

12th Asian Maize Conference
and Expert Consultation on

Maize for Food, Feed, Nutrition and Environmental Security

Bangkok, Thailand
30 October - 1 November, 2014

PROCEEDINGS



Organizers

Asia-Pacific Association of Agricultural Research Institutions (APAARI)
International Maize and Wheat Improvement Center (CIMMYT)
Food and Agriculture Organization of the United Nations (FAO RAP)
Department of Agriculture (DOA), Thailand



**12th Asian Maize Conference and Expert Consultation on
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Editors

**Raj Paroda, B.M. Prasanna, Bhag Mal
S. Dasgupta and M.L. Jat**

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The Organizers

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International Maize and Wheat Improvement Center

Headquartered in Mexico, the International Maize and Wheat Improvement Center (known by its Spanish acronym, CIMMYT) is a not-for-profit agriculture research and training organization. The Center works to improve food security and livelihoods by sustainably increasing the productivity of maize and wheat in the developing world. CIMMYT maintains the world's largest maize and wheat seed bank and is best known for initiating the Green Revolution, which saved millions of lives across Asia and for which CIMMYT's Dr. Norman Borlaug was awarded the Nobel Peace Prize. CIMMYT is a member of the CGIAR Consortium and receives support from national governments, foundations, development banks and other public and private agencies. For more information, please visit: www.cimmyt.org

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Department of Agriculture, Government of Thailand

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12th Asian Maize Conference and Expert Consultation on Maize for Food, Feed, Nutrition and Environmental Security

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Contents

Foreword	vii
Acknowledgements	ix
Acronyms and Abbreviations	xi
Introduction	1
Objectives	2
Inaugural Session	3
Plenary Sessions	7
Plenary Session 1: Keynote presentations	7
Plenary Session 2: Panel Discussion – Doubling Asia’s maize production in the next decade	8
Plenary Session 3: Keynote presentations	9
Plenary Session 4: Panel Discussion – Ensuring a vibrant maize seed sector in Asia through public-private partnerships	10
Plenary Session 5: Panel Discussion – Interface with farmers and entrepreneurs on opportunities for enhanced maize production and utilization in Asia	10
Plenary Session 6: Keynote presentations	12
Technical Sessions	12
Technical Session 1: Enhancing genetic gains in maize breeding	12
Technical Session 2: Maize for fodder/feed, specialty corn, value addition and processing	14
Technical Session 3: Stress resilient maize for Asia	15
Technical Session 4: Socioeconomics and innovative policies for enhanced maize production and impacts	16
Technical Session 5: Biotechnology for maize improvement in Asia	17
Technical Session 6: Strengthening maize seed systems in Asia	19
Technical Session 7: Regional assessment of maize in South Asia and Oceania: Country Reports	20

Technical Session 8: Regional assessment of maize in East Asia, South East Asia and West Asia: Country Reports	23
Technical Session 9: Precision-conservation agriculture for enhanced input use efficiency	26
Technical Session 10: Nutritional enhancement of maize	27
Technical Session 11: Adapting maize production to the changing climate	28
Technical Session 12: Enhancing gender equity and social inclusiveness	30
Recommendations	31
Annexures	
Annexure I. Welcome Remarks	35
Annexure II. Introductory Remarks	37
Annexure III. Introduction of the Theme	40
Annexure IV. Chairman's Remarks	42
Annexure V. Chief Guest's Address	44
Annexure VI. Program	48
Annexure VII. List of Participants	57


Foreword


Maize is a major food, feed and industrial crop and offers immense opportunities for attaining nutritional security in the developing countries of Asia. In fact, annual production growth rate in maize had been higher in Asia compared to global average, reflecting thereby tremendous potential for future upscaling and outscaling of innovations to have greater impact on livelihoods of smallholder farmers. The demand for maize is also expected to double by 2050. On the contrary, the maize production and productivity are severely constrained by an array of factors which need to be addressed urgently. For sustainable increase in yields and stabilizing prices, concerted efforts are required at the policy level to create enabling environment for long-term AR4D investments. The growing needs of the poultry and swine piggery sectors (especially in Southeast Asia and China), the expansion of maize seed industry, and the increasing interest of the consumers in nutritionally enriched and specialty maize products, require greater attention from both research and development viewpoints. Also, the CGIAR Research Program (CRP) on Maize “Global Alliance for Improving Food Security and the Livelihoods of the Resource-Poor in the Developing World” offers opportunities to catalyze stakeholder initiatives in the region to scale-out innovations in maize-based systems by building new public-private partnerships (PPPs).

Considering the above, the 12th Asian Maize Conference on “Maize for Food, Feed, Nutrition and Environmental Security” was organized jointly by the Asia-Pacific Association of Agricultural Research Institutions (APAARI), International Maize and Wheat Improvement Center (CIMMYT), Food and Agriculture Organization of the United Nations - Regional Office for Asia and the Pacific (FAO RAP), and the Department of Agriculture (DOA), Government of Thailand from 30 October - 1 November, 2014. The goal of the conference was to review the progress and identify opportunities for strengthening maize production, value chains and sustainable intensification of maize-based systems in Asia for enhancing food, feed, nutrition and environmental security. The Conference was attended by 292 participants from 30 countries. The participants represented a wide cross-section of stakeholders including researchers, policy makers, service providers, innovative farmers and representatives of various organizations including NARS institutions, the private sector, international agricultural research centers, advanced research institutions, non-government organizations, foundations and some funding agencies.

The Conference Program was structured in six Plenary Sessions on specific themes including special lectures and panel discussions and 12 Technical Sessions on various aspects relating to maize production and utilization. The Conference provided an open platform for the participants to review the ongoing efforts on maize research and development, strengthening value chains to ensure food, feed, nutrition and environmental security, identifying constraints and bottlenecks in production and productivity, and developing suitable recommendations and a strategic road map for enhancing (rather doubling) maize production and its utilization in Asia.

This publication summarizes the proceedings of the Conference. We highly appreciate the valuable contributions of the organizers, sponsors and participants in making this event a big success. It is our expectation that the recommendations of the Conference will draw attention of policy makers, administrators, researchers, industry leaders, farmers and other stakeholders' guidance to enhance maize production and utilization in Asia.


Thomas A. Lumpkin
Director General
CIMMYT


Raj Paroda
Executive Secretary
APAARI

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The organizers are grateful to the following **Co-Sponsors** for their generous financial support for organization of the Conference: CGIAR Research Program on Maize; United States Agency for International Development (USAID); Monsanto; Syngenta Foundation for Sustainable Agriculture; Maharashtra Hybrid Seeds Company (Mahyco); Bioseed; International Plant Nutrition Institute (IPNI); DuPont Pioneer; Rasi Seeds; and Borlaug Institute for South Asia (BISA). Also, the funding support received from the Global Forum on Agricultural Research (GFAR), the Council of Agriculture (COA), Chinese Taipei, and Sehgal Family Foundation, is very much appreciated.

