productivity of vegetables in Indonesia, 2008-2012

Item	2008	2009	2010	2011	2012	Growth[a]
Area harvested (ha)	1,201,375	1,304,235	1,340,884	1,312,311	1,318,616	2.43
Production (ton)	11,106,032	11,940,075	11,863,919	12,232,540	12,845,004	3.75
Productivity (ton/ha)	9.24	9.15	8.85	9.32	9.74	1.39
Per capita production (kg/y)	48.61	51.62	50.67	51.62	52.74	2.10

[a]Average annual growth rate during the period 2008-2012 (%/y)
Source of data: Ministry of Agriculture 2013

Table 4. Production of some important vegetables in Indonesia, 2008-2012 (ton)

No.	Commodities	2008	2009	2010	2011	2012	Growth[a]
1	Shallots	853,615	965,164	1,048,934	893,124	964,195	3.71
2	Garlic	12,339	15,419	12,295	14,749	17,630	11.05
3	Spinach	163,817	173,750	152,334	160,513	155,070	-1.07
4	Chili	1,153,060	1,378,727	1,332,356	1,903,229	1,650,831	11.45
5	String bean	455,524	483,793	489,449	458,307	455,562	0.10
6	Kangkong	323,757	360,992	350,879	355,466	320,093	0.01
7	Cucumber	540,122	583,139	547,141	521,535	511,485	-1.20
8	Cabbage	1,323,702	1,358,113	1,385,044	1,363,741	1,450,037	2.34
9	Petsai	565,636	562,838	583,770	580,969	594,911	1.29
10	Eggplant	427,166	451,564	482,305	519,481	518,787	5.02
11	Tomatoes	725,973	853,061	891,616	954,046	893,463	5.67

[a]Average annual growth rate during the period 2008-2012 (%/y)
Source of data: Ministry of Agriculture 2013

Table 5. Per capita production of some important vegetables in Indonesia, 2008-2012

No.	Commodities	2008	2009	2010	2011	2012	Growth[a]
1	Spinach	0.72	0.75	0.65	0.68	0.64	-2.73
2	Kangkong	1.42	1.56	1.5	1.5	1.31	-1.59
3	Cabbage	5.79	5.87	5.92	5.75	5.95	0.73
4	String bean	1.99	2.09	2.09	1.93	1.87	-1.43
5	Tomato	3.18	3.69	3.81	4.03	3.67	4.02
6	Cucumber	2.36	2.52	2.34	2.2	2.10	-2.72
7	Eggplant	1.87	1.95	2.06	2.19	2.13	3.37
8	Shallot	3.74	4.17	4.48	3.77	3.96	2.02
9	Garlic	0.05	0.07	0.05	0.06	0.07	13.02
10	Chili	5.05	5.96	5.68	8.03	6.78	9.78

[a]Average annual growth rate during the period 2008-2012 (%/y)
Source of data: Ministry of Agriculture 2013

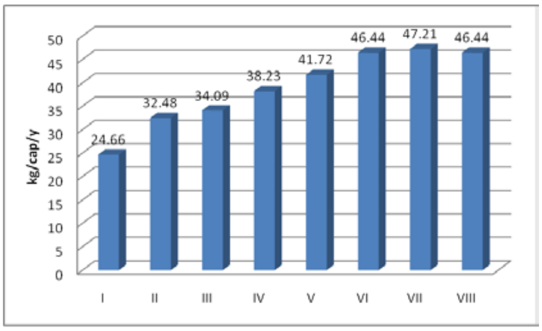

Figure 1. Household vegetable consumption by expenditure group, 2011

Note:	I	=	Less than IDR 100,000/cap/month	0.05% of population
	II	=	IDR 100,000-IDR 149,999/cap/month	1.44% of population
	III	=	IDR 150,000-IDR 199,999/cap/month	5.75% of population
	IV	=	IDR 200,000-IDR 299,999/cap/month	20.82% of population
	V	=	IDR 300,000-IDR 499,999/cap/month	30.94% of population
	VI	=	IDR 500,000-IDR 749,000/cap/month	19.63% of population
	VII	=	IDR 750,000-IDR 999,999/cap/month	9.21% of population
	VIII	=	IDR 1,000,000/cap/month and over	12.16% of population

Source: BPS-Statistics Indonesia 2012

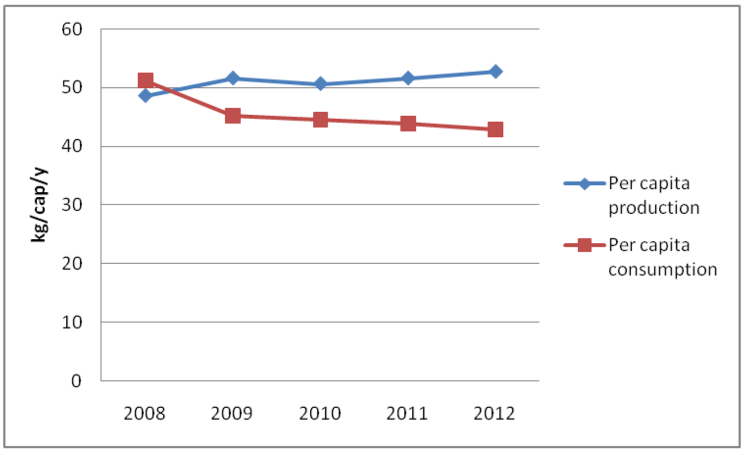

Figure 2. Per capita vegetable consumption and production in Indonesia, 2008-2013
Source: BPS-Statistics Indonesia 2009-2013a and 2013b and Ministry of Agriculture 2013

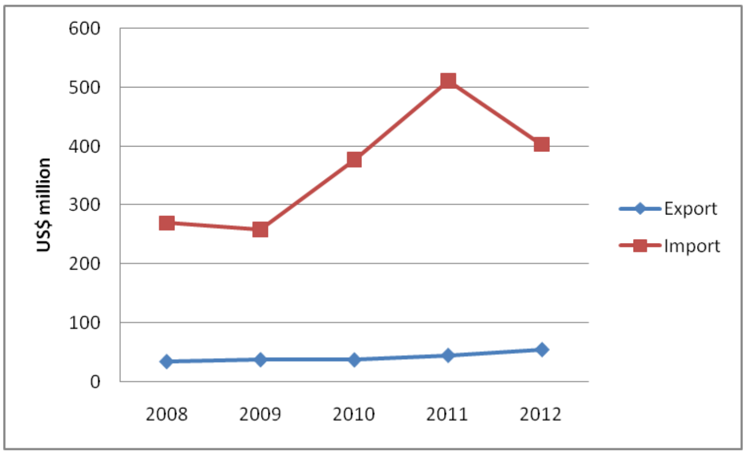

Figure 3. The value of Indonesian vegetable exports and imports, 2008-2013
Source: BPS-Statistics Indonesia, 2013c

Women's home gardens and food security: evidence from Bangladesh

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ABSTRACT

Home-based vegetable production has been recognized as a nutrition- and gender-sensitive intervention that has the potential to improve nutrition in developing countries, yet evidence is lacking. This study tested whether women's training in improved home gardens (including nutrition as well as technical aspects) contributes to increased production and consumption of vegetables, which are necessary preconditions for improving nutrition. The study used data from 582 poor rural women in two districts of Bangladesh (479 control and 103 intervention). The results show that the intervention increased the per capita production of mostly leafy vegetables from 19 to 33 kg per year (+71%). The diversity of production and

frequency of harvesting also increased. In terms of nutrient yields, the improved gardens increased the supply of plant proteins by 150%, iron by 186%, and vitamin A by 248%. The training had a small but significant impact on the diversity of vegetables consumed based on 30-day food frequency data. The training also increased the relative involvement of women in the home garden for all gardening tasks. These results indicate that women's home gardens are an effective intervention in Bangladesh to increase the supply and consumption of a diverse range of vegetables in poor rural households, thereby contributing to nutritional security.

Keywords
Evaluation; gender; homestead gardens; home-based food production; nutrition

INTRODUCTION

The diets of around 2 billion people remain deficient in minerals and vitamins (FAO 2012). Together with hunger, malnutrition is a key constraint to human health in developing countries. Improving nutrition requires the adoption of balanced diets consisting of a diverse range of food products as no single food item contains all the necessary nutrients required for a healthy life. Fruits, vegetables, and pulses are key dietary components rich in micronutrients and plant proteins. Unfortunately, the consumption of fruits and vegetables in developing countries generally falls short of the recommended amount of 400 g/day (WHO/FAO 2003).

Home-based food production systems have received renewed interest in recent years because they have the potential to contribute to improved household nutrition (Berti et al. 2004, Chadha et al. 2012, Gautam et al. 2009, Girard et al. 2012, Jones et al. 2005, Olney et al. 2009, Weinberger 2013). A home garden is an area around a dwelling where different vegetables, fruits and herbs are grown throughout the year for a household's own consumption, potentially integrated with animal production (Keatinge et al. 2012). Home gardens can contribute to improved nutrition by increasing the quantity and quality of foods produced and available for household consumption. Home gardens as well as food preparation are usually in the hands of women. Therefore, the combination of nutrition education and counseling with the promotion of home gardens can be particularly effective (Berti et al. 2004).

However compelling the concept, scientific evidence for the effect of home gardens on nutrition is still weak. In a review of literature on the effect of nutrition-sensitive interventions and programs on maternal and child nutrition, Ruel et al. (2013: 539) concluded that there is little evidence of the effectiveness of homestead food production, with the possible exception of vitamin A status.

Against this background, the objective of this study is to test the hypothesis that homestead vegetable gardens contribute to nutritional security. More specifically, this study assesses the short-term effect of women's homestead vegetable gardens on their vegetable production, households' consumption, and dietary diversity. The study is based on data from Bangladesh.

Bangladesh has achieved a marked decrease in both poverty and hunger, albeit from initially high levels. The prevalence of undernourishment decreased from 34.6% in 1990-92 to 16.8% in 2010-12 (FAO 2013). Yet the prevalence of malnutrition in rural Bangladesh is still among the highest in the world (ibid.). For example, stunting affects 42.2% of the female and 40.7% of the male children under the age of five (World Bank 2013). Increased vegetable consumption could help improve nutrition, but consumption is still below the WHO-recommended amount of 200 g/day. Mia et al. (2013) estimated vegetable consumption for mothers in three districts (Jessore, Barisal and Faridpur) to be 117 g/day, of which only 3 g/day were leafy vegetables.

In Bangladesh, home gardens have been promoted for decades by international and local NGOs as well as the Bangladesh Agricultural Research Institute (BARI) (Talukder et al. 2000, Bloem et al. 1996). For example, Helen Keller International has established home gardens for 900,000 households since 1990, combined with nutrition education (Iannotti et al. 2009). The home gardens increased the quantity of the households' food production within three months from 46 to 135 kg (Helen Keller International, 2004) and increased vitamin A intake among women and children (Bushamuka et al. 2005).

METHODS & DATA

Intervention and targeting

The home garden intervention evaluated in this study is part of a USAID-funded project. One of the aims of the project is to train several thousand women in nutrition and improved home gardens in a year. In 2013, 3,500 women were trained. The intervention focuses on the introduction of improved nutrient-rich vegetable varieties suitable to grow in a home garden. It included water spinach (or kangkong; Ipomoea aquatica), Indian spinach (or Malabar spinach; Basella alba), stem amaranth/red amaranth (Amaranthus spp.), okra (Abelmoschus esculentus), yard-long bean (Vigna unguiculata subsp. sesquipedalis), cucumber (Cucumis spp.), sweet potato (Ipomoea batatas) for vines and young shoots, and bitter gourd (Momordica charantia).

Women received a one-day intensive training focusing on nutrition and garden establishment. The nutrition training taught the importance of nutrition in preventing diseases, functions of various nutrients in the human body, and differences of vegetables with regard to nutrient content. It also taught cooking methods that optimally preserve the nutritional content of vegetables. Each training participant was visited afterwards to provide assistance in setting up the garden. The training participants were encouraged to share the learned knowledge with neighboring women after the training.

Those eligible for receiving project support had to meet the following criteria: First, the household must own less than one acre (0.40 ha) of land. This excluded the landless poor, who are likely to have the highest prevalence of malnutrition; home gardens are not a suitable intervention for this group. Second, priority was given to households with at least one child below the age of five. Third, the women must have some experience in growing vegetables, but have not previously received any similar type of intervention. Also, they should have an interest to participate in the project.

Methodology

Selection bias was minimized by comparing women who had received the project intervention in 2012 with women who had been identified by the project to receive the intervention in the subsequent year. The study thus makes use of the roll-out design of the project to identify a valid counterfactual. The fact that the same targeting criteria were applied to select the intervention and control group should ensure that the two groups are truly comparable. Although the project targeted different sets of villages in each year, there are no evident reasons to believe that the two groups had different characteristics (observable or unobservable) prior to the project intervention. Hence, selection bias should not be an issue. This can be verified in part by testing for significant differences in some key variables that can affect project outcomes such as land size, women's age, and compound area.

Data

Data were collected from two districts, Barisal and Jessore, where the intervention had taken place in 2012. To represent the intervention area, six upazilas (two for the intervention and four for the control) were purposively selected in each district (Table 1). Sample villages were selected from a list of all villages in selected upazilas. To get a self-weighted sample, the probability of selection was proportionate to the village size. Within each selected village, households were sampled randomly from the list of women who had or would participate in the training. The data were collected using a structured questionnaire during April-May 2013. Only women were interviewed for this study.

The study used a range of outcome indicators to quantify the effect of homestead vegetable gardens on households' vegetable production and consumption, but it did not address nutritional outcomes. Production data were collected using a 12-month recall period, separated for the two main seasons in Bangladesh (summer and winter). Indicators include the quantity of harvested produce from the garden and the frequency of planting and harvesting.

Consumption data were collected using a 30-day food frequency questionnaire. Following Hoddinott (1999), the weighted sum of the number of different vegetables consumed by the household over a 30-day period was calculated and then converted into an index using the minimum and maximum values as observed in the data.

RESULTS

Household characteristics

Table 2 shows that control and intervention households did not significantly differ in observable household characteristics other than the number of children below five years and the percentage of households with children below five years. Nevertheless, the results indicate the absence of a clear selection bias. Therefore, the control and intervention groups can be meaningfully compared.

Vegetable production and use

Table 3 shows that all women who were trained allocated a bigger space for home gardening. In total, the intervention group harvested on a weekly basis for a period of 10 out of 12 months. Aside from the significant differences in garden size and harvesting frequency, trained women planted a more diverse range of vegetables.

The average amount of harvested vegetables from the homestead garden was significantly ($p<0.01$) greater for the intervention group (33 kg/capita/year) than for the control group (19 kg/capita/year) (Table 4). This suggests that the training led to a 71% increase in the quantity of vegetables harvested from the garden. The results clearly show that leafy vegetables were the dominant type of vegetables for women who received the training, while cucurbits were the most important vegetable for the control group, accounting for 50% of the overall harvest. The results do therefore provide conclusive evidence that the training greatly increased the supply of food to the household through home gardening.

To understand how increased homestead vegetable production affects the household diet one needs to know how the harvested produce is used. Three quarters of the homestead vegetable produce is consumed within the household (Table 5). Of the remainder, 14-15% is shared with other households and 10-12% is sold.

The results of the 30-day food frequency data showed that intervention households have a slightly greater diversity in their vegetable consumption. On average, the intervention group consumed one additional type of vegetable ($p<0.01$) and their diversity index was slightly greater.

In the production aspect, women who received training in homestead vegetable gardening could provide the household an average of 90 grams per capita per day, whereas this was only 52 grams/capita/day for the control group. Improved home gardens can thus supply about 45% of the recommended per capita vegetable intake of 200 grams per day.

Role of women in the vegetable garden

The time spent per day in the home garden by women was 11 minutes for the intervention group and 4 minutes for the control group (Table 6). Generally, children were not involved in the home garden and the intervention did not change their involvement (not shown). Results suggest that the intervention increased the relative involvement of women in the home garden for all gardening tasks. Although the results suggest that homestead vegetable gardens helped empower women to some extent, a clear gender gap persists even with regard to home gardens.

DISCUSSION

This study showed preliminary results about the effect of homestead vegetable gardens on the production and consumption of vegetables in Bangladesh. The results are preliminary as they rely only on cross-sectional data on the immediate effect of home gardens one year after women were trained in nutrition and gardening. A follow-up survey is planned to verify these results and produce a more robust estimate of the average treatment effect using a double difference method.

The results of this study confirm the very positive effect of home gardens as reported by Bushamuka et al. (2005). That study reported a median vegetable production of 135 kg over three months for households participating in a gardening program and 46 kg for the control. However, it is problematic to compare these studies because home garden programs can be very different in the type and intensity of training, targeting, support, and vegetable varieties.

Evaluations of home gardens in Bangladesh as well as elsewhere have mostly been quantitative. There is a need for more qualitative studies to understand how home garden interventions affect the livelihoods of women and children. Gender aspects in particular need further study to determine if improved home gardens help women to gain more control over resources within the household.