I express gratitude to the **Chairs, Co-Chairs** and **Speakers** of the Plenary and Technical Sessions of the 12th AMC. The insightful presentations from the speakers, the vibrant discussions that followed each of the sessions, and the concluding remarks from the well-experienced and eminent Chairs/Co-Chairs formed the base for the “Recommendations” presented in this publication.

My sincere appreciation to the **Rapporteurs** of the 12th AMC Plenary and Technical Sessions – J.L. Karihaloo, Devendra Malaviya, B.S. Vivek, A.R. Sadananda, P.H. Zaidi, Daniel Jeffers, Raman Babu, Sudha K. Nair, K. Seetharam, M.L. Jat, Tek Sapkota, Christian Böber, Surabhi Mittal, Genevieve Renard and Miriam Shindler – for meticulously capturing the proceedings of different Plenary and Technical Sessions.

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The photographs used on the cover pages of this publication are sourced from CIMMYT Flickr Photostream which is duly acknowledged.



B.M. Prasanna

Chair, Program Committee & Member-Secretary, Organizing Committee,
12th Asian Maize Conference

Acronyms and Abbreviations

AAA	Affordable, Accessible, Asian
AATF	African Agricultural Technology Foundation
ACIAR	Australian Center for International Agricultural Research
AFA	Asian Farmers' Association for Sustainable Rural Development
AIAMMA	All India Agricultural Machinery Manufacturers Association
AMBIONET	Asian Maize Biotechnology Network
AMC	Asian Maize Conference
AMDROUT	Asian Maize Drought Tolerance
AMNET	Asian Maize Network
APAARI	Asia-Pacific Association of Agricultural Research Institutions
AR4D	Agricultural Research for Development
AREEO	Agricultural Research, Education and Extension Organization
BARI	Bangladesh Agricultural Research Institute
BAU	Bogor Agricultural University
BISA	Borlaug Institute for South Asia
BP	Bed Planting
BRAC	Bangladesh Rural Advancement Committee
CA	Conservation Agriculture
CAAS	Chinese Academy of Agricultural Sciences
CAPSA	Centre for Alleviation of Poverty through Sustainable Agriculture
CAU	China Agricultural University
CBOT	Chicago Board of Trade
CBSP	Community-based Seed Producer
CCAFS	CGIAR Research Program on Climate Change, Agriculture and Food Security

CGIAR	Consultative Group on International Agricultural Research
CIMMYT	International Maize and Wheat Improvement Center
COA	Council of Agriculture
CRP	CGIAR Research Program
CSAPs	Climate-Smart Agriculture Practices
CSISA	Cereal System Initiative for South Asia
CT	Conventional Tillage
DH	Doubled Haploid
DMR	Directorate of Maize Research
DNA	De-ribose Nucleic Acid
DOA	Department of Agriculture
FAO	Food and Agriculture Organization of the United Nations
FCRDI	Field Crops Research and Development Institute
FCRI	Field Crops Research Institute
FP	Farmers' Practice
GEM	Germplasm Enhancement of Maize
GESI	Gender Equity and Social Inclusion
GFAR	Global Forum on Agricultural Research
GHG	Green House Gas
GLS	Gray Leaf Spot
GM	Genetically Modified
GMS	Greater Mekong Subregion
GS	Genomic Selection
GWAS	Genome-Wide Association Studies
GY	Grain Yield
HAU	Henan Agricultural University
HMRP	Hill Maize Research Project
HSCPL	Hariyali Seed Company Pvt. Ltd.

HT	Herbicide Tolerance
HTMA	Heat Tolerant Maize for Asia
IARI	Indian Agricultural Research Institute
ICAR	Indian Council of Agricultural Research
ICERI	Indonesian Cereals Research Institute
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
ICT	Information and Communication Technology
IFPRI	International Food Policy Research Institute
IGFRI	Indian Grassland and Fodder Research Institute
IGP	Indo-Gangetic Plains
IIMR	Indian Institute of Maize Research
ILRI	International Livestock Research Institute
IMDA	Indian Maize Development Association
IMIC	International Maize Improvement Consortium
IPCC	Intergovernmental Panel on Climate Change
IPNI	International Plant Nutrition Institute
IPR	Intellectual Property Rights
IR	Insect Resistance
IRCs	International Research Centers
IRM	Insect Resistance Management
ITPGRFA	International Treaty on Plant Genetic Resources for Food and Agriculture
KKU	Khon Kaen University
KU	Kasetsart University
LcyE	Lycopene Epsilon Cyclase
Mahyco	Maharashtra Hybrid Seeds Company
MARDI	Malaysian Agricultural Research and Development Institute
MAS	Marker Assisted Selection

MDMV	Maize Dwarf Mosaic Virus
MMRI	Maize & Millets Research Institute
MMS	Maize-Maize–Sesbania
MoA	Ministry of Agriculture
MoAC	Ministry of Agriculture and Cooperation
MRS	Maize Research Station
MWM	Maize-Wheat-Mungbean
NAARM	National Academy of Agricultural Research Management
NARC	Nepal Agricultural Research Council
NARI	National Agricultural Research Institute
NARES	National Agricultural Research and Extension Systems
NARS	National Agricultural Research System
NICRA	National Initiative on Climate Resilient Agriculture
NMRI	National Maize Research Institute
NMRP	National Maize Research Program
NSFCRC	Nakhon Sawan Field Crops Research Center
NT	No Tillage
OECD	Organization for Economic Cooperation and Development
OPV	Open Pollinated Variety
PARC	Pakistan Agricultural Research Council
PCAARRD	Philippine Council for Agriculture, Aquatic and Natural Resources Research and Development
PNG	Papua New Guinea
PPPP	Public-Private-Producer Partnership
PPPs	Public-Private Partnerships
PT	Phosphate Transporter
QPM	Quality Protein Maize
QTL	Quantitative Trait Loci

R4D	Research For Development
R&D	Research and Development
RAU	Rajendra Agricultural University
RAP	Regional Office for Asia and the Pacific
RNA	Ribose Nucleic Acid
RNR	Renewable Natural Resources
RDC	Research and Development Committee
SAC	SAARC Agriculture Centre
SDC	Swiss Agency for Development and Cooperation
SeeD	Seeds of Discovery
SFSA	Syngenta Foundation for Sustainable Agriculture
SIMLESA	Sustainable Intensification of Maize-Legume based Systems in Eastern and Southern Africa
SJU	Shanghai Jiao Tong University
SMTA	Standard Material Transfer Agreement
SNP	Single Nucleotide Polymorphism
SPII	Seed and Plant Improvement Institute
SSNM	Site-Specific Nutrient Management
TAAS	Trust for Advancement of Agricultural Sciences
TAMNET	Tropical Asian Maize Network
UAS	University of Agricultural Sciences
USA	United States of America
USAID	United States Agency for International Development
VAAS	Vietnam Academy of Agricultural Sciences
VAMNET	Value Added Maize Network for Asia
WEMA	Water Efficient Maize for Africa
YAAS	Yunnan Academy of Agricultural Sciences
YPARD	Young Professionals for Agriculture Research for Development

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Introduction

Maize is a major food, feed and industrial crop around the world. The crop provides food security and income to several million smallholder farmers in Sub-Saharan Africa, Latin America and Asia. The area, production and productivity of maize have increased several-fold over the last five decades. In Asia, maize has recorded the fastest annual growth (around 4%), as compared to other cereals. Despite increased production, increasing and competing demands (food, feed, industrial uses) imply continued need to invest in maize research for development (R4D). The demand for maize is expected to double by 2050, which implies further need to enhance productivity significantly. At the same time, maize production and productivity in several Asian countries is severely constrained by an array of factors, including lack of access to improved seeds and other critical production-related inputs, lack of training and knowledge transfer for the resource-poor farmers, and abiotic and biotic stresses, the magnitude and dynamics of which are rapidly increasing under climate change.

Several factors are critical to effectively meet the present and future demand for maize in Asia. These include: integrating novel breeding techniques for improved genetic gains (especially under stress-prone environments); accelerating the development and deployment of high-yielding and climate-resilient maize; strengthening the maize seed sector and access to quality seed through public-private partnerships (PPPs); introducing precision-conservation agriculture and climate smart practices for sustainable intensification of maize-based cropping systems; empowering local stakeholders through cutting-edge technologies; and implementing innovative policies for stronger maize value chains and services for client communities.

The importance of maize in Asia's cropping systems has grown rapidly in recent years, with several countries registering impressive growth in production and productivity rates. There is scope for further expansion of maize area in the region, as well as tremendous opportunities for innovations in crop improvement, management and diversification. The international and national institutions engaged in maize research and development are also emphasizing foresight, technology targeting, partnerships involving all stakeholders and capacity development to effectively outscale innovations for greater impact. Innovations include single cross maize hybrids, quality protein maize (QPM), genetically modified (GM) maize, conservation agriculture (CA), small farm mechanization, transplanted maize, winter and spring maize area development, baby corn, sweet corn and biofuel production.

As Asia's agribusiness and food processing industries and economies continue to grow, the opportunities for the use of maize as food, feed, fodder and in industry will also increase

significantly. The growing needs of the poultry sector, the expansion of maize seed sector and increasing interest by consumers in nutritionally enriched and specialty maize products require greater attention both from the research and development viewpoints. Beyond the need for conducive policy support/environment, what is needed the most is greater investment on maize R4D in the region to harness the opportunities. There are also specific issues concerning the Asian maize industry that require urgent attention in order to harness the emerging opportunities. Also, the CGIAR Research Program (CRP) on Maize “Global Alliance for Improving Food Security and the Livelihoods of the Resource-Poor in the Developing World” offers options to catalyze stakeholders in the region to outscale innovations in maize-based cropping systems.

With this background, the 12th Asian Maize Conference and Expert Consultation on “Maize for Food, Feed, Nutrition and Environmental Security” was organized jointly by the Asia-Pacific Association of Agricultural Research Institutions (APAARI), International Maize and Wheat Improvement Center (CIMMYT), Food and Agriculture Organization of the United Nations (FAO RAP), and Department of Agriculture (DOA), Thailand, at Bangkok on 30 October–1 November, 2014. The Conference was co-sponsored by CGIAR Research Program on Maize, United States Agency for International Development (USAID), Monsanto, Syngenta Foundation for Sustainable Agriculture, Maharashtra Hybrid Seeds Company (Mahyco), Bioseed, International Plant Nutrition Institute (IPNI), DuPont Pioneer, Rasi Seeds, and Borlaug Institute for South Asia (BISA). Funding support was also provided by Global Forum on Agricultural Research (GFAR) and Council of Agriculture (COA), Chinese Taipei.

The Conference brought together 292 participants from 30 countries (Bangladesh, Bhutan, China, Fiji, India, Indonesia, Iran, Japan, Malaysia, Nepal, Pakistan, Papua New Guinea, the Philippines, Sri Lanka, Taiwan, Thailand, Turkey, Vietnam, Australia, Egypt, Germany, Italy, Kenya, Mexico, Netherlands, Spain, Switzerland, UK, USA and Zimbabwe). The participants represented a wide cross-section of stakeholders including researchers, policy makers, service providers, innovative farmers and representatives of various organizations including NARS institutions, private sector, international agricultural research centers and advanced research institutions, non-governmental organizations, foundations and funding agencies involved in maize breeding, biotechnology, production management, seed systems, and value chains.

Objectives

The overall goal of the conference was to review the progress and identify opportunities for strengthening maize production, value chains and sustainable intensification of maize-based systems in Asia for enhancing food, feed, nutrition and environmental security. The specific objectives were:

- To assess the regional priorities and niches for enhancing maize production and productivity
- To share experiences and the latest information/knowledge on cutting-edge maize technologies among the maize research and development community
- To create general awareness and provide a platform for synergies among institutions and stakeholders for better use of maize as food, feed and industrial crop in Asia
- To develop an innovative and impact-oriented regional strategy and road map that includes access to and accelerated adoption of resilient technologies, market opportunities, networks, investment priorities, and policy guidelines

Inaugural Session

The 12th Asian Maize Conference (12th AMC) commenced with a Welcome Address by **Dr. Anan Suwannarat**, Director General, Department of Agriculture (DOA), Government of Thailand. He highlighted the importance of maize in Asia and emphasized on the need for concerted efforts for strengthening research and development of maize in the region to overcome the present and future challenges. He mentioned about the urgent need for identifying regional priorities to effectively address the diverse problems being faced by the farmers and entrepreneurs. He advocated for an effective investment policy to be in place to boost the production and utilization of maize in the Asia-Pacific region.

Dr. Raj Paroda, Executive Secretary, Asia-Pacific Association of Agricultural Research Institutions (APAARI) in his introductory remarks described maize as a “wonder cereal” since no other cereal crop is used for as diverse an array of purposes as maize, including food, feed, fodder, biofuel and industrial purposes, and in as diverse regions in the world as Africa, Asia, and Latin America. The demand for maize in the developing world is expected to surpass the demands for both wheat and rice by the year 2020. While global maize production has increased by 3.70 per cent per year during 2001-02 to 2012-13, the growth rate was 5.60 per cent per year in Asia during the same period. The ‘maize-livestock revolution’ has arisen from a combination of population increase, changes in the diet of millions of people towards dairy and meat, increasing urbanization, and growth in disposable incomes. The continent accounts for one-third of global import trade in maize which will further increase due to increasing demand for maize in China and in other Asian countries.

Dr. Paroda mentioned that the Intergovernmental Panel on Climate Change (IPCC) in its Fifth Assessment Report highlighted the impacts being felt in South Asia due to the changing climate. The key challenge is to improve productivity of major crops like maize in the face of the changing climates and alleviate the huge risks associated with such changes. According to a recent analysis, climate change is already adversely affecting yields of maize in the Asian region, and the predicted losses by 2080 will be, on average, more than 15 per cent. There is no other way to tackle this challenge than through intensive development and deployment of climate resilient varieties and climate-smart production practices that enable the smallholders to adapt to the changing climate.