CONCLUSION

A comparison of data for 103 women who received training in nutrition and in setting up a homestead vegetable garden and 479 women who did not indicates that the intervention: a) nearly doubled the area of the home garden; b) induced the growing of leafy vegetables; c) allowed the women to harvest more regularly from the garden; d) substantially increased vegetable production; e) gave a small but significant increase in the diversity of vegetable consumption based on a 30-day recall; and f) strengthened women’s control over the homestead garden and significantly increased their involvement in activities that involve money. These positive findings strongly indicate that combined training in improved home gardens and nutrition makes an effective contribution to nutrition security.

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Table 1. Sample selection and stratification

Administrative level	Control	Intervention
Districts	2	2
Upazilas (subdistricts)	4	2
Unions	14	5
Villages	14	8
Households	479	103

Table 2. Household characteristics of intervention and control groups (average per household), 2013

Household characteristic	Control (N=147)	Intervention (N=103)	Sign.
Household size (persons)	4.74	4.63	ns
Adults (persons)	2.83	2.95	ns
Children below 5 years (persons)	0.63	0.34	***
Children 5-17 years (persons)	1.29	1.34	ns
Households with children below 5 years (%)	58.04	32.04	***
Male (%)	48.76	47.99	ns
Female (%)	51.24	52.01	ns
Cultivatable area on the compound (m2)	43.66	44.90	ns
Received credit (%) b	48.85	41.75	ns
Households who experienced a food shortage (%)a	80.58	76.41	ns

Notes: Significance levels: ***p<0.01, **p<0.05, * p<0.10, ns=not significant (p≥0.10). a Refers to the past 12 months. All other rows refer to the situation at the time of the interview.

Table 3. Comparison of garden management between the control and intervention groups (average per household), 2012-2013

Management aspect	Control (N=147)	Intervention (N=103)	Sign.
Area of land used for the home garden (m2)	17.37	44.98	***
Months with weekly harvesting	3.98	10.16	***
Summer			
# of different crops planted	2	6	***
Planting frequency	1	8	***
Harvesting frequency	16	63	***
Winter			
# of different crops planted	2	5	***
Planting frequency	1	6	***
Harvesting frequency	18	45	***

Notes: a Significance levels: ***p<0.01, **p<0.05, * p<0.10, ns=not significant (p≥0.10).

Table 4. Comparison of the quantity of vegetables harvested between the control and intervention groups, in kg per capita per year, 2012-2013

Crop	Control (N=147)	Intervention (N=103)	Sign.
Cucurbits	10.73	11.03	ns
Roots and tubers	0.58	1.56	**
Beans and pulses	3.69	2.56	ns
Leafy vegetables	2.97	13.95	***
Other vegetables	1.2	3.75	***
All vegetables	19.17	32.85	***
Average daily vegetable supply (gram/capita/day)	52.53	90.00	***

Notes: a Significance levels: ***p<0.01, **p<0.05, * p<0.10, ns=not significant (p≥0.10).

Table 5 Comparison of usage and diversity of vegetable consumption between control and intervention groups, 2012-2013

Usage/consumption aspect	Control (N=147)	Intervention (N=103)	Sign.
Use of the produce (%)			
Consumed within the household	75	74	ns
Shared with others	15	14	ns
Sold	10	12	ns
Number of different vegetables eaten	11.0	12.0	***
Vegetable diversity index (0-1)	0.28	0.33	***

Notes: a Significance levels: ***p<0.01, **p<0.05, * p<0.10, ns=not significant (p≥0.10).

Table 6 Time and rate of women participation in vegetable gardens, 2012-2013

Activity	Control (N=147)	Intervention (N=103)	Sign.
Total time spent on gardening (minutes/day)	4.4	10.6	***
Involvement of adult women per activity (%):			
Land preparation	46	57	***
Planting	54	78	***
Buying inputs	10	30	***
Weeding	52	78	***
Watering	55	78	***
Harvesting	55	89	***
Selling	11	33	***
Receiving the revenues	13	37	***

Notes: a Significance levels: ***p<0.01, **p<0.05, * p<0.10, ns=not significant (p≥0.10). Data refer to adult women only.

Thai consumer valuation of food safety labels on fresh produce

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ABSTRACT
Food safety has been considered a prominent issue in Thailand for a decade. Food safety labels (e.g., Q mark from the Ministry of Agriculture and Cooperative) were introduced to the market in order to assist consumers to recognize safe products, particularly fresh produce, which is the main concern of Thai consumers. However, there is no clear evidence on the value Thai consumers place on the labels and this is reflected in the reluctance of the fresh produce industry and particularly producers to comply with regulations to obtain certification and the label. This hinders the development of a market for safe fresh produce. It could also be a key constraint for the Thai government in its effort to present Thailand as “Thai Cuisine to the World” and for the industry to compete in the ASEAN Economic Community in 2015. This study is aimed at estimating the value Thai consumers place on food safety labels for fresh produce using a discrete choice experiment. The primary data were collected through a survey aimed at eliciting consumers’ preferences and willingness to pay (WTP) for Chinese cabbage, trading off between different types of food safety labels and private brands, price, and freshness. A sample of 350 Thai consumers took part in the survey administered at different locations in Bangkok and the surrounding area in July 2013. Multinomial Logistic Regression (MNL) was used to analyze the data. Results suggest that consumers value quality labels (i.e., Q mark, Royal Project brand plus Q mark, and Doctor's Vegetable plus Q mark). Freshness, brand and label, and price are all considered relevant attributes by consumers. We conclude by discussing the implications of our findings for businesses and policy makers.

Keywords
Thai consumers, Food Safety label, Discrete Choice Modelling, MNL, Chinese cabbage

INTRODUCTION
Food safety scares (such as mad cow disease, dioxins, avian flu, melamine contamination and *Escherichia coli* outbreaks) have raised awareness about food safety issues among consumers. The series of food scandals have not only reduced consumers’ confidence in food safety, but also threaten sustainability of food industry and trades. Usually, when consumers learn of a food safety incident and the

possibility that certain food is unsafe, they might simply stop consuming that type of food; hence, the specific food sector is heavily damaged (Mazzocchi et al. 2008). Food safety standards and labels are one of the tools used by several governments and firms to cope with food safety issues in the supply chain (e.g. Caswell 1998; Golan et al. 2004; Henson and Humphrey 2009; Hammoudi et al. 2010). In Thailand, however, most standards and regulations are weakly enforced on the domestic market compared to exported products, which are more strictly controlled by importer regulations and voluntary private standards (e.g. Global GAP in the EU) (Oates 2006; Takeuchi and Boonprab 2006). Food safety scandals still remain a prominent issue in domestic markets, for instance scandals related to chemical residues on some fresh produce (e.g. Chinese Kale and chili), an outbreak of *Clostridium botulinum* contamination in home-canned bamboo shoots. As a result, Thai consumers have increased awareness of the importance of food safety controls and are now more demanding regarding the quality and safety of food products, especially in urban areas (e.g. Posri et al. 2006; Takeuchi and Boonprab 2006; Roitner-Schobesberger et al. 2008; Lippe 2010; Lippe et al. 2010).

In order to meet consumer demand and to increase the level of food safety assurance provided by the market, the Thai government tried to strengthen regulation in the domestic market and to introduce a voluntary standard and the related food safety label in the market. In 2004, the government enacted a food safety policy named 'From-Farm-To-Table' or 'From-Farm-To-Forks' aimed at ensuring food safety monitoring and control system throughout the food chain [The National Bureau of Agricultural Commodities and Food Standard (ACFS 2011)]. Subsequently, in 2005, ACFS established a voluntary food safety label named "Q mark[1]" as an attempt to achieve food safety goals, to encourage competition in product markets, and to provide information to assist consumers in recognizing safe products, particularly fresh produce, that are the main concern of Thai consumers (Vanit 2006; Lippe 2010). Currently, Q mark is one of the dominant food safety labels for fresh produce in the Thai market.

Q mark products, however, have been distributed mainly through supermarket chains, while most Thai consumers still buy fresh produce at fresh markets. A majority of consumers are not aware of or do not understand the meaning of this label. Hence, the fresh produce industry and particularly producers hesitate to comply with regulations to obtain this certification and label, because they are uncertain about whether they will obtain the premium price to compensate the investment needed to comply with the standards. This hinders the development of a market for safe fresh produce. It could also be a key constraint for the Thai government in its effort to present Thailand as “Thai Cuisine to the World[2]” and for the industry to compete in the ASEAN Economic Community in 2015.

To facilitate the food safety label policy, consumers' preferences and willingness to pay (WTP) for a food safety label should be investigated. Thus, the social desirability of a food safety label could be pointed out for policy decision making. Furthermore, the study on consumers' preferences and WTP for different

[1] According to TACFS 9005-2548 (2005), section 4, in order to use Q mark, the primary production processes at farm level have to be in accordance with the requirements of national GAP (Good Agricultural Practices) standards and be certified by the certification body (CB); the production process and post-harvest activities (e.g. packing house facilities) have to conform to GMP (Good Manufacturing Practices) or HACCP (Hazard Analysis and Critical Control Points) and must be certified by the CB; the operators must observe procedures for tracing products and complying with traceability requirement; and products using Q mark will be tested for quality and safety.

[2] The Thai government's policy to promote Thailand to be the Kitchen of the World. It aims to promote Thai food to be one of the favorite food recipes all over the world, including export of raw materials and additional ingredients for Thai recipes with the highest creditability in safety, health and sanitation (http://www.thaifoodtoworld.com)

attributes of fresh produce (e.g. price, freshness, brand and label) is important for stakeholders (i.e. producers and firms) to take into account when they make a decision on production or marketing activities. For instance: which production system and certification schemes to apply, which is the market segment, which marketing tools should be used to promote the products, and what are reasonable prices to charge?

To the best of our knowledge, there is very little literature regarding this topic in Thailand. This study is aimed at filling this gap by estimating the value Thai consumers place on food safety labels for fresh produce, using a discrete choice experiment. Chinese cabbage is a representative product because it is a common fresh vegetable that Thais consume both raw and cooked on a regular basis. It is also the vegetable that Thai consumers are moderately concerned about because of chemical residues, and therefore, they might look for the guarantee of food safety before making a decision. Q mark is the main food safety label involved, while claimed[3] "Safe Produce (ผักปลอดสารพิษ)" and private brands (i.e. Royal Project "โครงการหลวง" and Doctor's Vegetables "ผักด็อกเตอร์") are also included in this study due to their existence and importance as brands and labels related to food safety in the market. Finally, we discuss possible suggestions for policy makers and the industry.

CHOICE EXPERIMENT TO ELICIT CONSUMERS' WTP

There are several techniques that could be employed to measure WTP. The choice experiment is one of the techniques that has been most used to elicit WTP of consumers for certain food attributes (e.g. Burton et al. 2001; Alfnes 2004; Rozan et al. 2004; Loureiro and Umberger 2007), particularly in situations where market data are non-existent or unreliable (Tonsor et al. 2009). In a choice experiment, respondents are asked to choose their preferred alternative among hypothetically constructed scenarios, where each scenario is a function of different attributes of the product (including price) and each attribute varies at different levels. By observing the changes in respondent stated choices with variation in the scenarios, the effect of the attributes on the choices can be derived. The advantage of choice experiment is that it allows the researchers to combine different product attributes that may or may not already exist in the market and force respondents to trade off one attribute against another (James and Burton 2003). Nevertheless, one main concern when using this technique is the potential presence of hypothetical bias[4] (Neill et al. 1994), a problem that is common to all the WTP elicitation techniques that rely upon stated preferences and that could be limited by using cheap talk[5] before the experiment (Silva et al. 2011).

A number of studies have attempted to examine consumers' valuation for food labels using choice experiments. For instance, Caputo et al. (2013) estimated WTP of food miles labels on cherry tomato, plum tomato, and beefsteak tomato and concluded that Italian consumers are willing to pay a price premium for food miles labels. Sackett et al. (2012) studied US consumers' WTP for sustainably produced steak and apples and found that the consumers have positive WTP for local, sustainable, and organic labels. Lippe et al. (2010) evaluated the preferences and WTP of consumers in Thai urban areas (Bangkok and Chiang Mai) for pesticide-safe cabbage and

[3] It is only a 'claim' without the guarantee or inspection from the government authorities or third parties.
[4] Respondents might overstate WTP in the hypothetical situation due to the lack of incentive to state the real amount.
[5] The script explains the problem of hypothetical bias to participants prior to administration of a hypothetical question. The premise behind this technique is that one might be able to reduce or eliminate the bias by simply making respondents aware of it regardless of its underlying cause.

concluded that Thai consumers in urban areas are willing to pay higher prices for safety labelled fresh fruit and vegetables.

METHODS

The data used in this study are drawn from a survey administered to a sample of Thai consumers during July 2013 in Bangkok and Nonthaburi, Thailand. Quota sampling according to the shopping outlets and convenience sampling methods were adopted to reach the target number of respondents (350). Fifty-seven percent of the respondents (200 persons) were recruited at the fresh markets and the rest (150 persons) were recruited at the supermarkets because Thai consumers still buy fresh vegetables mainly from fresh markets (Lippe et al. 2010). The questionnaire was administered face-to-face by trained interviewers in two fresh markets (Yingchareon Market and ATK) and three supermarkets (The Mall, Ngamwongwan, TOPs market, Kaset and Tesco Lotus, Bangsue) on weekdays and weekends and at different times of the day to cover a wide range of consumer types. Interviewers stayed near the fresh fruits and vegetables shelves and asked consumers to participate in the survey on a voluntary basis. Before the interview started, interviewers asked three screening questions related to: whether the participants were aged above 18 years old; whether they were the main household food shoppers; and whether they consumed vegetables and cabbages. If the respondents said yes to all questions, the interview started; otherwise the interviewers dropped the respondent. The interviews were conducted in Thai language and lasted 10-15 minutes.

The questionnaire comprised 4 parts: (1) dietary habits and consumption patterns; (2) choice experiment; (3) knowledge and attitudes of food safety and food safety label; and (4) household characteristics. The questions were the closed-form with multiple choice answers. In the attitude section, respondents were asked to give their opinion toward statements according to the 5-point Likert scale, from 1 (Strongly disagree) to 5 (Strongly agree). For the choice experiment part, respondents were presented with a set of 12 simulated choice shopping tasks and they were asked to choose a preferred alternative from two Chinese cabbages and a no purchase option. Each of the cabbage products was described and presented to respondents in terms of three attributes (price, freshness, and brand & label) at different levels. Table 1 shows the attributes and attribute levels evaluated in the choice experiments. As mentioned earlier, we considered 4 types of brand & label: “Q mark”, which is the main food safety label in the market; a label claiming “Safe Produce” ("ผักปลอดสารพิษ") which is widespread throughout the market; and two private brands “Royal Project” and “Doctor's Vegetables”, which are among the most well-known fresh produce brands in the market and are considered high quality, safe brands. Note that most products from these private brands have obtained the Q mark; thus, Q mark always appeared together with them in this experiment.

Prior to the choice experimental part, respondents were informed that the cabbage products presented to them differed only in terms of the three attributes described, and that all other attributes were identical. They were also informed about the meaning of each considered attribute. The choice situations were presented by using pictures and clear labelling to aid respondents' understanding (see example in Figure 1). The choice questions were presented in randomized order across respondents to mitigate any ordering biases (Loureiro and Umberger 2007). We also included a “Cheap Talk” script to be presented to the respondents right before the choice question to minimize the potential hypothetical bias in the responses.

Descriptive statistics analysis was used to describe Thai consumer characteristics in terms of socio-demographics, consumption habits and perception toward food safety and label. Mann-Whitney U tests (Mann and Whitney 1947) were employed to compare characteristics and attitudes between consumer groups (fresh market and supermarket). The choice experiment data were analyzed using a random utility framework (Marschak 1960). The multinomial logit model (MNL) for main effects was applied to analyze data using the package mlogit (Croissant 2012) available in the statistical software R2.14.2 (R Core Team 2013). Willingness-to-pay (WTP) for each attribute levels of 'brand & label' attribute were calculated by dividing the differences between the coefficient of each brand & label attributes and coefficient of reference level (no information) by the coefficient of price.

RESULTS

Consumers' socio-demographic characteristics and consumption habits

A total of 350 respondents completed the survey and the selected demographic attributes are provided in Table 2. The majority of respondents were female (86%), as expected when targeting the persons responsible for food shopping for Thai households. The average respondents are 43 years old. The majority of respondents had a University Degree (58% of respondents), i.e. Bachelor, Master or Doctoral Degree. The average household income was between 40,000 to 54,999 baht/month. However, income levels of respondents were quite diversified, ranging from lower income level (e.g. 10,000 - 24,999 baht/month) to upper income level (more than 70,000 baht/month). More than 25% of respondents were in the upper income level. Around 21% of respondents had children aged less than 8 years old at home and 23% of respondents had children between 9-15 years old at home. Comparing respondents at the fresh markets and supermarkets using Mann-Whitney U test, the age range ($z = -2.733$, $p = 0.006$), education ($z = -3.000$, $p = 0.003$) and frequency of fresh produce purchasing ($z = -3.243$, $p = 0.001$) were significantly different. Respondents at the fresh markets had higher average age range, lower average education level (high school) and higher frequency of purchasing (4 or more times per week).