Dr. Paroda emphasized that despite the availability of improved crop varieties with increased yield potential, optimum maize production is still not attained in several Asian countries generally because of poor crop management. Therefore, cropping systems will have to be made more robust and sustainable. New agricultural practices will not only have to prevent further soil degradation but also improve the resilience of the system while reducing production costs. While conservation agriculture principles are applicable to a wide range of crop production systems, application will vary with climate, biophysical soil characteristics, system management conditions, and farmers’ circumstances. Therefore, specific and compatible management components (e.g., rotation crops, soil and nutrient management strategies, pest and weed control, appropriately scaled implements) need to be identified through adaptive research with active involvement of farmers.

He highlighted that in several Asian countries, improving smallholder farmers’ affordability and access to quality seed of improved varieties, especially high-yielding, climate-resilient hybrids

is extremely important. Maize has spurred a vibrant seed industry in Asia. However, we do need to carefully assess the regional, inter-country and intra-country imbalances in terms of smallholder farmers' access to improved seed at affordable costs, and identify possible solutions to address this important constraint. Empowering the local communities to learn and to produce seed of improved varieties, including hybrids, and connecting them with appropriate markets assumes importance.

Dr. Paroda emphasized on the need to critically address the constraints to increased maize production and productivity in Asia, including the ways and means to enhance the affordability and access to improved technologies, reduce post-harvest losses, improve value-addition and effective marketing channels, and ultimately the income and livelihoods of the smallholder farmers. He advocated for a more holistic approach that requires not only intensified public-private partnerships, inter-institutional linkages, and collaboration among scientists, but also more active involvement of social scientists, extension specialists and the farmers. Research-extension-farmer linkages should be fostered for effective technology transfer and adoption. He also emphasized on the need for a Second Green Revolution for nutritional security and technology innovation for the benefit of the smallholder farmers. He hoped that 12th AMC will come out with a road map that will lead to sustainable growth in maize production, and enhanced productivity of maize in the smallholder farmers' fields in the Asian countries.

Dr. Thomas Lumpkin, Director General, International Maize and Wheat Improvement Center (CIMMYT), Mexico, introduced the theme of the Conference. He highlighted that Asia has made great strides in the last few decades to pull itself out of poverty. Yet, despite the rapid economic growth, 12.7 per cent of the region's population, 526 million people still suffer from food insecurity and 30 per cent suffer from malnutrition. Based on the current crop yields, feeding more than 9.5 billion people by 2050, and perhaps 12.3 billion by 2100, will not be a trivial task. In Asia alone, the demand for maize is expected to double by 2050. Sustainably increasing maize production will have a crucial impact on food security and livelihoods across the continent. The rising popularity of maize can largely be attributed to changing diets, especially the increasing demand for meat, poultry and dairy products. Today, more than 70 per cent of maize is used as poultry feed, due to its high cost-nutrient efficiency. This rising demand has also resulted in high imports in some countries.

Dr. Lumpkin emphasized on the need to focus on crop rotations, diversification and other improved agronomic practices that use conservation agriculture techniques to sustain soils and to protect the crop from biotic stresses, besides better policies, so as to protect smallholder farmers from high risks and financial vulnerability. He highlighted the opportunities to promote better use of the maize crop, including industrial uses, to stabilize the market. He stressed on the need to reach more smallholder farmers with modern communication technologies, and to widen genetic base of maize in order to reduce the risk of catastrophic diseases and make maize more adaptable to a range of environments.

Dr. Lumpkin further mentioned that the Conference provides a platform to look holistically at four distinct but interlinked areas of importance for maize production in Asia: food, feed, environmental and nutritional security. Malnutrition and undernutrition are at unacceptable levels in some parts of Asia. Efforts to enhance the nutritional value of rice and wheat will not be enough to help the people living on the continent who suffer from food insecurity. We need to bring

the same successes that we have seen in Africa with provitamin A-enriched maize and quality protein maize (QPM) to Asia. Dual purpose maize is one way to balance the benefits for both food and fodder. One crucial step in this process will be to further improve the biofortification of QPM with more essential amino acids, and thus bring even further benefits to the people who use it as staple food or for feed purposes.

He highlighted the need to mobilize our collective resources to help smallholder farmers and to achieve greater impacts on maize-based farming systems in Asia. This will require close partnerships with an array of institutions to develop and deploy high-yielding and climate-resilient maize varieties, promote adoption of conservation agriculture in maize-based systems, and digitally connect small farmers to innovations and recommendations based on global knowledge. He concluded by stating that Asia has had a wheat green revolution, then a rice green revolution, and now having a maize green revolution and we are here to support it.

Dr. Simon Hearn, Chairman, APAARI and Senior Advisor, Australian Center for International Agricultural Research (ACIAR), in his Chairman's remarks highlighted the importance of maize as a major food, feed and industrial crop around the world. He mentioned that in recent years, the importance of maize in Asia's cropping systems has grown rapidly, and there is tremendous scope for further expansion of maize as Asia's agribusiness and food processing industries and economies continue to grow. The growing needs of the poultry sector, the expansion of maize seed sector and increasing interest by consumers in nutritionally enriched and specialty maize products require greater attention both from the research and development viewpoints.

Dr. Hearn stressed that there are tremendous opportunities for innovations in maize crop improvement, management and diversification. Also, there is need for capacity development of stakeholders to effectively outscale innovations for greater impact. However, technological and policy issues concerning Asian maize industry need to be addressed in order to harness the emerging opportunities. There is also a great need to catalyze stakeholders in the region to outscale innovations in maize-based cropping systems through building new public-private-partnerships (PPPs).

Mr. Hiroyuki Konuma, Assistant Director General and FAO Regional Representative for Asia and the Pacific, in his inaugural address, highlighted that maize is a unique crop that stands out among the cereals because of its higher productivity, diversified uses and low prices. According to a recently revised FAO's Global Perspective Study "World Agriculture Towards 2030/2050", despite a sharp decline in cereal crop annual productivity growth between 1987 and 2007 if compared with that of the Green Revolution period, maize was the only major cereal crop which recorded nearly 2 per cent annual productivity growth during that period as against only about 1 per cent annual growth of rice and wheat. This was largely contributed by the success of agricultural research, effective agricultural extension and outreach efforts, and public and private sector partnerships for the expansion of hybrid maize varieties. The OECD-FAO Agriculture Outlook 2014-2023 which was published recently, indicated that world utilization of coarse grains, mainly maize, is projected to increase by 20 per cent in next 10 years by 2023. This would be driven largely by the expansion of demand for animal feed. Indeed, at present, about 58 per cent of maize is utilized for animal feed, while nearly 16 per cent is used for human food and remaining 26 per cent is for other uses including bioethanol production.

Mr. Konuma highlighted four key points: i) enhancing food production, ii) feed production iii) addressing nutritional problem, and iv) environmental sustainability. In spite of concerted efforts over the past half century, problems of food security and nutrition could not be solved entirely. This region still holds the highest concentration (nearly two-third) of the world's undernourished people. In the Asian context, maize is often seen as a poor people's food or the staple food for those living in highland and mountains. There are many people in rural areas and among indigenous tribes who are deeply dependent on maize for their food security and livelihoods. It is encouraging that farmers are increasingly shifting their interest on maize and bringing more area under maize cultivation. Maize is not only more productive than rice and wheat but also superior in terms of nutrition and prices. More awareness and motivational programs are needed to convince people to eat more maize in addition to our efforts in technological advancement, so as to reduce pressure on rice production and consumption.