We found that the respondents' characteristics are consistent with Bangkok census data in 2011 on average age (30-40 years old), average household income (48,951 baht/ month) and average highest level of education (high school). Nevertheless, the high proportion of higher education respondents might be due to the fact that the TOP supermarket (Kaset) is located near a University and several Government Offices; hence most of their customers have higher education levels. The high proportion of older respondents might be because older people have more time and tend to cooperate more in surveys, whilst the high numbers of respondents with an upper income level may be due to the fact that ATK is a high-end market, where quality products are sold at a high price.

Regarding fresh produce consumption habits, more than 67% of respondents purchased fresh produce at least 2-3 times per week. In addition, more than half of respondents had bought products with Q mark (61%) and Royal Project brand (79%) from time to time.

Consumers' perceptions toward food safety and food safety labels

Three hundred and forty seven respondents completed all the questions in this section. Most of the respondents were neutral or agreed with the statements. From the pooled sample, respondents agreed with the following statements: eating fresh produce is risky because of chemical residues or biological contamination; fresh vegetables with natural defects (e.g. holes made by pests) are safer; I have confidence in the safety of products certified by the government agency; and I am willing to pay more for fresh vegetables with food safety label. They tended to be neutral regarding the following statements: the quality and safety of fresh vegetables has been improving in recent years with respect to 10 years ago; the higher price of fresh vegetables may indicate better quality and safety of the products; I have confidence in the safety of fresh vegetables sold at reputable stores; I have confidence in the safety of products certified by private companies, international organizations and claimed "Safe Fresh Produce" labels.

We made a comparison between the respondent groups using the Mann-Whitney U test, and we found that perceptions toward the statement "I consider fresh vegetables with natural defects safer than others" were significantly different ($z = -3.358$, $p = 0.001$). Consumers shopping at fresh markets had a significantly higher mean value (3.89) than consumers at supermarkets (3.61). In other words, consumers at fresh markets thought that fresh vegetables with natural defects were safer than others. This means that consumers at fresh markets use appearance as an indicator of food safety more than the ones shopping at supermarkets.

The results indicate that respondents are not sure whether the quality and safety of fresh vegetables nowadays are better than before and they are aware of food safety risk from chemical residues or biological contaminations. This infers that there is a lack of confidence in fresh produce food safety in the market. For the surveyed respondents, price is not an indicator of higher quality and safety. On the other hand, natural defects (product appearance) are used as an indicator of safe fresh vegetables. Regarding trust in certification bodies, it seems that respondents have more confidence in the government agency than others. Finally, 70% of respondents said they are willing to pay more for food safety labelled vegetables.

Consumers' preferences & WTP for food safety label on Chinese cabbage

The parameter estimates of the MNL models are listed in Table 3 while Table 4 exhibits the marginal WTP values for the brand & label attributes. All coefficients of the model except Claimed "Safe Produce" label are significant at 1% significance level. This implies that attributes chosen in this research (freshness, price, and brand & label) are all considered as relevant attributes by consumers. The constants for the purchase of cabbage (options A and B) are positive and significant, meaning that consumers are willing to pay a price to purchase the product.

As expected, the coefficient for the price is negative, indicating that an increase in price will decrease consumer's use and lower the probability to buy. Regarding freshness attribute, cabbage that was harvested 2 days ago was less preferred by consumers, while produce harvested today and yesterday were similar in preference. With respect to brand & label attribute, the coefficients of "Q mark", "Royal Project & Q mark", and "Doctor's Vegetables & Q mark" attributes were significantly positive, suggesting that the use for Chinese cabbage with these brands & labels will be higher than for the one without a label. The coefficient of Claimed "Safe Produce" label is not significantly different from the overall average, implying that consumers give value to this label more than no information but less than the other labels. However, all coefficients of parameters in brand & label attribute (except claimed label) are not significantly different between them, implying that consumers do prefer to have a brand or label over nothing and over a claimed label, but they do not care too much about which label is presented.

With regard to our findings on brand & label information, consumers are willing to pay a large premium for branded & labelled cabbages compared to cabbage without information. This means that products with Q mark, Royal Project & Q mark and Doctor's Vegetables & Q mark are strongly preferred and would certainly gain a premium in the market relative to cabbage without any information.

It should be noted that the values calculated from the models are the average maximum values that the consumers are willing to pay to obtain the cabbage for their use—that is, the threshold beyond which they would more likely decide to keep their money in their pocket. It is not the recommended price to be set for the products with brand & label, because it is the level of premium that would make the consumer surplus equal to zero and might lower the probability that consumers will buy the product.

DISCUSSION AND CONCLUSIONS

We assessed Thai consumers' preferences and WTP for food safety labels and other relevant attributes of fresh Chinese cabbage using choice experiments. We found that freshness, price, and brand & label are all relevant attributes to Thai consumers. Freshness is the most significant attribute, followed by brand & label, and price. In agreement with previous studies (Lippe 2010), freshness is the most important attribute affecting Thai consumers' decisions to buy fresh produce. From the attitude part, we found that most consumers agreed or strongly agreed that fresh vegetables with natural defects (e.g., holes made by pests) are safer than others. The reason that consumers relate physical appearance with safety of products might contribute to the fact that food safety and quality are not easy to identify at the sale point; therefore, consumers tend to rely upon extrinsic factors such as freshness, appearance, labels, certifications, and brand names in their purchasing decision (Verbeke 2005; De Jonge et al. 2007; van Rijswijk and Frewer 2008).

The results suggest that surveyed consumers are willing to pay a premium price for Q mark, Royal Project & Q mark, and Doctor's Vegetables & Q mark labelled products over unlabelled ones. They are also ready to pay a lower premium for Claimed "Safe Produce" label, showing their need to be reassured about food safety. This finding implies that when providing such information (food safety) with certain guarantees (by certification and/or brands or, at a lower degree, simply with a claim), consumers are better off (having higher utility). Thus, food safety labels based on a reliable and properly enforced quality assurance system would be socially desirable, since they could reduce asymmetric information between seller and buyer and reduce searching time and cost for consumers (Caswell 1998; Giannakas 2002; Jahn et al. 2005). The premium prices in this study indicates the perceived need to have safer food available on the market and social desirability to be informed by food safety labels. In other words, Thai consumers have low confidence in the food safety of fresh produce products in the market or have low trust in the mandatory regulation, so that they search for an "extra" guarantee in terms of certification or well-known brands (Henson and Northen 2000; De Jonge et al. 2007). Hence, if the government is not able to increase its investments in enhancing the overall food safety level, the food safety label policy should be supported and continued in order to improve the market of safe fresh produce products.

We found that consumers are willing to pay for any guaranteed brands and labels, so, for them, a specific brand & label does not matter; they prefer just to have an additional guarantee. Consumers' indifferent feelings toward brands and labels could bring benefits and drawbacks. The positive aspect is that there is room for food safety labels in the fresh produce market. The private sector could use food safety labels to signal to consumers that products are safe, and trusted brands and labels could become a tool to differentiate products and to enhance the competitiveness in the high-value market (Henson and Reardon 2005). On the other hand, the need for reassurance may provide market incentives for fake or self-claimed labels as well, if consumers do not receive correct information or are not well-informed regarding the labels. It should be noted that surveyed consumers placed a value on “claimed” labels less than on the other labels because we informed them about the meaning of "claimed" label in advance. In the study, surveyed consumers were in a position to understand that claimed label does not possess any real guarantee in terms of certification, but it was only based on trust in the claimer; however, they attributed some additional value to claimed safety compared to no information. Apparently, information provision to consumers is vital for food safety label.

The results from the attitude part indicate that Thai consumers have higher confidence and trust in government certification over private certifications; hence, the Q mark could be the most promising food safety label in the market. However, the results from the experimental part show that there is no significant difference between government-led and well-known private brands suggesting that both government labels and private brands have a chance in the market. Nevertheless, government agencies must play an important role in disseminating knowledge and information regarding food safety and food safety labels in order to mitigate the risk of consumer deception by fake or self-claimed labels.

For producers and private firms, our results suggest that there is a need for higher food safety levels in the fresh produce supply chain. There is a potential market share for fresh produce products bearing food safety labels, so that they can be used to differentiate the products from competitor products. Producers applying for food safety certifications and labels should have a better chance to approach (especially large) retailers in the middle and high-end markets. This is confirmed by the fact that five large retail chains (Siam Makro, Central Food Retail, CP All, Tesco Lotus, and Big C) signed an agreement to support and distribute food products with ThaiGAP certifications (certification for good agricultural practices, which is one of the food safety certifications applicable at farming level (Thai Post 2013).

Since the respondents in this study were mainly from the city of Bangkok and the surrounding area, the study findings cannot be generalized to Thailand as a whole. However, the results can serve as an input for a wider study to be extended in other areas of Thailand. An important limitation is that, although we chose to put brand & label attributes together with the Q mark to be more realistic, this implies a drawback that with this design we cannot separate the effect of private brands (Royal Project and Doctor's Vegetables) from the effect of the certification label (Q mark): we only know that the cumulated effect is not different from the effect of Q mark alone. In further research, brand attribute and label attribute could be separated in the experimental design to define the effect of each attribute on consumer preferences. In this case, an interaction term between attributes and consumer characteristics and/or consumption pattern should be included in the design. Consumers’ perception toward food safety & label and its effect on consumers' preferences should be tested as well. Furthermore, the impact of information of brand & label on consumers' preferences should be tested to confirm our assumption regarding importance of information for the food safety label policy.

As a final remark, we point out that our results suggest that food with a safety label is beneficial for Thai consumers. Hence, the food safety label policy should be supported to achieve food safety targets and to provide consumers with information and protection from deception. Information and trust are vital for the policy as they are the main components in the food market. The Q mark is currently the most promising food safety label because it could be accessed by all small farmers and can be found in all markets; however, the improvement of the credibility of the system and the enforcement of the regulation are crucial and urgently required. The dissemination of information regarding food safety, certification and labels should be able to effectively reach consumers. Finally, food safety labels can be used as an incentive to promote safe production/consumption in accordance with the international trend. This would be necessary for Thailand in the light of the strategy of positioning itself as “Thai Cuisine to the World”.

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Table 1. Attributes and levels of fresh Chinese cabbages used in the choice experiment.

Product attribute	Attribute level
Price	25, 50 (average market price in June 2013), 75, 100 baht/kg
Freshness (day after harvest)	0 day (today), 1 day (yesterday), 2 days (2 days before)
Brand and Label	No information, Claimed “Safe Produce”, Q mark, Royal Project & Q mark, Doctor's Vegetables & Q mark

Table 2. Socio-demographic characteristics and consumption behavior of the sample.

Characteristics	Percent of total (%)		
	Wet market (N=200)	Supermarket (N=150)	Pooled sample (N=350)
Gender			
Female	87.00%	85.30%	86.30%
Male	13.00%	14.70%	13.70%
Age (Mean, st.dev.)	44.91 (14.530)	40.39 (15.421)	42.96 (15.067)
19-30 years	21.20%	32.00%	25.90%
31-40 years	16.70%	20.70%	18.40%
41-50 years	22.70%	18.70%	21.00%
51-60 years	24.20%	18.00%	21.60%
More than 60 years	15.20%	10.60%	13.10%
Educational level (Median)	4	4	4
1 = Less than middle school	18.00%	7.30%	13.40%
2 = Middle school	7.50%	3.30%	5.70%
3 = High school or equal	18.50%	18.00%	18.30%
4 = University degree	51.50%	68.00%	58.60%
5 = High Vocational Certificate	4.50%	3.40%	4.00%
Average household income (Median)	3	4	4
1 = Less than 10,000 baht/month	7.00%	4.00%	5.70%
2 = 10,000 - 24,999 baht/month	20.50%	22.70%	21.40%
3 = 25,000 - 39,999 baht/month	25.00%	14.70%	20.60%
4 = 40,000 - 54,999 baht/month	15.50%	16.00%	15.70%
5 = 55,000-69,999 baht/month	10.00%	12.00%	10.90%
6 = 70,000 baht/month or more	22.00%	30.60%	25.70%
Having children < 8 years living with you	24.00%	16.70%	20.90%
Having children 9-15 years living with you	25.50%	20.70%	23.40%
Frequency of buying fresh produce (Median)	4	4	4
1 = Once per month or less	2.50%	4.70%	3.40%
2 = 2-3 times per month	7.50%	10.00%	8.50%
3 = Once per week	18.50%	24.00%	20.90%
4 = 2-3 times per week	35.50%	42.70%	38.60%
5 = 4 or more times per week	36.00%	18.60%	28.60%
Have ever bought Q mark products	62.00%	60.70%	61.40%
Have ever bought Royal Project brand products	77.50%	80%	78.60%

Table 3. Estimated parameters for the multinomial logit model.

Coefficients	Estimates
Intercept (option A)	2.8221***
Intercept (option B)	2.6174***
PRICE	-0.02058***
FRESHNESS	
Today[a]	0.7277***
Yesterday	0.1761***
2 days ago	-0.9038***
BRAND & LABEL	
No information[a]	-1.2413***
Claimed "Safe Produce"	-0.0966
Q mark	0.4751***
Royal Project & Q mark	0.4206***
Doctor's Vegetables & Q mark	0.4421***
Number of respondents	350
Number of observation	4200
Log likelihood	-3086.5
$\chi 2$	1824.6
McFadden R2	0.2282

Note: *, ** and *** significant at the 0.10, 0.05, and 0.01 level, respectively
The results are from effect codes produced by R 2.14.2.
[a] are the reference levels of the attributes, the coefficients was calculated by:
coefficient (ref.lev.) = - Σ coefficients (attribute levels)

Table 4. WTP estimates for the multinomial logit model.

Attribute	WTP (baht/kg)
Q mark	83.38
Royal project & Q mark	80.74
Doctor's vegetables & Q mark	81.78

Note: No information (no brand & label) is a reference point

Which of the following three choices do you prefer for each choice set?

Option A	**Option B**	**Option C**
 Freshness = today Claimed “Safe Fresh Produce” ("ผักปลอดสารพิษ") 25 baht/kg	 Freshness = yesterday 75 baht/kg	Neither A or B
I choose ...		

Figure 1. An example choice scenario included in the choice experiment.

Growing forward: the potential of horticulture in the agriculture, rural and food policy adjustments of AEC member states

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ABSTRACT

Due to come into effect in 2015, the Association of South East Asia Nations' (ASEAN) ASEAN Economic Community (AEC) is an attempt to create a strong integrated regional economic bloc. Yet, the accelerated deadline, ambitious milestones and obstacles in the way of its achievement have generated significant criticisms of the manner in which the AEC is being formed and raised questions as to its likely impact on different sectors of the ASEAN economy. In relation to agriculture, the historical experience of other trading blocs suggests that moves towards economic integration and the reduction of internal trade barriers simultaneously pose serious challenges and create significant opportunities for the sector.

Successfully responding to this situation will require significant adjustments in agricultural, rural and food policy. With its capacity to produce diverse high value products, horticulture may have an important role to play in these adjustments offering options for high value diversification to the regions farmers. Employing existing academic and policy literature this paper assesses the likely impact of the AEC on the regions agriculture, outlining the challenges and opportunities that the introduction of the AEC poses. The paper reviews current debates concerning the implications of the introduction of the AEC on a wide range of policies that relate to agriculture, food and rural development in the region. The paper then identifies additional policy adjustments to support agriculture in the region in adapting to the social and economic changes introduced by the AEC, thereby contributing to the organisation's successful implementation. Elements of these adjustments should include efforts to support the diversification of the agricultural landscape and output, a move towards self-reliance rather than self-sufficiency, and cross-border initiatives. The paper concludes by outlining how the development of high value horticulture in the region can contribute to the successful implementation of such adjustments.

Keywords

AEC, Agriculture, ASEAN, ASEAN Economic Community, Food Security, Regional Integration, Rural Development.