Mr. Konuma further emphasized that maize production has been increasing due to its high demand mainly as poultry feed or livestock feed. Besides, it is also used as feed in aquaculture. Expansion of maize cultivation will continue in future due to its nutritional advantage over other feeds and also cost effectiveness. Economic development, demographic changes, incomes rises, and food diversity will increase demand for more fish and meat. For that purpose, we have to produce more animal feed to meet the everincreasing demand of meat and fish products. Maize could be a good option for this purpose over other animal feeds.

He also highlighted that maize is nutritionally superior to any other cereal crop grown in this region. Therefore, maize must be promoted in the region as a matter of urgency in order to reduce malnutrition of children. Maize grains are rich in vitamins A, C and E, carbohydrates, and essential minerals, and contain 9 per cent protein. They are also rich in dietary fiber and calories which are good source of energy. Our efforts to include maize as food for children should be doubled in order to reduce undernutrition of our children. Use of maize as a key ingredient of winning food or complimentary food for young children as a nutrition supplement should be further promoted.

Mr. Konuma stressed that for Asia, increasing productivity of key crops like maize is important to enhance food security and environmental sustainability. Sustainable intensification is the challenge we have to address in the years ahead. We know that excessive uses of natural and external resources to increase production and productivity of rice and wheat during the green revolution period had brought negative impact to natural environments, which are beyond recoverable levels in some areas. Obviously, future food production in this region should come from an environmentally sustainable way that brings minimum disturbance to already fragile environments. FAO is promoting the "Save and Grow" approach to improve the situation.

Finally, Mr. Konuma emphasized that food security should be the first priority. Public-private partnerships, international exchanges of information, germplasm and technologies, and adoption of a value chain approach in the context of Asian transition can make a difference to our future efforts. He re-emphasized the importance of agricultural research, as future development of maize sector is deeply dependent on varietal improvement and sustainable intensification.

Following the Inaugural Session, the Conference Program included **three Plenary Sessions for keynote presentations**, and **three Plenary Sessions for panel discussions** on specific themes: i) Doubling Asia's maize production, ii) Ensuring a vibrant maize seed sector in Asia, and iii) Interface with farmers and entrepreneurs. In addition, the Conference included **12 Technical Sessions** on the following topics:

- (i) Enhancing genetic gains in maize breeding
- (ii) Maize for fodder/feed, specialty corn, value-addition and processing
- (iii) Stress resilient maize for Asia
- (iv) Socioeconomics and innovative policies for enhanced maize production and impacts
- (v) Biotechnology for maize improvement in Asia
- (vi) Strengthening maize seed systems in Asia
- (vii) Regional assessment of maize in South Asia and the Oceania
- (viii) Regional assessment of maize in East Asia, Southeast Asia and West Asia
- (ix) Precision-conservation agriculture for enhanced input-use efficiency
- (x) Enhancing nutritional quality of maize
- (xi) Adapting maize production practices to the changing climate
- (xii) Enhancing gender equity and social inclusiveness.

Plenary Sessions

Plenary Session 1: Keynote presentations

Co-Chairs: *Nick Austin* (ACIAR, Australia)
Thomas Lumpkin (CIMMYT)

Rapporteur: *B.S. Vivek* (CIMMYT)

In the **Keynote lecture** on “Maize research-for-development scenario: Challenges and opportunities for Asia”, **B.M. Prasanna** (CIMMYT) highlighted the importance, status and prospects for maize growth in Asia. Although Asia has registered strong growth rate of maize in the recent years due to its multi-faceted uses (food, feed, fodder, specialty corn, and industrial purposes), there has to be significant improvement in maize productivity to meet the sharply growing demand. Effectively meeting the present and future demands of maize in Asia warrants integration of novel techniques such as doubled haploidy, marker-assisted breeding, high-throughput field-based phenotyping, mechanization of breeding operations, and decision support tools for improved genetic gains and breeding efficiency; accelerated development and deployment of high-yielding, climate-resilient and nutritionally enriched maize; strengthening of the maize seed sector and access to quality seed; scaling-up precision-conservation agriculture and climate-smart practices for sustainable intensification of maize-based cropping systems; building a new generation of maize scientists, professionals and agri-business entrepreneurs, especially among women and youth; and implementing

innovative policies and partnerships for stronger maize value chains and services for client communities. The focus must be on accelerated deployment of improved varieties and innovative agronomic management practices for sustainable intensification of maize-based cropping systems in Asia.

In another **keynote lecture** on “Maize in Asia: Drivers of change”, **Subash Dasgupta** (FAO RAP, Thailand) focused on important factors driving maize growth in Asia, and highlighted the changes in the cropping patterns and farming systems, expansion of maize into new areas, greater involvement of the private sector in seed development and distribution, and growing demand for feed arising from increased consumption of livestock-derived food products. He emphasized on the need for improved genetic resources, and expanded use of hybrids. With the overall area expected to increase at a comparatively slower pace in Asia than in the recent years, gains in output have to be mainly driven by productivity increases. There has to be a paradigm shift from “grow and save” to “save and grow”, with three underlying principles: (i) enhancing productivity and profitability; (ii) increased resource use efficiency; and (iii) ecological sustainability. To effectively address issues related to maize production and productivity in Asia, establishment of a maize production hub within the Greater Mekong Sub-region (GMS) countries (Myanmar, Lao PDR, Cambodia, Thailand and part of China), besides proactive government policies supportive of maize cultivation, and allocation of adequate public resources, were suggested in this presentation.

Plenary Session 2: Panel Discussion – Doubling Asia’s maize production in the next decade

Moderator: *Raj Paroda* (APAARI)

Panellists: *S.K. Vasal* (Mexico)
Md. Rafiqul Islam Mondal (BARI, Bangladesh)
Nguyen Van Bo (VAAS, Vietnam)
Edwin C. Villar (PCAARRD, Philippines)
Clive Murray (SFSA)

Introducing the topic, Dr. Paroda stressed on the need for Asia to double its maize production to meet the fast-growing demand. Annual yield gains will have to be increased from current 1.6 per cent to around 2.4 per cent. This warrants intensive efforts for scaling-up and scaling-out innovations for greater impact; such innovations must include GM maize, doubled haploid (DH) technology, marker assisted selection (MAS), conservation agriculture (CA), climate-resilient varieties coupled with climate-smart agriculture practices.

The following key points emerged during the discussion:

- Genetic base with which the maize breeders are working in the Asian NARS is quite narrow and the available genetic variability is not being fully exploited. The genetic resource base needs to be widened for expeditious development of high-yielding and better quality maize hybrids with higher adaptability to diverse farming situations.
- There is a significant need in Asia for enhancing production of livestock feed. Developing maize varieties with resilience to both biotic and abiotic stresses and balanced use of

inputs are both critical for improving maize yields in a sustainable manner. GM maize in the Philippines has contributed significantly towards enhancing maize production. Other maize-growing countries in Asia must explore the possibility of improving maize production and reducing the cost of cultivation using GM maize.