INTRODUCTION

The Association of Southeast Asian Nations (ASEAN) was originally formed in August 1967 by Indonesia, Malaysia, Singapore, Thailand and the Philippines (Jones 2004 ASEAN 2013a). In the years since, its membership has expanded to incorporate Brunei, Cambodia, Laos, Myanmar and Vietnam. By contrast with, and to some extent as a deliberate rejection of, western perspectives on development and regional co-operation. ASEAN espouses an explicitly "Asian" approach to regional co-operation, which places importance on the community rather than the individual, privileges order and harmony over personal freedom and emphasises a respect for political leadership (Milner 1999; Smith & Jones 1997). While this formula has been regarded as important for the organisation ability to overcome differences between individual cultures and promote regional cohesion (Tay & Estanislao 2001), it has in other respects acted as a brake on the pace at which collaboration has developed in the region, preventing moves towards regulatory harmonisation that have characterised the development of other trade blocs. Recently, however, the bloc has made significant moves toward extending its role. Academic and political commentators have pointed towards disparate factors behind this development. Jones (2011) highlights the inspiration provided by the new regionalism model that arose out of a need for stability in the face of the financial insecurity in the 1970s and the failure of models of economic development based on self-sufficiency; as Eithier puts it developing countries chose to abandon the "*...basically autarkic, anti-market, policies they followed...* [so as to] *join the multilateral trading system*." (p. 1149, Eithier 1988). Although the AEC was not proposed until much later, the instability which has been a feature of the Asian markets for some time makes new regionalism's claim to facilitate a localised stability appealing to Southeast Asian states that previously faced developmental issues (p. 2, Kawai and Wignaraja 2008). Of more immediate concern may be the economic, political and regulatory pressures in the global market. In particular, the presence and growing influence of increasingly powerful trading competitors has had a profound impact on world trade with many issues increasingly being resolved at a regional as opposed to a national level, and growing concerns over the position of smaller states in this scenario. Burton (2007), for example, suggested that the AEC was a "...response to the growing economic power of China and India". Cuyvers et al. and Das argue that the growing awareness of the trading power of entities such as the North American Free Trade Agreement (NAFTA) and the European Union encouraged the movement from an almost wholly political ASEAN foundation to the AEC (p. 4, Cuyvers et al. 2005; p. 126, Das 2006). The Asian Financial Crisis of 1997-98 and the 2008 Global Financial Crisis also had negative impacts on the region's economy, which have led to a growing belief that the existing ASEAN structures are ineffective in the face of such challenges (p. 6, Hill & Menon, 2010; p. 83, Connors et al. 2004) and faced a loss of credibility as a result (p. 170, Narine 2002). In theory, a strong and effective AEC could help to rebuild a strong regional commercial structure and rebuild the region's credibility as a cohesive economic and political bloc capable of participating more effectively in multilateral trade negotiations (Baldwin 2006).

One outcome of these developments and the consequent movement towards greater integration it encompasses was the agreement in 2007 to a blueprint for the creation of an ASEAN Economic Community (AEC). The AEC is planned as one of the three principle pillars of a stronger and more integrated ASEAN (ASEAN 2008; p. 9, Dosch 2013) alongside the ASEAN Political-Security Community and the ASEAN Socio-Cultural Community (ASEAN 2003, 2009a; ASEAN Secretariat 2008). The

AEC's main objectives are to create a single market and production base, introduce competition into the economic region, fully integrate it into the global economy and create a region of equitable economic development (Hew 2008). To achieve this AEC will have to transform ASEAN into a region with free movement of goods, services, investment, skilled labour, and freer flow of capital (ASEAN Secretariat, 2008). Originally it was planned that the AEC be implemented from the start of 2020 subsequently it was decided to accelerate the formation of the organisation with a view to the AEC being implemented in 2015. The scale of the task in hand and the accelerated timeframe pose a significant challenge to the ASEAN states and there can be little doubt that the blueprint for the AEC has implications for member state policies. The objectives of the AEC have effectively governed the region's approach to economic concerns in the recent past (Hansaku 2013).

The challenges that the AEC poses to ASEAN member states are most often expressed in terms of the experience of rapid urbanisation, changing patterns of demand of a growing middle class and rapid transformation in the regions manufacturing and service sectors. However, the region still incorporates large, rural populations. Discussing the narrowing of the development gap, Plummer and Yue (p. 165, Plummer and Yue 2009) acknowledge that there are vast inequalities at national level as well as within the region that must be addressed in order to "achieve the AEC", in particular identifying the implications of income inequality between rural and urban areas as a potential drag on the areas economic growth (p. 169, Plummer and Yue 2009; pp. 20-21, Narjoko and Wicaksono 2009). They go on to suggest that the AEC's successful introduction is dependent on certain issues relating to its impact on the dynamic relationship between urban centres and rural areas being resolved or at least partially addressed by national governments prior to policies being established to do so at a regional level. Thus the implications of the AEC project on agriculture, rural and food policy in member states also demand scrutiny. In this paper the academic and grey literature concerning the AEC's formation is considered with a view to identifying current thinking concerning the key implications of the formation of the ASEAN Economic Community for agriculture, rural and food policies in member states. In the next section we identify what is likely to be the key impact of the AEC for the economic and policy context in which agriculture is undertaken in Southeast Asia.

The AEC and Trade Liberalisation – A new regional context for agriculture

Globally agricultural policy enjoys a chequered relationship with trade liberalisation programmes, Chandra and Kumar (p. 439, Chandra and Kumar 2010) highlighted the fact that agriculture is not included in the World Trade Organisation's liberalization process, Diaz-Bonilla et al. pointed out, that while liberalization has been utilised to address food security, this has not been universally recognised as a success (pp. 333-334, Diaz-Bonilla et al. 2004). In relation to food and agriculture, activities, which are pivotal to the policy goals of many developing nations, divergent trade goals and development perspectives have contributed to the failure to create a cohesive and strong global trading system (p. ix, Diaz-Bonilla et al. 2006). Other commentators provided strong evidence that trade liberalisation fails developing nations, exposing them to "pressures from powerful countries" without delivering the promised boost in economic growth (p. 20, Lumina 2008).

Regardless of the debate over the extent and nature of the impact of current global movements towards trader liberalisation, the reduction and elimination of internal trade and barriers are central components of the AEC. In ASEAN, states will have to accept significant structural transformations to accommodate the trade regulatory freedoms required for the ASEAN single market to be effective (Hix & Jun 2005; Hew 2005; Das 2012).

In relation to agriculture, commentators dispute likely impact of trade liberalisation. Historically the agricultural policies of national governments in the region have been, and indeed continue to be largely dominated by policies of food autarchy, in particular focusing on the role of rice as the region's staple food crop (Wong 2012). The presence of conflicting views on trade liberalisation and long standing national commitments to such autarchic measures as rice self-sufficiency and the protection of home markets highlight the challenge facing the AEC. In relation to agriculture the political leadership in ASEAN countries must achieve a delicate balance between the programme of free market liberalisation associated with the creation of a single ASEAN market and the traditional policy priorities of supporting domestic production of certain staples. This is reflected in the experience of the Common Effective Preferential Tariff (CEPT) scheme, under which states in the ASEAN Free Trade Area (AFTA) must apply no more than a 5% tariff rate to products originating within the region. A paper by the International Law Office (2008, pp. 1-2) points out that rice must be excluded from the scheme with the tariffs imposed on other products essentially being the responsibility of the member states. Within AFTA and as of 2010, member states still had an average of 20 items excluded from CEPT, with Cambodia and Burma having 39 each and only Brunei and Singapore having eliminated tariffs on all agricultural products (Kawai & Wignaraja 2010). This reflects the historical importance within the bloc of the principle of non-interference and the reluctance within ASEAN to impose measures on member states. As the same report points out, *"...failure to integrate ASEAN's diverse markets will mean a loss of investment and economic opportunities to regional competitors, such as China and India. This tension between the need to integrate and the reluctance to yield national sovereignty is the main factor affecting the development of the AEC."* (p. 1 in International Law Office 2008). However, the implementation of CEPT also demonstrates a degree of progress in the move toward the elimination of trade barriers. According to a study by Pasadilla (2006), AFTA tariff reductions have made significant progress towards trade harmony between ASEAN states, with tariffs for Indonesia and the Philippines being 4-5%. Further progress will depend on the extent to which forces pressing member states to achieve a greater level of integration can overcome the principle of non-interference (p. 424, Emmerson 2007; Jones 2011; Collins 2013).

Conflicting ideas concerning the extent to which liberalisation will be achieved within the ASEAN has given rise to different views concerning its likely impact on agricultural markets within the region. This has in turn given rise to a range of views on how governments in the regions should respond. According to some commentators, should the AEC bring a degree of tariff uniformity then agriculture policy will benefit from simplification and harmonisation of standards throughout member states (p. 353, Mahmood 2013). Discussing the anticipated impact of trade liberalisation on food, agricultural and rural policies, Corbett elaborates a positive scenario in which agricultural produce is rendered free from barriers that otherwise hinder the development of trade links, thereby encouraging efficient agricultural processes, economic growth in rural areas and enhanced food security (pp. 105-106, Corbett 2008). According to this view, though member states will need to be competitive, this will enhance practices and ensure that policy is of benefit to nations and the region as a whole. However, food policy and rural policy can only benefit from reduced tariffs if systems and structures are developed alongside trade liberalisation in relation to, for example, integrated transport networks and technology sharing (p. 107, OECD 2011; p. 55, United Nations 2004) Thus for those who regard the elimination of trade barriers in primarily positive terms additional policy adjustments relating to the formation of the AEC focus on equipping the agricultural sector in member states to benefit from the opportunities it creates.

Other commentators suggest that the implications of the introduction of the AEC will be more mixed in a region where historically the state has played a central role in agriculture. Examining the possible impact of zero tariffs Oktaviani and Haryadi, concluded that, while Malaysian and Thai welfare would increase as a result of better trade balances, Singapore and Vietnam would suffer (p. 22, Oktaviani and Haryadi 2008). Yue disagrees, arguing that the Philippines and Thailand would suffer welfare loss (p. 114, Yue 2010). The speculation over the impact of the reduction of trade barriers has therefore resulted in dichotomous views with some commentators pointing to its overall benefit while others highlight its mixed impact on welfare. This in turn has contributed to conflicting perspectives on what the AEC will mean for agricultural production and the further policy adjustments that may be required among those interested in the development and implementation of agricultural and rural policy. For example, Dent proposes a more holistic approach to the challenges presented by trade liberalisation stressing the need for balance between community building and economic stability as key aims of policy (p. 105, Dent 2008). Taking this idea further, Plummer and Yue suggested that food policy should be based on a greater diversity of products and affordable prices (p. 55, Plummer and Yue 2009) . Such diversity would result in less reliance on certain crops for member states, fewer issues in terms of food availability and greater social and economic stability in the long run. Simultaneously, such a scenario would help to meet the demands of an increasingly discerning Asian consumer.

Wider policy implications of the AEC

The previous section highlights key differences of opinion concerning the impact of the AEC on rural and agriculture areas in the region. One perspective rehearses established ideas about structural transformation during which rural areas become "factory floor" for the production of food and raw materials. In this scenario agricultural productivity rises as production becomes more efficient and rural populations fall resulting in what Timmer 2012 describes as "virtually a world without agriculture." Timmer's 2005 analysis of agriculture in Asia points out, that with the exceptions of Hong Kong and Singapore, neither of which had any agriculture to begin with, no state has successfully navigated its way out of poverty via rapid transitions in its economic, social and political landscape without agricultural productivity rising alongside urban and societal development: "...agriculture, through higher productivity, provides food, labour, and even savings to the process of urbanization and industrialization. A dynamic agriculture raises labour productivity in the rural economy, pulls up wages, and gradually eliminates the worst dimensions of absolute poverty." (p. 3, Timmer 2005) The dynamism Timmer speaks of is largely expressed in terms of a well rehearsed trajectory; the future of rural areas is shaped by the agricultural modernisation and urban driven economic growth (p. 139, in Haggblade et al. 2007; pp. 118-119, Losch et al. 2012). There is significant evidence to suggest that this is in fact occurring in the region, Siddique for example demonstrates that Brunei, Indonesia, the Philippines, Malaysia, Thailand and Vietnam have all experienced an enhanced agricultural contribution to their individual economies (p. 150, Siddique 2011) between 1984 and 2007. However the experience of other global regions (see for example Durand and Van Huylenbroeck 2003) as well as voices in the literature concerning the ASEAN itself challenges this view on the future of rural areas pointing instead to the ongoing “multifunctional” role of such locations. From this perspective “...the success of ASEAN governments in steering change depends as much upon the effective management of rural and agricultural policy as it does on policies that support industrial development and the growth of the cities” (p. 2, O’Reilly 2013). Among the key concerns of policy makers a number of issues stand out. These include:

The AEC and rural development

Some critics have pointing to the need for policies to diversify the general agricultural landscape so as to develop national infrastructure, strengthen the economy, maintain market relevance, enhance the quality of rural life and alleviate poverty (p. 47, Joshi et al. 2007). Concerns about the future development of rural areas are likely to have significant implications on the policies of member states. While agriculture policy is likely to continue to support measures that enhance productivity, the development of policy in the areas of food, agricultural and rural development must also address issues such as poverty eradication, food security, rural depopulation and environmental protection into account if stability is to be achieved and maintained (p. 17, Oxford Business Group 2012). The implications of the AEC on the member states therefore are not only likely to be felt in such areas of policy as trade regulation but will extend into policies addressing the specific development needs of rural areas.

Development gap

The development gap in the region is one of the most pressing issues that the AEC will confront in the coming years. Differences between levels of wealth and welfare in ASEAN states are enormous. While Singapore is one of the wealthiest nations in the international community “...in many parts of Myanmar, Laos, and Cambodia, rural men and women have no access to modern health care, healthy foods, or modern communications” (p. 20, Dorch 2013). The contrasting economic conditions of different ASEAN countries as well as the very different ways in which these economies are structured have very significant implications for the way in which the AEC is likely to impact on agriculture. This situation presents significant challenges for AEC member states in relation to rural, agricultural and food policies. Not least because of the almost inevitable pressure that many will experience to reduce the gap in as short a time frame as possible. Sanyal (p. 246, 2010) warns against a one size fits all approach. His analysis of rural decline suggests that the AEC may simply serve to leave those unable to benefit from enhanced in the productivity of mainstream agriculture behind. For policy makers, this suggests that measures introduced to implement the AEC may disadvantage certain less developed regions. In this context it may be necessary to consider measures that address the specific challenges facing these regions to encourage diversification and development in line with regional goals. This is a view aired by Menon (p. 10, Menon 2012), who advocates the use of regional aid via an established body in order to narrow the gap between nations.

Food security

Chandra and Lontoh (p. v, Chandra and Lontoh 2010) identify food security as one of the key challenges that may face the AEC. The 2007/08 food price crises had a significant impact in the region, leading to a perception that existing agricultural policies have not been effective in ensuring food security in the ASEAN (p. 169, Than 2001). Wong demonstrated that many of the principle short-term responses to this crisis were initiated at the national level in individual ASEAN member states, yet the regional response was of far less significance than these unilateral measures (p. 1, Wong 2012). A range of factors point to the potential significance of a regional dimension to food security policy in the region. These include the growing role of the AEC itself and with it the possible impact of possible changes in agricultural production, trade and consumption in the region that may be related to the AEC. In addition, new challenges posed by such issues as urbanisation, global instability and growing concerns over the question of food safety within a regionalised agricultural sector have also led to calls for more permanent solutions based on long-term regional self-sufficiency (p. 294, Sridharan and Srinivasa-Raghavan 2007). For the ASEAN moves towards such a regional food security policy involves a balancing act between the established food security objectives of existing agricultural programmes, the trade and economic priorities of the AEC and the growing recognition of a need for common regulatory frameworks and production standards.

The adoption in 2009 of the ASEAN Integrated Food Security (AIFS) Framework and the Strategic Plan of Action on ASEAN Food Security (SPA-FS) explicitly linked food security objectives with measures to improve the economic wellbeing of farmers in the ASEAN region (ASEAN 2009b). Among the measures outlined in this document were a range of actions aimed at boosting the supply of traditional staples (or main crops) and building up emergency reserves. In addition, the strategy outlined a range of broader measures to boost agricultural production that included issues of much more direct relevance to the AEC itself. These included moves aimed at fostering greater intra-regional trade in agricultural products such as commitments to compliance and implementation of the ASEAN Trade in Goods Agreement (ATIGA) with respect to trade in food products. The strategy also included measures aimed at enhancing food safety and innovation in agriculture. Iin this respect the development of the ASEAN good agricultural practices was viewed as a vehicle through which regional standards could be devised and implemented to enhance food safety while simultaneously opening up global markets to ASEAN member states (see, for example, Salleh et al. 2007, Wannamolee 2008). While such measures have sought to address issues relating to food safety and security, they also relate in a very direct way to issues that lie at the heart of the AEC agenda—in particular, the harmonisation of national standards in agricultural goods is regarded as a critical driver to the growth of the sector to enhance the safety and hence marketability of foods produced in the region, which in turn is regarded as an important element in the AIFS (p. 13, Pettman 2013).

While independent research on the implementation of ASEAN-wide quality standards and good agricultural practices exists, limited evidence raises questions about the extent to which these strategies have been effective in meeting either food security objectives or contributing to farmer incomes. While considerable progress has been made in establishing harmonised standards, the extent to which harmonisation of standards within the AEC has been effectively implemented has been questioned. While Pettman argues that the ASEAN Policy Guideline on Standards and Conformance operating via 12 working groups has contributed significantly to the harmonisation of standards in different sectors, there continues to be a lack of integration and achievement of goals. It is argued that 'MRAs are often bilateral, with the more developed countries in the grouping taking the lead', probably causing 2-stage harmonisation due to trust issues (p. 11, Pettman 2013). In relation to agriculture and the adoption of good agricultural practices this is reflected in national studies that highlight the weakness of current, largely voluntary, national good agricultural practices programmes and the need for greater regional co-ordination and enforcement (see Salleh et al. 2007)

In addition to concerns over implementation of specific measures, concerns have also been raised over the capacity, and indeed willingness of national governments to accept significanct macroeconomic adjustments that may be needed to move from a national to a truly regional food security policy. Food security remains a key political issue in the region, one that has been used by states to advance their own interests in recent years, potentially undermining the AEC and ASEAN attempts to achieve policy cohesion in this area. Chandra and Lontoh cite two examples of this *"…key rice producing countries in the region, such as Thailand and Vietnam, chose to supply global food needs at the expense of fulfilling the needs of other ASEAN member countries, notably the Philippines. This development undermined regional solidarity, which is supposedly a key component of the organization's efforts to achieve an ASEAN Economic Community by 2015. Another worrying concern that threatened to jeopardize overall ASEAN solidarity was the announcement by several rice producing nations in the region of their intention to set up an Organization of Rice Exporting Countries."* (p. v, Chandra and Lontoh 2010).

Both issues illustrate the capacity of domestic priorities in the politically charged area of food availability in general and the protection of domestic rice production in particular to hamper collective development, such as the current voluntary approach adopted in relation to the development of good agricultural practice regimes. Critics have also identified further weaknesses in the conceptual framework regarding food security. Cash crops, for example, still dominate land use in many rural areas of the region. For example, Malaysia still produces rubber, palm oil and sawlogs, with Indonesia cultivating rubber, coffee, tea and tobacco (p. 48, Daquila 2005). Tongzon highlights the resultant structural and technological dualism that exists between a sophisticated cash crop sector and a smaller food-producing subsector (p. 69, Tongzon 2002)—a situation likely to be further exacerbated unless national governments are able to effectively enforce measures aimed at the adoption of good agricultural practices and harmonisation of standards for a wide range of producers.

Addressing the implications

The issues highlighted in the previous section suggest that the implications of the AEC are likely to expand well beyond simple adjustments in trade and regulatory frameworks. Concerns over some of the potentially negative impacts on specific sectors of economies within countries, have contributed to a considerable degree of resistance on the part of some states, specifically Thailand, to address financial liberalisation. Kanithasen et al. (p. 1, Kanithased 2011) speaks of a reluctance and lack of encouragement to do so, advocating the employment of a "virtuous circle" of financial integration that utilises competition and technology transfer so as to benefit all member states. In short, Kanithasen et al. suggest that the challenges facing individual members of the AEC require a multifaceted approach if they are to be resolved. Dent (p. 105, Dent 2008) elaborates this approach, describing it as an economic “community building project” with a unified framework and “holistic regional integration agenda.” to overcome the “...strong reluctance from individual ASEAN member countries to transfer sovereignty to a supranational authority which is needed to establish a more formal and binding institution that can more effectively support deeper integration” (p. 2, Medalla & Yap 2008). A multifaceted approach is also required to address food security, Wong for example argues that a complex, multi-scale solution will lead to stability, but only if such an interconnected approach incorporates elements like the role of rice, the preference of self-reliance over self-sufficiency, demand management, cross-border initiatives, the role of the private sector and food safety (pp. 1-2, Wong 2012).

CONCLUSIONS

A significant diversity of opinion exists concerning the likely impact of the AEC on agriculture within member states between those who regard its development in a largely positive light and those who regard it as posing problems for specific rural areas. There is nevertheless a general recognition that the challenges that the AEC poses to rural areas will be variable and complex, and will require additional policy adjustments in order to avoid or address the impact of AEC-driven changes in the regional economy. The experience of other regional economic blocs suggests that addressing these issues effectively is fundamental not just to the future of these rural areas but also to the balanced development of the wider national and indeed regional economy. Addressing the impact of the AEC’s implementation on rural areas is an integral part of the AEC project and will require the adoption of new approaches to understand how variable processes of change affect rural areas. Given the variation within the region, such approaches need to recognise the diverse ways in which different areas are affected by and respond to the challenges of the AEC. Rather than producing “magic bullets,” there is a need for research that supports more flexible policy regimes, which are more responsive to the diversity of cropping systems markets and consumer demand.

In this context, it may be that while policy towards agricultural and rural areas will continue to support the industrialized farming of a limited number of monoculture crops, it can best do so alongside other measures that support the development of a more balanced agricultural sector. While the actual shape of such policies are necessarily difficult to predict, elements of them may include a recognition that the AEC and its impacts constitute a specific “ASEAN” phenomena. While these events may have parallels in similar processes that have, or are occurring, elsewhere it is a distinct process requiring the formulation of specific “local” responses to specific local opportunities and problems. Policies to successfully manage the transition to a more open AEC market may, for example generate the possibility of areas benefitting from the premiums that high quality, high value agriculture may command. In addition, the ability to develop local standards and traceability offers ASEAN players the capacity to show leadership as is evidenced experience of halal certification in Malaysia (Qureshi et al. 2012). In this context high value diversification may become an important component of the policy response to the AEC may thus involve. Offering farmers the opportunity to move away from the production of staples, while simultaneously taking advantage of the increasingly diverse dietary demands of the region’s growing urban population. In this context such policies may look to the “unfunded revolution” in horticulture (Weinberger and Thomas 2005) and the many examples of successful diversification within the

ASEAN horticulture sector as the evidence of the potential for horticulture to play a central role in this process. It is essential to enable individual rural areas to integrate into high value supply chains, which make the most of local competitive advantages and traditional crops.

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Small-scale vegetable production and marketing systems for food and nutrition security: Challenges and prospects for Southeast Asia

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ABSTRACT

For more than a decade, the overall number of micronutrient-deficient and overnourished people has been increasing year-on-year. This trend will continue, despite the significant reduction in undernourishment in most countries of Southeast Asia. Horticulture will play a pivotal role in any approach to fight the threats of both micronutrient deficiency and overnourishment. Besides the crucial role for nutrition and health, horticulture can foster economic development by raising incomes of smallholder farmers, increasing employment and opening new market opportunities. Landless people also can benefit from an emerging and growing horticultural sector through own production and opportunities in other parts of the value chain, such as processing and trading. Hence, horticultural activities pave the way for the integration of subsistence farmers, the landless and other resource-poor people once excluded from markets into broader economic activities, and thus play a significant role in sustaining rural communities. Women in particular are empowered by a vibrant horticultural sector, as they move from being dependent day labor and become self-employed entrepreneurs. In addition, poor households in urban areas benefit through improved access to fruit and vegetables and an increase in employment opportunities in the horticultural sector.

GlobalHort as an international consortium advocates and promotes innovation in horticulture for development with a multi-sector, multiple-actor approach to collaboration in research, capacity development, and technology-generating activities. The increased production, processing, marketing, and consumption of fruits and vegetables and other horticultural crops will lead to the improvement of human health and wellbeing as well as the creation of employment and wealth in Southeast Asia and will benefit in particular smallholder farmers and poor households. Besides advocating and promoting horticulture for development, GlobalHort's core activities are networking, attracting funding and coaching funded research projects as well as facilitating capacity development, education and training to support smallholders investing in horticultural enterprise.

Keywords

Horticulture for development, nutrition-sensitive agriculture, GlobalHort, Southeast Asia

THE SITUATION AND CHALLENGE

Although the effort to fight malnutrition has been ongoing for several decades and has been intensified again in the last couple of years, the present situation of global food security does not look bright, and in the near future the issue will still sadly stay on top of the global development agenda. Although the global number of energy-protein undernourished people (which are affected by "hunger") is at present 840 million and is decreasing slowly but steadily (FAO et al. 2013), the number malnourished people is increasing. Globally there are more than two billion micronutrient-deficient people suffering from “hidden hunger” (FAO 2013) and more than one billion overnourished people suffering from overweight or even obesity (FAO 2014). The good news for Southeast Asia is the fact that the most rapid progress in reducing the numbers of chronically hungry people was in this region. From 1990/92 to 2011/13 a decrease from 140 million down to 64 million (31% of the population to 11%) was documented for the region, whereas the global decrease for all developing countries together was from 24% to 14% only (FAO et al. 2013).

However, the micronutrient deficiency of people in Southeast Asia is severely endangered. According to the World Health Organization of the United Nations (WHO), vitamin A deficiency is especially high in Southeast Asia, besides Africa, and hardest hit are preschool-aged children and pregnant women (WHO 2014). The same holds true for iron deficiency (anemia), of which the greatest number affected is in Southeast Asia with 315 million (mainly in preschool-aged children and non-pregnant women), while in Africa the highest proportion (48 to 68%) of individuals are affected (WHO 2014). Although steady progress has been made in reducing the number of people suffering under iodine-deficiency, mainly due to strengthened salt iodization programs and improved monitoring, still Southeast Asia has with 76 million the largest number of school-age children with low iodine intake (WHO 2014).

Besides the critical development in the area of micronutrient deficiency, it is disturbing that overweight and obesity play an increasing role in low-income countries in general. Although the prevalence of child overweight was still highest in high-income countries with 14%, low-income countries are closing up with up to 7%. The rate of increase between 1990 and 2010 has been similar in low-income and high-income countries, but Southeast Asia, besides Africa, has had an even higher increase from 1.8% to 5.8%. Besides the prevalence of child overweight, Southeast Asia is showing a rapid increase among adults in the numbers of cases of overweight and diet-related non-communicable diseases (WHO 2014).

What is even raising more concern is the fact that according to the WHO report, “… many countries reported the use of media to promote healthy diet, but less than half of the countries in all regions specifically promoted greater consumption of fruits and vegetables…” (WHO 2013). According to the report, only the Americas present a positive exception, where 70% of countries reported promotion of consumption of fruits and vegetables at national scale. This means that the responsible persons in the relevant ministries either do not understand the positive correlation between the consumption of fruits and vegetables and the health status of individuals (especially regarding aspects of micronutrient deficiencies and overweight) or this link is not sufficiently proven. In either case, scientists and people involved in capacity development and awareness-raising programs have to increase their efforts to prove this relationship and to make politicians and ministerial staff understand and act.

One key cause of micronutrient deficiency and overnourishment is the missing or under-valued aspect of nutritious food and well-balanced diets in policy as well as research and development. Fighting micronutrient deficiency is often seen only as technical challenge and hence is tackled with technical solutions, for instance nutritional or dietary supplements or biofortification. However, to reduce micronutrient deficiency and overnourishment, a systems approach is needed to deliver a well-balanced diet.

Part of the systems approach at policy level is the better understanding of the linkages between agriculture and health. To increase the importance of nutrition, essential issues are upgrading the topic "nutrition" and bringing it up to a higher political level of acceptance and recognition, instead of hiding the topic in some departments in the Ministry of Agriculture or Ministry of Health. If a Ministry of Nutrition is not possible in most countries in the short-term, at least nutrition could be upgraded to a cross-cutting theme in the relevant ministries, as for instance gender has found its way as cross-cutting topic in the policy arena.

NUTRITION-SENSITIVE AGRICULTURE

The recommended systems approach integrates agriculture, health and nutrition, education and other sectors to focus on more diversified, local production systems, and take a more holistic view of the factors that contribute to both agricultural and food systems. This includes the consideration of a more diverse range of food sources, processing methods, marketing channels and utilization opportunities, which can lead to improved and more balanced nutritious diets. In the center of such more integrated and biodiverse agricultural systems, the production to consumption of fruits and vegetables as well as aquatic and small animals should play a crucial role providing the means for a balanced diet and environmental resilience (Slavin and Lloyd 2012; Desjardins 2014). In addition, diversity of production might also provide protection from internal and external market disruptions and hence also buffer and stabilize the diets of consumers.

As concept, nutrition-sensitive agriculture expands the scope of the agro-food system to a system encompassing all elements from input delivery, production of food to distribution networks, storage, processing, retail and utilization including consumption with a specific view on nutrition[1]. Thus the scope expands from merely producing a sufficient amount of calories to taking into account vitamins, minerals and other micronutrients that are required for healthy living, environmentally sustainable food production, and food processing and utilization to ensure that food reaches consumers in an optimal state. Nutrition-sensitive agriculture as a systems approach aims to narrow the gap between available and accessible food and the food needed for a healthy and balanced diet. The approach explicitly incorporates nutrition objectives into agriculture and the agricultural value web. By looking at agriculture with a specific "nutrition lens," nutrition-sensitive agriculture addresses the utilization dimension of food and nutrition security, including health and child care, education and (traditional) knowledge, as well as the economic, environmental and social aspects of a sustainable development. Main objectives of nutrition-sensitive agriculture are to promote the design and adaptation of cropping, farming and food systems to specifically combat nutritional deficiencies (improved access to a diversified diet rich in micronutrients), and to overcome and prevent malnutrition by improving the nutritional status of specific groups (especially women, children, the poor) through improving availability of, and physical and economic access to, nutritious food. The concept of nutrition-sensitive agriculture calls for a paradigm shift from "producing tons" to "supplying nutritious food" (Jaenicke and Virchow 2013).

To enable the transformation to nutrition-sensitive agriculture, there is a need for some crucial aspects to be taken into account, which include: (i) awareness raising and capacity building programs in the field of nutritious food in which fruits and

[1]For more details on nutrition-sensitive agriculture see Jaenicke and Virchow, 2013.

vegetables will play a crucial role; (ii) appropriate focus on specific beneficiary group(s), which suffer the most under micronutrient deficiency; (iii) food value chains with the chains' links and single elements from production through to consumption being nutritious-sensitive; (iv) appropriate mechanisms for inter-sectoral and inter-organizational collaboration within the countries; and finally (v) enabling policies and government structures to express the political will to fight malnutrition and micronutrient deficiencies and implement appropriate interventions.

HORTICULTURE FOR DEVELOPMENT

At present, the crops that can have the most significant positive impact on the reduction of micronutrient deficiency and overnourishment—fruit and vegetables—are marginalized. This is a dramatic misconception, because fruits and vegetables can induce general socio-economic development not only at the individual level of the producer, but also throughout the whole value chain at local and national levels.

Horticultural produce (i.e., fruit and vegetables) plays a significant and crucial role in a balanced diet, which is a precondition for addressing "hidden hunger" by providing micronutrients to over two billion people suffering from the consequences of micronutrient deficiencies. The role of horticulture in the fight against dietary micronutrient deficiencies is crucial—especially considering the ongoing emphasis the international agricultural research community continues to place on staple crops, without paying sufficient attention to the issue of hidden hunger using a systems approach. Hidden hunger is mainly tackled by biofortification of staple crops, which may be beneficial in the short-term, but in the long-term, may increase more health problems than it will solve. Crop and diet diversification, especially through increased consumption of fruits and vegetables, is a better approach addressing hidden hunger. However, challenges regarding availability, affordability, and even safety of fresh fruit and vegetables have to be considered and solved to optimize the contribution of horticulture to more diverse diets.

Besides its potential to improve health, horticulture, especially smallholder horticulture, is a powerful tool for alleviating rural poverty and to enable poor people to grow out of absolute poverty. Due to its high land productivity, horticultural production plays a significant role in poverty alleviating through urban / peri-urban agriculture. However, growing high value but perishable crops like most fruits and vegetables demands a high level of knowledge and pre-consideration regarding production, marketing and utilization. Being high value, fruits and vegetables not only enable small-scale farmers to escape poverty, it also opens the door to farmers and others, becoming agricultural entrepreneurs throughout the whole food value chain.

Due to its high labor intensity, horticulture has the potential to create employment throughout the value chain from production to processing. Besides utilizing family labor in an optimal way, horticultural production and processing creates employment for non-family labor. Employment opportunities in the agribusiness supply and service sector of horticulture are manifold and are increasing significantly with the increase of horticultural production. When coupled with operations like washing, grading, packaging, storing, transporting and further processing, employment opportunities are significantly increased. By creating rural employment opportunities, horticulture can sustain rural communities and can reduce the rate of especially young people out-migrating from the rural areas into urban centers. Most employment generated through horticultural value chains is based on local, national and regional market integration. On average, there is only a minor proportion (in some countries significant) of production of and value from internationally exported horticultural crops, which creates high-level standard employment opportunities, mainly in food processing.

Smallholders can break away from subsistence farming through the production of horticultural crops. This development has various reasons, of which one is essential: Only a small minority of farmers producing horticultural crops are utilizing them solely for household consumption or for selling. Instead, most farmers are producing vegetables for the double purpose of household consumption as well as selling the produce on the market (Weinberger and Lumpkin 2007)[2]. This tendency of market integration of vegetable farmers is, for instance, in Cambodia 99% (in Bangladesh 96% and in Lao PDR 99%). In contrast, only 11% of Cambodian rice farmers (and 19% of rice farmers in Bangladesh and 23% in Lao PDR) are integrated into market activities (Weinberger and Lumpkin 2005).

Horticultural production, marketing, processing and consumption does not only lead to nutritious and economic benefits for those involved; behavioral changes are also observed. The production, handling and marketing of horticultural crops provides safe and rewarding work for women and girls. Engagement into horticultural activities by women enables them quite often to take up a more self-confident role in their own families and related communities (e.g., Bushamuka et al. 2005). In addition, female income in a household is spent as a much bigger proportion on family matters, for instance for improved diets and supporting children's school attendance, and especially often permitting the education of girls. In general, in normal agricultural farming, women can only lead the family entity if the male household head has passed away or abandoned agriculture. In horticultural activities, it is easier for women to lead and become entrepreneurs of their horticultural activities throughout the whole value chain from production to processing, while their male partners stay in agriculture or move into other business. Horticulture provides opportunities for women to become entrepreneurs rather than day laborers in packinghouses owned by foreign investors; it empowers women in their communities.