- Doubling maize production in Asia is possible through intensive focus on improved hybrids, small farm mechanization, public-private partnership, availability of quality seed, outscaling farm innovations, and linking farmers to markets.
- Each national agricultural research system (NARS) should lay greater emphasis on developing and promoting better single cross hybrids, including nutritionally enriched maize, so as to double maize production preferably by 2030 *i.e.* much before the set target for 2050.
- Since global demand of maize is likely to increase significantly for food, feed as well as industry, exciting innovations in maize must be outscaled through required policy interventions.
- Use of single-cross hybrids has led to great success in several maize growing countries. Hence, the area under single-cross hybrids need to be expanded in Asia through greater involvement of private sector and by having required provisions for intellectual property rights (IPR).
- In order to diversify the uses of maize, concerted efforts need to be made to promote value-added products, including corn oil, starch, feed and silage, and even ethanol production.
- For doubling maize production in Asia, there is considerable need for enhancing (almost tripling) investments in AR4D, including that on human resource development, besides enhanced regional/global partnerships.

Plenary Session 3: Keynote presentations

Co-Chairs: *William Dar* (ICRISAT)
Simon Hearn (APAARI)

Rapporteur: *Christian Böber* (CIMMYT)

In the **keynote lecture** on “Present and potential impacts of changing climate on maize-based cropping systems in Asia: Strategies for adaptation”, **Clare Stirling** (CIMMYT-CCAFS) indicated global warming as the most robust aspect of climate change related to agricultural production. Strategies for adaptation to climate change can be distinguished at different levels: incremental, adaptive and transformative. Transformative strategies, such as new ecosystem services and introduction of climate-resilient varieties, would provide the largest gains, although these strategies are also associated with higher levels of complexity and costs than, for example, incremental changes like changes in planting time or plant spacing. Technologies alone will not be sufficient for farming communities to effectively adapt to climate change; other barriers (institutional, economic, and social) must be addressed. Adaptation efforts also need to involve all stakeholders, including farmers, extension agencies and policy makers. Mitigation is about the best agricultural practices; therefore, input-use efficiency must be targeted. Adaptation does not mean compromise on yields; therefore, maximizing productivity in target environments while adapting to climate change is important.

Plenary Session 4: Panel Discussion – “Ensuring a vibrant maize seed sector in Asia through public-private partnerships”

Moderator: *Marco Ferroni* (SFSA)

Panellists: *Arvind Kapur* (Rasi Seeds, India)
Bijendra Pal (Bioseed, India)
Shilpa Divekar Nirula (Monsanto, India)
Fan Xingming (YAAS, China)
John McMurdy (USAID)

Public–private partnerships (PPPs) are important for strengthening maize value chains in Asia, especially in terms of undertaking strategic research, developing and scaling-up new technologies, and deploying products that can improve the livelihoods of the smallholder farmers in the developing countries.

Though PPP has been under discussion for many years now, there are very few successful examples of PPPs related to crop improvement and seed sector. Lack of trust between public and private institutions and dysfunctional policies are two of the major reasons for the failure of many PPP initiatives. Also, most of the existing PPPs are for dissemination/delivery of ready-made products from the public sector, rather than in strategic research areas designed to develop and deliver tailor-made projects that meet the requirements of the clients as well as seed industry. Another major factor deeply affecting PPPs for developing a vibrant seed sector is the lack of a conducive policy environment that can effectively promote smooth and legitimate flow of germplasm between public and private institutions.

The panellists highlighted some key factors that determine the success of PPP projects, including:

- Coming together of partners with complementary skills/expertise and resources
- Mutual trust and respect for each other’s intellectual property
- Formulating and implementing a project plan with clear objectives and agreed timelines
- Ensuring impact through generation and dissemination of products of value
- Involving end user industry, a critical partner in demand generation
- Identifying institutional bottlenecks to effective partnerships, including policies, based on past experiences or lessons learnt

To strengthen the maize seed sector in Asia through PPPs, the panel highlighted pre-breeding, upstream research, agronomic packages, and farm extension as possible areas.

Plenary Session 5: Panel Discussion – “Interface with farmers and entrepreneurs on opportunities for enhanced maize production and utilization in Asia”

Moderator: *Mark Holderness* (GFAR)

Panellists: *Esther Penunia* (AFA, Philippines)
Ambika Pandey (Hariyali Seed Cooperative Ltd., Nepal)

Md. Abdul Mazid (BRAC, Bangladesh)
Yash Sahrawat (YPARD)
Taweesak Pulam (Sweet Seeds Co. Ltd., Thailand)
Baldev Singh (AIAMMA, India)

The following major points emerged from the discussion:

- Partnership means not only working for the farmers but also with them. Farmers should not be treated as just end users of technologies but should be effectively integrated in the research process. Farmers' participation at the developmental stages of a project is essential. Not only will this help researchers to understand what farmers want, but will also improve adoption trends. We need to further evolve from the PPP (Public-Private Partnership) model to a PPPP or public-private-producer partnership whose mission should be to improve food, nutritional and environmental security.
- An individual farmer may not have the capacity alone to participate in agricultural research, including development/validation of new technologies. Farming communities, which are already popular across some parts of Asia, ensure that the poorest farmer is not left behind and benefits from new seed and technologies that are appropriate for smallholder farmers reach those concerned. For example, community level mechanization allows farmers to have access to machinery without significant capital investments.
- Farmer participation is even more important when it comes to youth. In some parts of Asia, up to 60 per cent of the population is below the age of 35. Urgent action needs to be taken to motivate young people back into farming. Young people are leaving villages and farming and moving to cities and into urban-based employment. To attract youth into agriculture, the sector needs to be made financially viable, and the youth must be involved in decision making. Shifting agriculture from a labour-intensive industry to a knowledge-intensive system where information and communication technology (ICT), marketing and business management are integral components could be an important step towards a youth-driven agricultural sector.
- Research organizations need to approach farming communities with an integrated approach, i.e., right from on-farm research, seed production of improved varieties to post-harvest storage and access to markets.
- There is often an assumption that farmers are aware of new varieties and the agronomic package of practices, but this is not always the case. Teaching farmers good agronomic practices is as important as providing the right seed. Showing farmers the success that others have had with a new product or a technology will have a positive cascading effect.

In a **special lecture** that followed the Panel Discussion, **H.S. Gupta** (BISA) introduced the genesis, vision and mandate of the Borlaug Institute for South Asia (BISA) to the 12th AMC participants. He highlighted the importance of strengthening food, nutrition and environmental security in South Asia, in the light of global climate change, increasing population, widespread malnutrition, degradation/erosion of natural resource base and changing demands. BISA, an international institution established jointly by CIMMYT and the Government of India having three centers in India (Ladhowal, Punjab; Pusa, Bihar; Jabalpur, Madhya Pradesh), is working

towards developing sustainable agricultural technologies and approaches that ensure food and nutrition security and reduce poverty in South Asia, besides providing a platform for training a new generation of scientists to work on wheat and maize systems in South Asia, in close partnership with national and international institutions.