Finally, horticultural production protects and enriches agro-biodiversity through utilization of modern varieties and also indigenous and often neglected or underutilized horticultural crops. The importance of indigenous crops has been high in the past and is increasing (again) these days. In several countries, indigenous vegetables are contributing 50% or more to the average vegetable uptake of a nation's diet, for instance in the Philippines and Thailand, Rwanda and Uganda (Yang 2010). It has been also shown that quite often indigenous vegetables providing a high proportion of the nutrition needs, especially for the poor in a country (Weinberger and Msuya 2004). Due to high inter-species diversity, horticulture provides comparatively the most options for diversifying smallholder agriculture to develop new markets, spread risk, and adapt to new realities associated with climate change. The largest pool of plant genetic resources for food and agriculture in genebanks and other conservation facilities continues to grow. For instance, the genebank of AVRDC – The World Vegetable Center maintains more than 60,000 accessions of 440 species from 155 countries. In addition, many indigenous species and landraces have potential as horticultural crops but are at risk of being lost. Their survival can be secured by connecting them to a value chain, besides conserving them in the relevant conservation facility.

[2]Interesting to note that Weinberger and Genova present results from Bangladesh in which the degree of market integration in vegetable production is the same independent of farm size, which is not the case for staple crops (Weinberger and Genova 2005).

It has been discussed that horticulture (i.e., fruit and vegetables) has a high potential, besides improving the nutrition and health status of consumers, to create wealth or reduce poverty. It also creates employment and new market opportunities in addition to its potential of empowering women and protecting and enriching agro-biodiversity. This multifunctionality of horticulture is commonly captured in the concept of “Horticulture for development – H4D”. However, horticulture and horticultural activities along the value chains are not the silver bullet with which all problems of malnutrition and poverty can be solved, especially in low-income countries. There are many serious constraints limiting the actors to capture the potential benefits of horticultural production, marketing, processing and consumption. The most relevant limiting factors for “Horticulture for development” are: (i) lacking or inadequate education and training in all aspects of the value chain (production, processing, marketing); (ii) the restricted access to affordable extension services; (iii) the limited knowledge of food safety; (iv) restricted market access including access to credits and insurance systems; (v) imperfect infrastructure of which roads and cool chains are the most relevant; (vi) high requirements of quality and quantity of (super-) markets; (vii) unsatisfactory land tenure; (viii) insufficient inputs (seed, fertilizer, pesticides, micro-irrigation); and last but not least (ix) the missing technologies (locally adapted, sustainable and productivity increasing technologies).

WHO ARE THE SMALL-SCALE FARMERS ENGAGED IN HORTICULTURAL PRODUCTION?

Market integration of small-scale horticultural farmers needs capacity development, especially in the areas of agribusiness (Virchow et al. 2008). However, even capacity development efforts will not be sufficient to enable all small-scale farmers to become successful and innovative horticultural entrepreneurs. Three questions have to be discussed to understand the general plight of small-scale farmers globally: (1) who are these small-scale farmers involved in vegetable production? (2) why are they involved in vegetable production? and (3) are they all successful?

About 50% of all chronically undernourished people worldwide are small-scale farmers, whereas the landless rural population and the urban poor compose 20% each of all hungry people. Herdsmen, fisherfolk, forest dwellers and other indigenous and marginalized people make up the remaining 10% of the malnourished (UN-HRC 2010). The reasons why food producers are the group hit hardest by hunger are diverse and cannot be discussed here, but it strongly assumes that small-scale farmers are dominantly not small-scale farmers because they want to be, but because they are forced to be.

There is only limited research undertaken so far to understand better why small-scale farmers are involved in vegetable production. Are the small-scale farmers engaged in horticulture per se in the group of the “better-off”? If so, is horticultural production the reason for being economically more successful than other small-scale farmers, or is the sound economic situation the basis for the small-scale farmers to engage in the high-value, but also high-risk endeavor of horticultural production and marketing? What actually happens, if opportunity costs (for instance of labor or land) increase? Will these small-scale farmers terminate or neglect their horticultural activities or will the male small-scale farmers leave horticultural production to the women? In line with all these questions, one has to analyze whether, after all, high-value (and high-risk) crops are too expensive to be produced, processed and consumed by small-scale (risk-prone) farmers?

It is often assumed that small-scale farmers are only lacking external limited resources for further, successful development. Following this argument, it is implicitly assumed that with sufficient external resources, all small-scale farmers could be better off. However, at present, there is not enough evidence-based research results and hard data for policy advice on how to support small-scale farmers to become engaged in horticulture and to improve their horticultural activities, if they are already engaged. What we do know is that there is not "THE" small-scale farmer engaged in horticulture. Broadly speaking, there are at least four different groups of small-scale farmers according to their competence and capacity that follow different pathways of development and should be supported in very different ways[3]. These four groups can only be sketched out very briefly and more research as well as development work has to be take place in this area[4]:

(1) *Innovators and change agents:* These "women and men of action" are willing to take risks and want to change their situation. If these farmers have farming and or marketing-related skills and they encounter a conducive political and economic environment, they will stay in rural areas and on their farms and become entrepreneurs. These potential entrepreneurs have to be promoted and supported like all business people. The support should cover competence and capacity development, especially in managerial activities, besides improving their access to improved farming and horticultural production, marketing and processing technologies, depending on their interests and opportunities.

(2) *Migrators to urban areas:* If these "adventurers" and risk-taking farmers do not experience an encouraging rural environment, they will leave for urban regions with their subjective expectations of success. If they are successful in their new urban life (which even can be in urban / peri-urban agriculture), they may become part of the important group of people transferring remittance back to the rural areas, supporting their families and their families' agricultural and non-agricultural rural activities, and contributing in such way to the rural development of their home region.

(3) *Mainly risk-averse small-scale farmers:* These farmers stay behind and do farming without an alternative ("better than nothing"), but they are resilient enough to keep going and to run their farms despite all the external and internal setbacks, drawbacks, and limitations. They are hardworking but in sub-optimal and often marginalized conditions, but this group of farmers will—for (at least) the next 40 years—essentially feed themselves and a big proportion of the world's population. These small-scale farmers have to be supported to keep them sustainable. The support should include adapted technologies suitable for their harsh conditions, as well as various forms of institutional support. Horticultural support should aim more on production for home consumption and local marketing and networking (sustaining the crucial kinship and other relationships). Besides these informal security nets, insurance schemes and other social security nets should secure their survival and production.

(4) *Small-scale farmers who cannot survive by farming:* Due to various economic and social reasons, this group has to be supported by having social and capacity development measures in place to enable them to find their way out of agriculture and into other (rural) opportunities of employment and making a living.

[3]The differentiation will even increase, if external drivers are also taken into account – like integrated marketing chains, unfair competition, decline in average farm size, impact of HIV/AIDS and other pandemics – see Hazell 2005.

[4]Fan et al. are taking a different approach based on profitability and stages of economic transformation – see Fan et al. 2013.

From the horticultural perspective, small-scale farmers leaving the agricultural production system should be encouraged to utilize their knowledge to grow vegetables for home consumption, especially for the benefit of the household women and children.

CONTRIBUTION of the GLOBAL HORTICULTURAL INITIATIVE

As an international consortium the Global Horticulture Initiative—GlobalHort—advocates and promotes innovation in horticulture for development, taking into consideration the different future pathways of development of small-scale farmers and their families. GlobalHort's engagement is undertaken with a multi-sector, multiple-actor approach to collaboration in research, capacity development, and technology-generating activities. GlobalHort's mission is to improve human health and wellbeing and to create employment and wealth through increased production, processing, marketing, and consumption of fruits and vegetables and other horticultural crops with a special focus on smallholder farmers and poor households. Four core activities fulfil its general objective:

- Advocating and promoting horticulture for development (H4D) and greater support for H4D initiatives worldwide:
  - Advertising and supporting horticultural events targeting developing countries;
  - Lobbying for new funding opportunities and resources for horticulture from institutional or private donors;
  - Promoting any program for assessing productivity, profitability, safety and sustainability of horticultural crop production in developing countries;
  - Stimulating and promoting the creation of new and sustainable economic opportunities for small-scale farmers and landless laborers in developing countries;
  - Interfacing with other global initiatives to strengthen human health and horticultural plant sciences.
- Networking, connecting and informing the diverse and dispersed community of H4D professionals:
  - Set-up, maintenance and animation of a virtual portal of horticultural research for development;
  - Establishment of partnerships and agreements with data base owners and information providers for free access to scientific and technical information for South partners;
  - Stimulating networks and encouraging new ones;
  - Fostering linkage between horticulture and the health communities, mapping and statistics for horticulture;
  - Regional coordination.
- Identifying researchable constraints to smallholder horticulture as well as instigating and coaching applied research projects – always in partnership with other organizations:
  - Facilitating, hosting and managing programs of research for development implemented by partners;
  - Encouraging pooling of partners and facilitating proposal writing;

– Stimulating, fostering and guiding additional horticultural research on problems that are neglected, especially by the private sector, or topics relevant to international development.

- Facilitating capacity development, education and training to support smallholders investing in horticultural enterprise:
  – Establishing linkages and partnerships with higher educational institutions for promoting training and capacity building;
  – Organizing training sessions with the skilled and experienced partners in developing countries;
  – Organizing e-learning programs with specific partners;
  – Organizing workshops and seminars open to policy makers and private sector actors (retailers and distributors in particular) to better implicate these partners in the horticultural sector.
  –

At present, GlobalHort's members represented on GlobalHort's Board of Directors are in alphabetic order: AFSTA (African Seed Trade Association), Agrinatura (European Alliance on Agricultural Knowledge for Development), AVRDC – The World Vegetable Center, Bioversity International, FAO, FFF (Federation of Free Farmers from the Philippines), GFAR (Global Forum on Agricultural Research), Horticulture Innovation Lab and ISHS (International Society for Horticultural Science). All members are working towards the common goal of improving global health and prosperity through horticultural crops. All other organizations with similar goals are welcome to join forces and to collaborate with GlobalHort and its member organizations.

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The Indian Vegetable Research Program and its application in Asia

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ABSTRACT
Substantial progress has been made towards improving food and nutrition in South and Southeast Asia during the last decade. Nonetheless, achieving the MDG hunger target still remains a challenge for the region. To sustain and strengthen food and nutritional security, we need technologies to address the challenges including emerging pests and diseases, declining and degrading land and water resources, and the threat of climate change. Although improved varieties have contributed much to the increase in production levels, we need matching agronomic technologies to exploit their full potential in the future. Such emerging technologies include grafting, enhancing natural resource utilization efficiency using crop specific micronutrients and fertigation technologies, employing pollinators, novel insect control strategies, and postharvest management and packaging systems. The region needs to increase production of vegetables accompanied by a decline in average cost of production, i.e. more efficient growth to ensure better access to nutritious food. As the region faces common issues and challenges, regional cooperation and concerted efforts through partnerships must be further strengthened. Since the region represents two-thirds of the humanity, any progress in nutrition made in this region would have a greater impact than anywhere else.

Keywords: Vegetables, India, Improvement, Future thrusts, Regional cooperation

INTRODUCTION
Asia has been a mega-center of economic growth during the last few decades. The average GDP for developing Asia grew at 8.5% compared to 3.8% for the entire world (IMF 2012). In spite of this economic progress, poverty still rules a majority of the South and Southeast Asian nations. Growth can raise incomes, but higher economic growth may not reach everyone, especially those in rural areas. Despite fastest economic growth, there were 360 million undernourished people in South and Southeast Asian nations in 2011-13, which represented 43% of the world total. 91% of them live in just 6 countries (India, China, Pakistan, Bangladesh, Indonesia, and

Philippines). The achievement of the Millennium Development Goal (MDG) to halve the proportion of extreme hunger from 20% in base year 1990 to 10% in 2015 became very uncertain, considering the rate which remained at 16% in 2010 (Hiroyuki 2012).

The global population is projected to reach around 9.1 billion by year 2050. Most of this growth will be in the developing world. The size of the Asian population will reach nearly 5 billion (56% of the world population) by that time. To meet the demand of this larger, more urban, and richer population, FAO estimates that the world food production must increase by 70% (100% in developing countries alone). If we fail to achieve this goal in South and Southeast Asian nations, it will have a great impact on world hunger and global security. Continued dietary deficits in micronutrients and vitamins may emerge as a more serious nutritional problem than a lack of energy in Asia over the coming decades. Further, the precarious situation of the world humanity is its dependence on three food crops: Wheat, maize and rice, which supply more than 50% of humanity's calories. Starchy foods account for the bulk of share of the source for dietary energy in most South Asian countries, especially in Bangladesh, Nepal and India, where the rate of undernutrition is identically high (Table 1). Other serious challenges, such as soaring food prices and volatility, stagnation of expansion or decline of arable land, scarcity of water resources, frequent occurrence of natural disasters, high crude oil prices leading to high costs of agricultural inputs and transport, competition in the use of land and water, and decline of investment in agriculture are a matter of concern in this region.

In this context, vegetables provide an opportunity not merely as a means of diversification and intensification, but form an integral part of food and nutritional security, an essential ingredient of economic security of the region. Since the region represents nearly two-thirds of the humanity, any progress in nutrition made in this region would have a greater impact than anywhere else.

THE INDIAN VEGETABLE RESEARCH SYSTEM

Vegetable research in the Indian NARS system is conducted by national level institutes governed by ICAR along with universities at state level to cater to their specific regional needs. The major national level institutes of ICAR involved in vegetable research include IIHR, Bengaluru; IIVR, Varanasi; IARI, New Delhi; CPRI, Simla; DOGR, Pune etc. State Agricultural Universities viz., TNAU, Coimbatore; KAU, Thrissur; PAU, Ludhiana; YSPUHF, Solan; CCSHAU, Hissar; GBPAUT, Pantnagar etc. have been actively involved in vegetable research with significant achievements to their credit.

The vegetable crop improvement programme started with the evaluation of native and introduced diversity to select desirable types. Natural diversity available has been utilized directly through evaluation and selection and also through hybridization and selection, leading to the development of promising cultivars, some of which are still popular with farmers due to their high yield potential and other desirable characteristics. All India Co-ordinated Research Project (AICRP) on vegetables initiated in 1971, for multilocation testing of vegetable varieties with 29 testing stations in 8 agro-climatic zones of the country, has helped release a total of 408 varieties/hybrids to date, of which 252 are open pollinated varieties, 113 hybrids and 43 disease resistant varieties (Table 2).

TECHNOLOGICAL INTERVENTIONS THAT FUELLED GROWTH DURING THE LAST TWO DECADES

- Tapping hybrid vigor has revolutionized vegetable farming in India. Hybrids play a key role in maximizing the production and productivity of both self-pollinated and cross-pollinated vegetable crops.
- Development of male sterile lines and their commercial exploitation economized hybrid seed production.
- Disease-resistant varieties, especially from public sector research institutes, are extremely popular even today in this era of hybrids. Eg. Arka Anamika (Okra), Arka Manik (Watermelon), Arka Komal (French Bean).
- Emergence of the private sector, which made a clear impact in hybrid development and commercial seed production.
- Seedling nurseries have emerged as a rural enterprise for producing quality vegetable seedlings.
- Technology for high intensity peri-urban farming of vegetable crops is well adopted.
- Concerted breeding efforts have helped in increasing the average nutritive value (ANV)/unit area/unit time of vegetables. Contribution of improved varieties in increasing the nutritive value over the period 1990-2013 in India is illustrated in Table 3. High yielding, high nutrition varieties with shorter crop duration have doubled the mean ANV/m^2/ day from 1.08 to 2.17 during this period.
- Agricultural department support for special purposes like drip irrigation, mulching, polyhouses etc has made a great impact on adoption of these technologies.

GROWTH OF HYBRID VEGETABLE SEED INDUSTRY IN INDIA

The hybrid vegetable seed industry in India is estimated to be ₹ 1000 Cr ($ 200 M) and including open pollinated (OP) varieties, it is around ₹ 1800 Cr ($ 350 M). It was in the 1970s that tomato and capsicum hybrids were first introduced and demonstrated to the growers in India. The advantages were apparent. Hybrids were subsequently introduced in other vegetable crops like chilies, cauliflower, brinjal, okra, watermelon and melons. Initial releases in these crops were also through direct introductions. During the 1980s some Indian companies decided to embark on development of breeding programs through locally recruited talent. The decision paid off with hybrids in tomato, chilies, watermelon and melons entering the arena successfully. The hybrids developed had better adaptability besides being grower friendly and satisfying the needs of consumers. This led to a rapid switch over from OPs to hybrids across the subcontinent. Major reasons for the success and widespread adoption of hybrids by the growers included higher and continuous harvests, improved fruit attributes like firmness leading to better transport qualities, better fruit characteristics, adaptability, etc. Tomato ₹ 185 Cr ($ 36 M), okra ₹ 150 Cr ($ 29 M), chilli ₹ 140 Cr ($ 27 M) and cauliflower ₹ 90 Cr ($ 17 M) top the list of hybrid seeds marketed in India (Table 4). All these crops have shown a steady increase in volumes over the years (Anand, 2013, pers. comm.).

ISSUES AND CHALLENGES FOR THE FUTURE

While demand for vegetables is increasing due to population increase, economic growth, increasing income level, health consciousness, rapid urbanization, improvement in connectivity, etc., the productivity of vegetables still remains low in

South and Southeast Asia, varying from 7.4 t/ha to 13 t/ha compared to 19 t/ha in China and 37 t/ha in the Republic of Korea. Although some countries in Asia have achieved good growth in the production of vegetables, production remains very low especially in SAARC and ASEAN countries, which face almost similar challenges.

- **Shrinking and deteriorating land-water resources:** Population pressure on natural resources in the region is highly intense and often results in degradation. Water has been the greatest limiting factor for cultivation. Depleting groundwater compounded by low water use efficiency made the situation worse. Various measurements reveal that there has been a decline in the groundwater level of 4 cms each year during the last decade in India. Apart from quantity, the quality of water resources is also deteriorating. Salinity and alkalinity is continuously increasing and damaging farm production.

- **Inefficiencies in resource use**: Farming is progressively becoming resource intensive. Per unit cost of production is increasing at a rate that is making farming unprofitable. The challenge is to introduce a regime of low cost farming by judicious and efficient use of inputs. In India, fertiliser consumption has been increasing over the years and today India is the second largest consumer of fertilizer in the world after China, using 26.5 million/t of NPK. Deficiencies and imbalance of major and micronutrients in our soils have been on the rise continuously over the last four decades and is likely to worsen. The other major inputs, mainly quality seed, is weak. The problem is compounded by spurious inputs in the market. Above all, the rural work force in agriculture is drastically decreasing.

- **Inefficient growth**: With the rising incomes, demand for cereals declines and the demand for fruits, vegetables, milk, eggs, oil increase. This tendency is universal and with rapid urbanization and awareness about nutrition, this tendency shall get a fillip and is likely to continue. However, growth during the last decade was accompanied by a sharp increase in food prices, especially vegetables in India. The resulting high food inflation is considered adverse for food security of low income households and for macroeconomic stability. Increase in production by pushing more and more resources for each incremental unit of output involves increase in unit cost of production and rising stress on natural resources fueling inflation and unsustainability. As is now universally recognized, "availability" is only one of the conditions to ensuring food security. The other is "access to food by economic entitlement". Hence, the region needs increase in production that is accompanied by decline in average cost of production, i.e. efficient growth.

- **Climate change**: Vegetables are generally sensitive to environmental extremes. Climate change is likely to aggravate this further. As per the Natural Disasters Risk Index 2010, majority of South and Southeast Asia falls under extreme risk category, with the maximum number of events during the last 30 years than any other region in the world with mean temperatures rising, frequent floods and droughts. In India, significant negative impacts have been implied with medium term (2010-2039) climate change, predicted to reduce yield by 4.5-9%, implying a 1.5% reduction of national GDP.

Vegetable research priorities for the future

The achievements of the past shall be difficult to replicate unless we respond to the emerging challenges and redesign the research programs accordingly. An understanding of the above challenges also suggests the direction in which research actions have to be taken to remove or at least alleviate these problems. Some of them include the following.

Germplasm management

- Catalogue of vegetable biodiversity for better access and maintenance.
- Effective utilization of wild resources through pre-breeding for specific traits.

Crops	Germplasm lines need to be collected
Tomato	Resistant to late blight (*Phytophthora infestans*)
Tomato & Chilli	Resistant to *Ground nut bud necrosis virus* (GBNV)
Watermelon	Resistant to *Watermelon bud necrosis virus* (WBNV)
Okra	Resistant to *Yellow vein mosaic virus* (YVMV)
Cauliflower	Black rot resistant lines

- Bio-prospecting of novel genes for productivity, quality and resistance to viruses, fungal, bacterial, insects and nematodes: allele mining and association mapping approaches to be followed.

Breeding for multiple disease resistance and emerging problems: There are several diseases that are major constraints for vegetable cultivation in India (Table 5). Source of resistance for many of these have been identified and incorporated into desirable backgrounds.

Several disease resistant varieties have been released through All India co-ordinated trials. Most notable include, resistant varieties to bacterial wilt in tomato, chili and brinjal, yellow vein mosaic virus in okra, powdery mildew and rust in peas, downy mildew and anthracnose in cucurbits. Arka Anamika (okra), Arka Komal (French bean), Arka Manik (watermelon) are popular vegetable varieties possessing disease resistance. All the above varieties have been developed through conventional breeding methodologies. Recently, two tomato hybrids (Arka Samrat and Arka Rakshak) possessing combined resistance to TyLCV, bacterial wilt and early blight have been developed. Marker-assisted selection was employed for incorporating Ty-2 gene (TyLCV resistance) into these varieties. These are one of the first examples of marker-assisted selection for disease resistance in vegetable crops in India.

No source of resistance could be located in cultivated species for several emerging biotic stresses (Sidhu and Rao 2012). Few such challenges in vegetable crops are listed in Table 6. Such cases need long term strategies for pre-breeding involving wide hybridization and breaking linkage drag through generation of genomic resources, construction of molecular maps, developing linked markers and pyramiding of resistance genes through marker-assisted selection. Such strategies will help link germplasm with the breeding programs more efficiently.

Breeding for abiotic stress tolerance: Abiotic stress tolerance is also turning out to be an important area for research. Hybrids with better water use efficiency/drought tolerance and heat-tolerant hybrids that enable growers to take up remunerative crops in summer are important. The input costs of fertilizers are increasing and therefore development of hybrids with better nutrient use efficiency that can maintain yield under low input regimes would benefit growers.

Grafting technology including rootstock breeding involving studies on plant architecture, nutritional uptake, flowering, soil pathogens, salinity, drought and nutritional quality.

Enhancing the potentiality of pollination control systems such as male sterility, gynoecy, self-incompatibility, diversification and introduction in back grounds of good combiners with desirable characters.

Enhancing natural resource utilization efficiency

- Soil fertility management: nutrient balance and residues, emphasis on micronutrients
- conservation farming: zero tillage and microbe diversity, organic farming
- water productivity: pulsed irrigation, virtual deficit, root zone wetting
- canopy management

Disease management*:* Diagnostics, vaccines, pathogen diversity assessment and fungicidal resistance management. Understanding molecular basis of host pathogen interaction to design effective molecular strategies for disease tolerance.

Pollinators*:* especially under polyhouse conditions and commercial seed production.

Novel insect control strategies*:* RNAi silencing of target genes, sterile insect technology, and female pheromone traps.

Postharvest management: Put emphasis on preharvest practices to enhance postharvest life. Develop packaging systems for cold chain management in emerging retail chains.

Crops for diversification*:* Moringa, coccinia, vegetable soybean, Lima bean, cluster bean.

Crop improvement for speciality traits like herbicide tolerance, increase in shelf life and biofortification.

Greenhouse vegetable production*:* Developing production practices for high value and exotic vegetables under cost effective protected structures like polyhouse, nethouse and rain-shelters for year-round supply.

Emerging areas: Techniques for more gain per breeding cycle: Doubled haploidy and genome-wide selection. Space breeding.

Research on linking farmers with markets and managing trade distortions in the globalised market.

OPPORTUNITIES AND AVENUES FOR CONTRIBUTION AND COLLABORATION

The Asia-Pacific region is endowed with a rich diversity of vegetable crops that can be grown in a range of environments from temperate to tropical climates. Focused efforts must be continued on conservation and use of lesser known traditional vegetable species and varieties to avoid the further erosion of plant biodiversity.

- Many of the diseases affecting vegetable crops are common across the region, but considering the variability in the pathogens and the genes governing resistance, different answers are needed for different regions. Attempts to introduce uniform solutions may be counterproductive; hence the need for collaborative efforts to understand pathogen and R-gene diversity and deploy specific solutions.

- Sharing, testing and adoption of vegetable varieties across nations of the region: Under SAVERNET Project (2002-2006) several Indian vegetable varieties like Arka Komal (French bean), Arka Manik (watermelon), Arka Anamika (okra), Arka Vikas, Pusa Sheetal (tomato), Arka Niketan, AFDR (onion) Arka Suryamukhi (pumpkin) have spread to the markets of neighbouring countries. Several examples are presented in Table 7 (Shanmugasundaram 2002). Currently, a regional adaptive trial program for vegetables in SAARC countries (SVATNet Project 2012) is in progress.

- Improving the efficiency of economic unions in vegetable trade would help in complementing regional requirements in vegetables and managing volatility.

- Improving quality standards of Asian produce: Brand building and engaging in cooperative competition among the nations of the region through capacity building in safe vegetable production and adoption of standard operating protocols for quarantine across the region.

- Regional cooperation and partnership for the promotion of vegetables should be strengthened with the aim to share knowledge and experience, learn from best practices and lessons, and promote concerted efforts towards the attainment of common goals to achieve food security and nutrition.

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Table 1: Extent of dietary imbalance in selected countries of South Asia (1990 to 2005)

Country	Under nutrition	Dietary energy from starchy staple (%)		
		1990-92	1995-1997	2003-2005
Bangladesh	46	85	84	82
India	48	66	64	60
Maldives	30	51	45	40
Nepal	45	79	77	73
Pakistan	38	56	53	51

(Adapted from Hiroyuki, 2012)

Table 2: Varieties and hybrids released through coordinated trials up to 2013 in India

S No	Crop	Open pollinated varieties		Hybrids		Disease resistant varieties	
		Private	Public	Private	Public	Private	Public
1	Chili	0	20	9	2	0	0
2	Capsicum	0	4	3	3	0	0
3	Brinjal	0	48	12	19	1	8
4	Tomato	0	36	19	11	0	7
5	Onion	0	20	0	0	0	0
6	Garlic	0	7	0	0	0	0
7	Okra	0	0	4	4	0	14
8	Peas	0	24	0	0	0	12
9	Cowpea	1	10	0	0	0	0
10	Dolichos	0	4	0	0	0	0
11	French bean	0	9	0	0	0	0
12	Cauliflower	0	15	2	2	0	0
13	Cabbage	0	5	5	1	0	0
14	Bottle gourd	0	9	2	2	0	0
15	Sponge gourd	0	4	0	0	0	0
16	Muskmelon	0	10	0	3	0	0
17	Bitter gourd	0	5	2	2	0	0
18	Carrot	0	4	0	0	0	0
19	Cucumber	0	4	1	1	0	0
20	Watermelon	0	2	1	1	0	1
21	Pumpkin	0	5	0	1	0	0
22	Bush squash	0	1	0	0	0	0
23	Ash gourd	0	5	0	2	0	0
24	Ridge gourd	0	0	1	1	0	0
Total		**1**	**251**	**59**	**54**	**1**	**42**

Table 3: Comparison of increase in potential yield of average nutritive value (ANV) of vegetables in India over the period 1990 to 2013

Vegetable	ANV[a]	Yield levels (t/ha)		ANV/m^2		Duration		ANV/m^2/ day	
		1990	2013	1980	2013	1980	2013	1980	2013
Tomato	2.39	45	100	101	339	160	100	0.63	3.39
Brinjal	2.14	25	60	51	128.4	200	160	0.27	0.80
Capsicum	6.61	30	60	173	396.6	130	180	1.33	2.20
Okra	3.21	15	25	43	80.25	90	100	0.48	0.80
Watermelon	0.90	40	60	23	54	120	85	0.19	0.63
Amaranth	11.32	30	30	204	339.6	50	50	4.08	6.79
Onion	2.05	40	45	78.7	92.75	150	120	0.52	0.76
Carrot	6.48	20	25	107.6	162	90	80	1.20	2.02
Mean	4.38	30.62	50.62	97.66	199.07	123.75	109.37	1.08	2.17

[a] ANV as per Grubben (1978)
(The ANV (Grubben, 1978) can be used to rank vegetables according to those nutrients considered important and obtained from vegetables based on yield per unit area and efficiency of production on an area-time basis.)

Table 4: Vegetable hybrid seed market size by volume and value

Crop	**Estimated Volume (kg)**	**Estimate Market Value ₹ (Cr)**	**Estimate Market Value $ (M)**
Regular (dual purpose) Tomato TYLCV	12,000	65	12.5
Regular Non TYLCV Tomato	20,000	60	11.5
Acidic TYLCV Tomato	25,000	50	9.6
Acidic Non TYLCV Tomato	10,000	10	1.9
Chili Pepper	70,000	140	26.9
Watermelon	120,000	54	10.4
Muskmelon	15,000	12	2.3
Okra	1,500,000	150	28.8
Ridge Gourd	50,000	15	2.9
Bitter Gourd	100,000	30	5.8
Bottle Gourd	120,000	19	3.7
Cabbage	50,000	55	10.6
Cauliflower	50,000	90	17.3
Cucumber	40,000	32	6.2
Eggplant	50,000	25	4.8
Sponge Gourd	30,000	7	1.3
Carrot	30,000	17	3.3
Pumpkin	40,000	10	1.9
Capsicum	4,000	18	3.5
Radish	140,000	7	1.4
Total		**866**	**166**

Table 5: Biotic stresses of national importance in vegetable crops

Group	Pathogen	Crop
Fungal	Phytophthora	Solanaceous crops
	Fusarium	Cucurbits and Okra
	Rust	Legumes
	Downy mildew and Gummy stem blight	Cucurbits
Bacterial	Ralstonia	Brinjal
Viruses	TYLCV	Tomato
	YVMV and ELCV	Okra
	CMV/CVMV	Pepper
	MYMV	French bean

Table 6: Target diseases for pre-breeding in vegetable crops

Crops	Target traits for Pre-breeding
Tomato	Late blight, *Ground nut bud necrosis virus*
Chili	*Ground nut bud necrosis virus*, Anthracnose
Watermelon	*Watermelon bud necrosis virus* (WBNV)
Okra	*Yellow vein mosaic virus* (YVMV)

Table 7: Varieties of crops released in different countries through exchange and evaluation in SAVERNET

Country benefited	Country of origin	Crops	Varieties
Bangladesh, Bhutan, Nepal, Pakistan	India	Tomato	Pusa sheetal, Arka Vikas, Pant Bahar, Punjab Chhuhara
India	Sri Lanka	Tomato	T-245, T-89
Bangladesh	India	Eggplant	Pant Rituraj
Bangladesh, India	Sri Lanka	Chili pepper	MI-2, KA-2
Bangladesh, Sri Lanka	India	Onion	Arka Niketan, Agrifound Dark Red, Pusa Red

(Adapted from Shanmugasundaram, 2002)

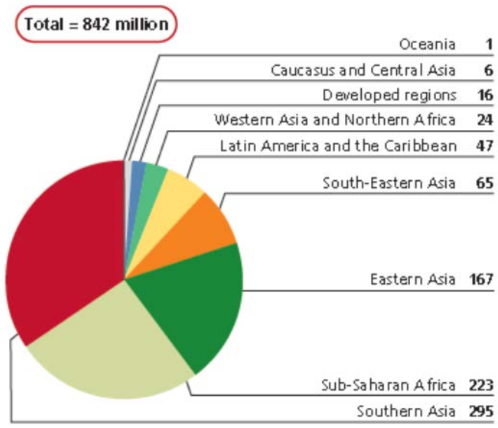

Figure 1: Undernourishment in 2011–13, by region (millions)
(Source: FAO, 2013)

Scaling up technologies for small-scale vegetable farming systems in Southeast Asia

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ABSTRACT
This paper describes the role of the U.S. Agency for International Development (USAID) agricultural research strategy for scaling-up small farmer vegetable systems in Southeast Asia, as part of the U.S. Government's Feed the Future initiative. The production, marketing, and research of vegetables are part of Feed the Future's portfolio for reducing hunger, stunting, and poverty. Short-term impact is focused on horticultural value chain projects managed by USAID field missions in countries such as Cambodia and Bangladesh, whereas long-term impact is pursued through global research initiatives that address sustainable intensification (SI) of targeted agro-ecological zones. Small-scale vegetable farming is an opportunity to: reduce malnutrition, hunger, and poverty; generate employment; create niche market opportunities for smallholder farmers on small acreage; and generate income for women. Unlike agronomic crops (e.g., corn, wheat, rice, sorghum) that require larger land availability for economies of scale, vegetable crops can be profitably grown under reduced acreage. Urbanization favors intensive production of high-value vegetable crops. Examples of technologies that could be scaled up to improve vegetable production include solar irrigation pumps, drying beads for vegetable seeds, integrated pest management (IPM), and biologically-based pest control techniques.

Keywords
Horticulture, income-generating, niche markets, nutrition, peri-urban, urban agriculture, value-chain, vegetables, scaling

INTRODUCTION
This paper describes the role of the U.S. Agency for International Development (USAID) agricultural research strategy for scaling-up small farmer vegetable systems in Southeast Asia, as part of the U.S. Government's Feed the Future initiative. The initiative is led by the Office of Agricultural Research and Policy (ARP) as part of the Bureau of Food Security (BFS). The production, marketing and research of vegetables are part of Feed the Future's portfolio for reducing hunger, stunting and poverty. Short-term impact is focused on horticultural value chain projects managed by USAID field missions in countries such as Cambodia and Bangladesh; long-term

impact is pursued through global research initiatives that address sustainable intensification (SI) of targeted agro-ecological zones (Bowman 2013).