Plenary Session 6: Keynote presentations

Co-Chairs: *Nguyen Van Bo* (VAAS, Vietnam)
B.M. Prasanna (CIMMYT)

Rapporteur: *B.S. Vivek* (CIMMYT)

In the **special lecture** on “Nutritionally enriched maize: Adoption and impact in Asia”, **S.K. Vasal** (Former Distinguished Scientist, CIMMYT) traced the history of development of Quality Protein Maize (QPM). He emphasized on the following for enhanced impact of QPM in Asia: genetic diversity and exploitation of heterotic patterns; overcoming regional biotic and abiotic constraints; better understanding of modifier gene complex; stacking of QPM trait with either one or a combination of high oil, kernel methionine, provitamin A, kernel Fe or Zn; reducing time span of QPM conversion programs using biotechnology tools; continuing research on kernel modification and stability; maintaining protein quality during breeding efforts; availability of modest protein quality analysis facilities; preventing QPM contamination through genetic isolation; trained manpower in QPM research; more research on QPM feeding trials in animals and humans; and encouraging use of QPM in processed foods and traditional preparations.

In another special lecture on “New developments in production of doubled haploids in maize”, **Albrecht Melchinger** (University of Hohenheim, Germany) highlighted the major advantages of doubled haploids (DH) in maize breeding, and discussed the desirable characteristics of an effective sorting system for maize haploids, including the currently used *R1-nj* colour marker, and a prototype for rapid identification of haploids using kernel oil content as marker. University of Hohenheim has recently developed temperate haploid inducers with ≥ 8 per cent haploid induction rate, and an oil content of ≥ 10.5 per cent. Collaboration with CIMMYT is ongoing to develop next-generation tropicalized haploid inducers with high-oil marker to overcome the limitations of existing *R1-nj* based haploid inducers.

Technical Sessions

Technical Session 1: Enhancing genetic gains in maize breeding

Co-Chairs: *S.K. Vasal* (Mexico)
Suwit Chaikattiyod (DOA, Thailand)

Rapporteur: *Sudha K. Nair* (CIMMYT)

In the **keynote lecture** on “Strategies for germplasm enhancement of maize”, **Walter Trevisan** (GEM, USA) highlighted that less than 10 per cent of the genetic diversity available in maize is used worldwide. Introgression of exotic germplasm in modern maize breeding program is important to enhance genetic gains. Germplasm enhancement of maize (GEM) project in USA is a successful example of public-private partnership, involving

most of the companies and universities working on maize breeding along with USDA and some international co-operators. So far, 265 inbred lines were developed from 30 maize races and released in the past 20 years. The GEM allelic diversity project, since 2010, is incorporating new methods of haplotype discovery and doubled haploid strategy in addition to conventional GEM work flow. Nearly 200 DH inbred lines have been developed and released from 60 races in 2014, which had 75 per cent adapted corn belt germplasm and 25 per cent exotic lines. Besides GEM, there have been successful examples of exotic germplasm introgressions from Argentina, Brazil, Mexico, Thailand, Kenya and Zimbabwe. The knowledge of germplasm sources and their attributes are very important to help drive the introgression work. The availability of good local adapted germplasm to anchor these introgressions, and the ability to introgress them while preserving heterosis will dictate the success of these works.

Kevin Pixley (CIMMYT), in his presentation on “Seeds of Discovery (SeeD): Characterizing and utilizing maize genetic resources for germplasm diversification”, discussed the progress made so far through the SeeD project. The project, funded mainly by the Mexican Government, focuses on molecular and agronomic characterization and use of genebank accessions in genetic improvement of maize and wheat. About one million measurements have been logged-in already as part of about 34 trials conducted on a number of important traits of maize along with high density genetic profiles of about 25,000 genebank accessions of maize, analysis of which would help to catalogue useful genetic variations. In a pilot study, SNPs in several major genes contributed by genebank accessions have been found to be significantly associated with Tar spot resistance in maize, which has emerged as one of the most important biotic stresses in Mexico. The project also focuses on bridging the germplasm between genebank and breeding lines by way of prebreeding and supply of prebred germplasm directly to the breeders. The scope of this project could possibly be extended to Asia through survey of priority traits, collaborative phenotyping of traits of interest, providing efficient database access, and capacity building.

Jose Luis Araus (University of Barcelona, Spain) presented on “High throughput and precision phenotyping for improving abiotic stress resilience of maize”. He highlighted precision phenotyping at the field level as important for improving breeding efficiency, especially in stress-prone environments, and for enhancing genetic gains. High-quality experimental sites are required for developing improved germplasm. Mapping the spatial variability and adopting improved experimental designs are important for enhanced reliability of breeding trials. Available low-cost, remote-sensing based approaches that make field-based precision phenotyping affordable for NARS and small seed companies were also presented.

Kiru Pillay (Monsanto, South Africa) made a presentation on “Water Efficient Maize for Africa (WEMA): A model partnership for tropical maize improvement”. The WEMA project, coordinated by African Agricultural Technology Foundation (AATF), is a case study of a successful public private partnership for developing drought tolerant maize hybrids with improved water stress tolerance. The project is successfully being implemented in five countries in Sub-Saharan Africa, namely, Kenya, Uganda, Tanzania, Mozambique and South Africa, tapping the complementary strengths of CIMMYT, Monsanto and NARS partners, in terms of maize germplasm, conventional breeding, molecular breeding, and transgenic approaches.

Technical Session 2: Maize for fodder/feed, specialty corn, value addition and processing

Co-Chairs: *Eskandar Zand* (AREEO, Iran)
Sergie Bang (NARI, Papua New Guinea)

Rapporteur: *Devendra Malaviya* (IGFRI, India)

Christian Böber (CIMMYT) delivered a **keynote lecture** on “The rapid growth of poultry industry in Asia: Implications for research and development”. Maize value chains are growing more sophisticated with the transformation of poultry and livestock industries in Asia. Asia accounts for more than 25 per cent of global poultry production. This is a significant opportunity for the small and marginal maize farmers. However, the risk involved due to increasing avian diseases may adversely affect maize demand and must be duly taken into consideration. Availability of low-priced, high-quality feeds is critical for poultry production to remain competitive. Development and distribution of biofortified maize, including QPM and high methionine maize, with enhanced levels of limiting amino acids, holds significant economic potential. Examining the potential of innovative value chains to capture the quality attributes of feed ingredients from farmers to poultry firms is one area of research capturing attention of the private and public sectors.

Michael Blümmel (ILRI) gave a lecture (through Skype) on “The fodder value of maize stover vis-à-vis other cereal residues and opportunities for improvement through crop breeding and value addition”. There is general perception that maize stover is inferior to that of sorghum stover. Against this perception, recent studies in India revealed that the cost of milk production with maize stover feeding is Rs 14.5, as compared to sorghum (Rs 18.2). However, because of high volume, transportation of maize stover was found to be costlier; chopping decreases this ratio to 1.5. Around 5 per cent units in digestibility can be exploited in the released and pipeline maize hybrids without detriment to grain yields. Similar level of improvements seem achievable through targeted improvement. Therefore, assumptions about stover from one species being superior to another is counter-productive. It is important to look at the whole value chain: demand > crop improvement > stover transport and fodder marketing > feed and fodder processing > dairy producers.