The problem: Population growth, food demand, world hunger, malnutrition

By the middle of the 21st century, the world population will increase 30% to more than 9 billion. Nearly half of the world's population lives in cities. By 2030, 60% of the population will live in urban areas, and reach 70% by 2050 (Wilson, 2014). Food production will need to increase 70% to meet increased demands. How are we going to realistically meet the increased demand for food? More efficient technologies and crops will need to be developed to address this challenge—and equally important, better ways of applying these technologies locally for farmers. A greater emphasis is needed on high-value vegetable crops that create jobs and economic opportunities for rural communities; enable more profitable, intensive farming of small tracts of land in urban areas; and employ smallholder entrepreneurs, especially women.

In sub-Saharan Africa and Asia, 80% of farmland is managed by smallholders (i.e. farmers working on 10 hectares or less). Urbanization and economic development have made global agriculture increasingly differentiated. Many hinterland farms remain largely self-sufficient, while farms closer to markets become increasingly specialized (i.e., vegetable and fruit crops) and linked to agribusinesses (Masters et al. 2013). Changes are occurring in family farm sizes in Asia and Africa, with less land available per family, until urban nonfarm business activities increase to absorb new workers. Unlike Africa, the average farm size in Asia is increasing through consolidation (Masters et al. 2013). This creates better opportunities for scaling up small vegetable farming systems in Southeast Asia.

In regards to nutrition, more than 70% of the world's malnourished children live in Asia. Some three billion in the world are malnourished due to poor or inadequate diet (Hughes and Keatinge 2013). Around 11% of Southeast Asia's population, about 67 million people, suffer from undernourishment. There are opportunities for increased vegetable production and consumption to ensure a diet rich in vitamins and micronutrients (Bowman 2013). High-value vegetable crops can also be produced profitably on small acreages, which is highly advantageous for smallholder farmers.

What is Feed the Future?

USAID leads a global portfolio of 10 federal agencies that support President Obama's U.S. global food security initiative, Feed the Future, http://www.feedthefuture.gov/. Besides USAID, Feed the Future draws on the agricultural, trade, investment, development and policy resources and expertise of the U.S. Department of Agriculture, the U.S. Department of State, the U.S. Department of Commerce, the Millennium Challenge Corporation, the Overseas Private Investment Corporation, the Peace Corps, the U.S. Department of the Treasury, the U.S. African Development Foundation, and the Office of the U.S. Trade Representative. Feed the Future works with partner countries to sustainably reduce poverty and hunger by growing the agriculture sector and improving nutrition (Fig. 1).

What does Feed the Future do?

Feed the Future was created to address the root causes of global hunger, extreme poverty, and undernutrition. To achieve this, Feed the Future agencies work with partner countries to develop their agriculture sectors. USAID supports Feed the Future through its portfolio to develop and scale up technical innovations to boost the productivity of smallholder farmers, who are the key to unlocking agricultural growth, improving nutrition, and transforming economies (Fig. 2).

Why Horticulture? Opportunities for small-scale vegetable farming

In much of Southeast Asia, (particularly Cambodia, Myanmar, and Lao PDR), vegetables appear in markets erratically, with seasonal, localized gluts and shortages. The quality of vegetables is also highly variable (Hickey 2010). The result is poor access to vegetables and widespread undernutrition. In Myanmar, for example, the per capita daily availability of vegetables is less than 50% the recommended per capita daily dietary intake of vegetables (300 g/day) (FAO 2009). As the demand for vegetables increases in Southeast Asia, so will the need for the technologies to sustain value chains in a manner that does not jeopardize health and the environment. Dangerous levels of pesticides are unfortunately common in many Southeast Asian markets, especially on vegetables (e.g. Sarnsamak 2012). Unlike rice, mechanisms of pest resistance in vegetables remains poorly understood (Fan et al. 2014; Sangha et al. 2008, 2013). There is not only a need to develop more pest-resistant vegetables but also a need to build the value chains that will give farmers reliable access to seeds.

Improving value chains for horticultural crops, including vegetables, addresses the Millennium Development Goals (MDGs) and the objectives of Feed the Future (Bowman 2013; FTF Innovation Lab Horticulture 2014 [http://horticulture.ucdavis.edu]; ISHS World Horticulture 2012 [www.harvestingthesun.org]). These include:

- Eradicating extreme poverty and hunger
- Achieving universal primary education (through increased farm income)
- Promoting gender equality and empowering women
- Reducing child mortality
- Improving maternal health
- Combating HIV/AIDS, malaria and other diseases (through better nutrition, which enhances absorption and efficacy of medicines for treatment)
- Ensuring environmental sustainability (through sustainable intensification of horticulture in high priority, agro-ecological zones)
- Developing a global partnership for development (with governments, NGOs, AVRDC, CIGAR, etc.)

Hence, small-scale vegetable farming is an opportunity to reduce malnourishment, hunger, and poverty; generate employment; create niche market opportunities for smallholder farmers on small acreage; and generate income for women (Davies 2012, 2014; Konuma 2013). Unlike agronomic crops (e.g., corn, wheat, rice, sorghum) that require larger land availability for economies of scale, vegetable crops can be profitably grown under reduced acreage. Furthermore, increasing rural road development with closer access to peri-urban and urban markets favors high-value, intensively-grown vegetables, compared to agronomic crops (Reardon 2013)

Approaches to scaling up

USAID and the Feed the Future (FTF) initiative recently gathered with development partners for two Global Learning and Evidence Exchange (GLEE) events on scaling up the use and adoption of agricultural technologies (Hartmann and

Linn 2008 [http://agrilinks.org/events/richard-kohl-and-johannes-linn-scaling-agriculture]). Scaling is not a new initiative—it is harvesting what has been done and figuring out how to move from project-level results to population-level scale to achieve lasting, broad-based impact. It is about getting programs right on the ground so they support scaling up of what is working. Most importantly, it is about engaging with multiple partners and building momentum that will outlast initial projects (MSI 2012; UNDP 2012).

What we want from scaling-up. Robust global development is about scaling-up sustainably through value chains. From scaling we want to have impact, sustainability and learning. Fidelity of the technology or process must be balanced with modifications and changes needed for adapting its use. To have sustainability, one needs to win over farmers or whoever is adapting the technology. It is not just getting the new technology out there, it is also winning "hearts and minds" to adapt the technology or process. To be successfully adapted locally, there needs to be both a desire for the technology and also an understanding of using it. There is also a research component. In adaptive management, the technology needs to be modified and adapted to the local environment as does the approach one uses to spread the technology. There is also learning, which implies much more than checking off boxes during Monitoring and Evaluation (M&E). It is a marriage of research through development. The research process goes beyond the initial development of the technology. Research should ideally happen throughout the entire dissemination and scaling-up process—from initial development through adoption to further modification.

Scaling means sustainability and impact that is driven more by incentives than the efficiency of the technologies (Bowman 2014). For scalability, you have to have alignment with incentives. Scaling is not just about hitting large numbers. One has to build financial and political capacity (multiple pathways) to create an enabling environment where adoption explodes, i.e. grows exponentially. It is important that organizations such as USAID and the World Vegetable Center (AVRDC) stimulate technology adoption without distorting the market. Projects are needed to achieve a critical mass of adopters that triggers wide-scale adoption. Scaling therefore entails shifting from a managed to a self-sustained growth approach (Bowman 2014).

Scaling up differs from Project Management (Table 1) (Cooley and Kohl 2006).

Table 1. How *Scaling up* Differs from *Project Management*

Project Management	***Scaling up***
• Linear	• Non-linear & Iterative
• Beneficiaries and Non-Beneficiaries	• Winners and Losers
• Clear ownership and decision rights	• Multi-stakeholder, "Nobody-in-Charge"
• Dedicated Resources	• Usually not resourced
• Skills: technical, management & financial	• Skills: Boundary spanning, system strengthening, advocacy, aligning incentives

The components of scaling. The *scaling approach* includes spaces, pathways (e.g., value chains, drivers, and balancing adaption with fidelity to the technology or process (Fig. 3 and 4). *Scaling outcomes* include impact, sustainable adoption, technology and approach (Cooley and Kohl 2006). USAID supports 24 Innovation Labs that draw on the expertise of top U.S. universities and developing country research institutions in tackling some of the world's greatest challenges in agriculture and food security. Several Innovation Labs support research to advance smallholder vegetable farming, such as Innovation Labs for: Climate Resilient Crops, Integrated Pest Management (IPM), Nutrition, Sustainable Agriculture and Natural Resource Management (SANREM), Food Security Policy, and Horticulture. The universities and research centers in these Innovation Labs need to work closely with NGOs and private sector partners in order to achieve scale (Cox et al. 2002; Ockwell et al. 2014).

Sample technologies

Examples of technologies that could be scaled to improve horticultural production for smallholders include solar irrigation pumps, drying beads for vegetable seeds, IPM and biological control techniques, and orange fleshed sweet potato (OFSP) (Bouis and Islam 2012). An example of a scaling plan is summarized in the diagram below (Fig. 5).

CONCLUSION

USAID's Administrator Raj Shah challenged USAID Missions and partners to reach more smallholder farmers with promising agricultural technologies to meet the goals of Feed the Future. Technologies that improve vegetable production are particularly suited to addressing the needs of smallholders in Southeast Asia to increase income, food security, and nutrition. National and international research institutions have traditionally developed and adapted new technologies for smallholders, while bringing that technology to farmers was traditionally done by extension departments or the private sector. Increased collaboration between research centers, national programs, and the private sector is needed to scale-up appropriate technologies for vegetable production to meet smallholder demand.

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Figure 1. Feed the Future (FTF) goals are to sustainably reduce global poverty and hunger.

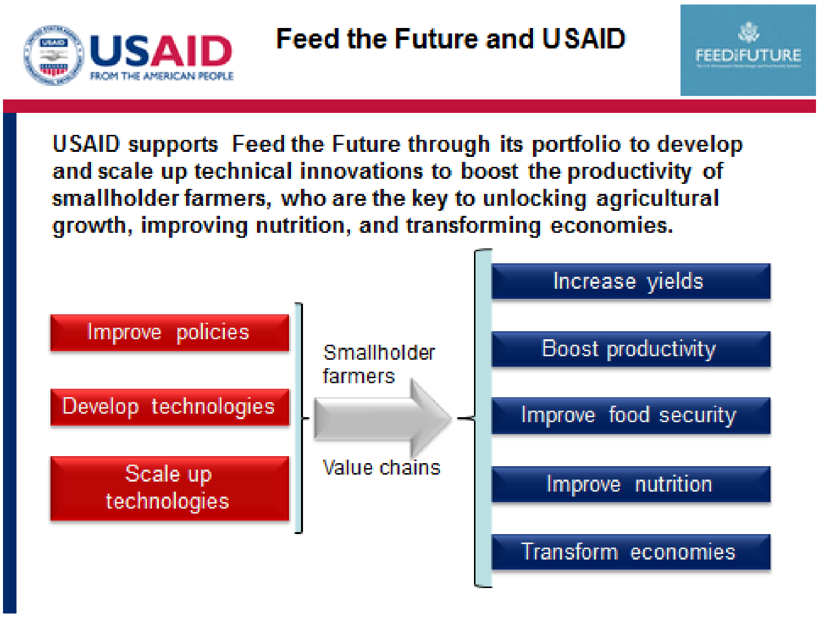

Figure 2. **USAID supports Feed the Future (FTF) through its portfolio to develop and scale up technical innovations to boost the productivity of smallholder farmers.**

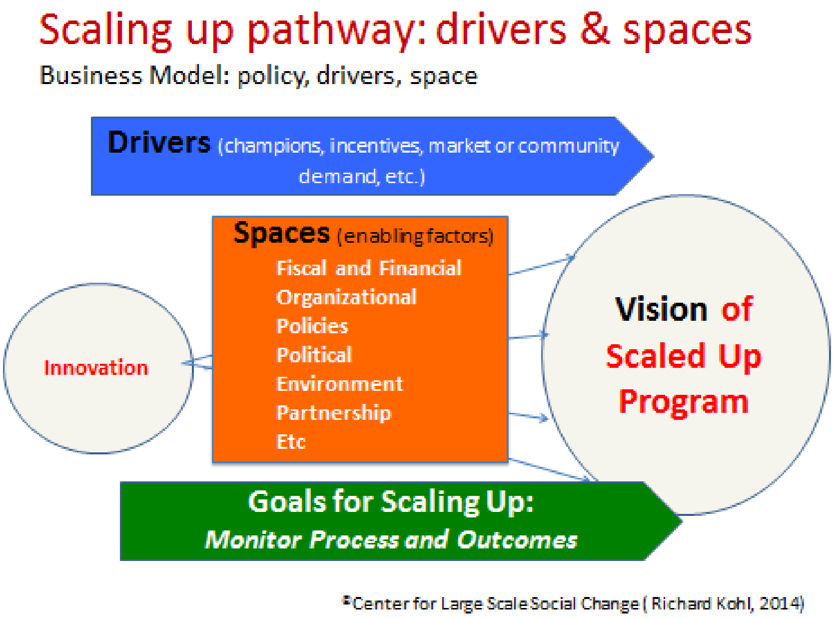

Figure 3. The components of scaling include drivers, spaces (enabling factors), goals for scaling up, with the vision of the scaled up program.

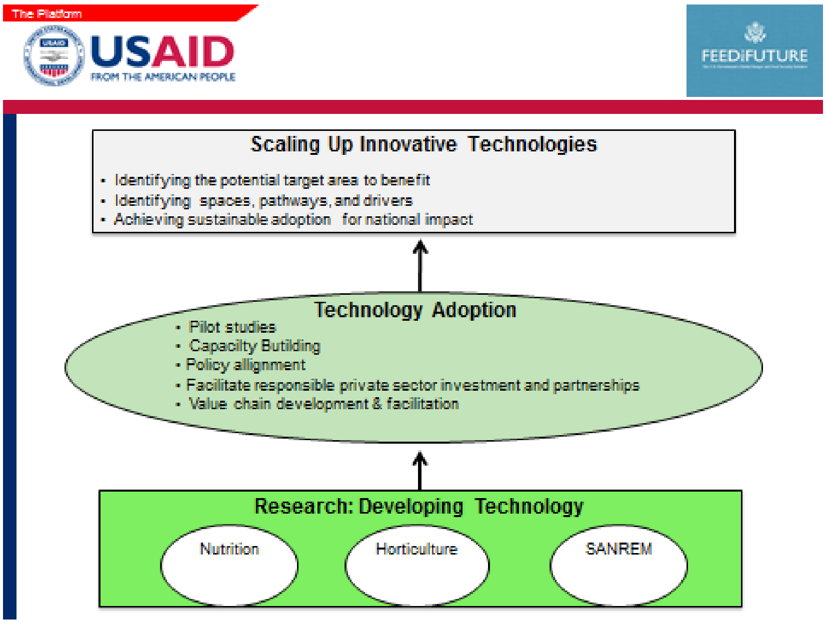

Figure 4. Scaling up innovative technologies includes identifying targets, developing the technology and technology adoption.

Scaling Plan: Orange Fleshed Sweet Potato

Focal Technology: Orange-Fleshed Sweet Potato (OFSP)  • Cultivation of superior OFSP varieties has the potential to impact nutrition, resilience to climate change and women's empowerment • Target population: Smallholder farmers in Malawi's Central Region (encompassing FTF ZoI)	**Context:** *Country Strategy Background:* FTF targets smallholder farmers (0.5-1.2 ha) in the Central and Southern Regions. In FTF ZoI, 61% of population lives on <$1.25/day; 40% of households report moderate to severe hunger; 48% of children <5 are stunted, and the prevalence of children 6-23 months with a minimum acceptable diet is 18%. Legumes and dairy are target value chains, but OFSP's potential to improve nutrition, increase climate resilience and empower women justifies its inclusion. *Constraints & Risks:* Drought; sweet potato weevil and sweet potato virus; limited commercial demand from processors. *Opportunities:* Potential to improve Vitamin A consumption; drought tolerance increases resilience of maize-based farming systems; some interest from commercial processors; existing technology for processing at village-level; women's empowerment.
Current Efforts: • 101,047 households have been reached through the distribution of OFSP vines over three years under existing programs in Malawi (not limited to FTF ZoI or USAID supported programs) • Title II MYAP in Malawi has promoted OFSP production and consumption in the Southern Region (some overlap with FTF ZoI) • Sweet potato (OFSP and other varieties) is currently planted on 204,200 hectares in Malawi; analysis shows that more than 300,000 additional hectares are suitable for sweet potato production	**Path Forward:** *Pathways:* Increased farmer demand for clean OFSP vines from agro-dealers; increased demand for OFSP for processing by village-level and commercial processors *Three-Year Targets:* • 300,000 farmers will adopt OFSP production • 60,000 additional hectares will be under OFSP cultivation • 15 organizations (associations, CBOs and private enterprises) will adopt OFSP production and processing technologies *Key Partners:* CIP, IFPRI, Presidential Initiative on Poverty and Hunger Reduction, ICRISAT, Seed Trade Association of Malawi (STAM)

Figure 5. **Scaling plan for orange fleshed sweet potato (OFSP) in Malawi.**

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