Karmol Lertart (KKU, Thailand) gave a talk on “Breeding purple waxy corn for health and wellbeing”. The presentation highlighted the recently developed purple maize varieties and hybrids in Thailand, which fit well with the concept of “eat your colours every day” to be healthy by inhibiting free radicals and reducing the risk of chronic diseases. Purple corn products have potential to fight against cancer, hypertension, high blood pressure, cholesterol and obesity. A variety of food products, such as Miracorn, are developed from purple corn, and marketed with high acceptability in Thailand. Further, the anthocynin content of maize can also be used as natural edible colouring agent.

Usha Singh (RAU, India) made a presentation on “Development and commercialization of value added food products of QPM for nutritional security”. She highlighted that proteins present in QPM are of high quality (up to 80% digestibility) and hence, can be effectively used to fight protein malnutrition and hidden hunger. Various ready-to-eat QPM products were successfully developed, technologies perfected and disseminated to villagers in Bihar (India).

Technical Session 3: Stress resilient maize for Asia

Co-Chairs: *Inia B. Seruiratu* (MoA, Fiji)
Md Rafiqul Islam Mondal (BARI, Bangladesh)

Rapporteur: *Daniel P. Jeffers* (CIMMYT)

In his **keynote lecture** on “Abiotic stress-resilient maize for adaptation to climate change in Asian tropics”, **P.H. Zaidi** (CIMMYT) highlighted that more than 80 per cent of the maize production in Asia is under rainfed conditions, with yields approximately half of that of irrigated maize in the region. Many biotic and abiotic stresses impact maize production in the region. Higher yielding and stress resilient maize has to be a major component for increasing productivity and improving yield stability across the region. There is a greater need than ever before to work in a coordinated network to characterize the production environment, identify the key critical points affecting yield potential and yield stability, and establish the capacity to perform precision phenotyping under managed stress. It is possible to link selection for several diverse abiotic and biotic stresses, including drought, waterlogging, anaerobic germination, heat tolerance, and foliar disease resistance for developing commercially viable stress resilient varieties. An example was presented on obtaining rapid genetic gains through the use of genomic selection versus only phenotypic selection. CIMMYT-Asia team has recently developed hybrids with tolerance to heat and drought. Intensive efforts are now required to deploy such hybrids in targeted Asian agro-ecologies.

M. Shalim Uddin (BARI, Bangladesh) made a presentation on “Multi-trait selection index for excess water tolerance in maize at seedling stage”. In Bangladesh, >10 per cent of the total maize growing area is affected by floods and waterlogging. A simple seedling screening method can be used to select for flooding tolerance. Two key secondary traits, shoot length and shoot dry weight under waterlogging stress were identified as the best indicators for detecting waterlogging tolerant genotypes. Based on multi-trait selection, seven inbred lines were identified as tolerant to excess water stress.

Jie Chen (SJU, China) gave a talk on “Understanding of *Curvularia lunata* pathogenicity differentiation induced by resistance varieties”. In China, *Curvularia* leaf spot caused by *Curvularia lunata* is an important disease of maize. In a detailed study utilizing RNA sequencing and proteomics, the interactions between the pathogen and the host were dissected. Adaptive variation of pathogen virulence induced by resistant host was linked to an overlapped network of multiple factors, including melanin, toxin, enzymes and stress proteins. *Sod* and *tsa1* genes can be used as markers for adaptive virulence variation at transcription level; *Sod* gene can be used as a marker at the early stage of pathogen–host plant interaction. Markers reflecting the virulence differentiation could be either at transcript level or translation level. The study highlighted that analyses of host-pathogen interaction at the molecular level could provide insights into field observations, and possible targets for developing improved host resistance to important diseases.

Siwilai Lapbanjob (NSFCRC, Thailand) made a presentation on the “Effect of maize dwarf mosaic inoculating at various growth stages on yield of Nakhon Sawan 3”. The study determined the critical stages for yield loss due to maize dwarf mosaic virus in a susceptible drought tolerant commercial maize variety in Thailand, Nakhon Sawan 3. Controlled inoculations at different

developmental stages identified the greatest yield losses occurred with infection at the V1-V3 growth stage, but infection up to the V9 stage of development at approximately 30 days after planting led to significant yield losses. Management practices, especially reflective mulches to control the aphid vector, need to be used up to this critical stage (V9) for reducing losses to MDMV in a susceptible variety.

Buddhi B. Acchami (NMRRP, Nepal) presented a paper on “Temporal variation of stem borer damage in maize at Chitwan, Nepal”. Several species of stem borer are very important insect pests of maize across the Asian region. A study was undertaken in Nepal to look at the insect population dynamics throughout the year with sequential planting under natural infestation. Leaf damage and per cent damaged plants were the lowest in the cool December – January planting, while later plantings, especially in May, were more severely affected. Stem borer damage was reduced during the warm rainy summer plantings in July and August. A basic understanding of stem borer damage throughout the year was obtained, and can also be used to improve phenotyping for this group of insect pests at Chitwan, Nepal.

Rajkumar Zunjare (IARI, India), in his presentation on “Genetic analyses of resistance to stored grain weevil (*Sitophilus oryzae*) in maize”, highlighted that post-harvest losses in the Asian region are quite severe due to stored grain pests, especially grain weevils. Phenotyping for post-harvest pests was set-up under controlled conditions in India to evaluate a broad range of genotypes and for identifying factors leading to improved host resistance to weevils. Grain weight loss, insect fecundity and germination percentage were combined to develop a selective cumulative resistance index for characterizing the responses of maize genotypes. Inheritance studies revealed that besides significant genotype × environment interaction, both additive and non-additive gene actions were important for resistance to stored grain weevil.

Technical Session 4: Socioeconomics and innovative policies for enhanced maize production and impacts

Co-Chairs: *Raghunath Ghodake* (NARI, Papua New Guinea)
David Spielman (IFPRI, USA)

Rapporteur: *Christian Böber* (CIMMYT)

In her **keynote lecture** on “Policy frameworks for effective innovation, dissemination and adoption of maize technologies in Asia”, **Katinka Weinberger** (CAPSA, Indonesia) emphasized on the need for broadening the policy frameworks for agricultural innovation to address new types of arrangements, networks and stakeholder relationships. Innovative approaches are required to enhance coordination and institutional design of agricultural innovation systems, to create space for research-extension interface, enhance the quality of extension services, and address the needs of smallholder farmers, women and youth. Governments should also develop and implement a coherent strategy for agricultural innovation that is well embedded in overall agricultural development and investment strategies.

Olaf Erenstein (CIMMYT), in his presentation on “Scaling maize innovations in a changing Asia”, reviewed the maize sector development in Asia over four decades (1973-2013). Significant dichotomy exists in the subsistence and commercial maize production systems in Asia, reflecting diverse clients with differing needs. There is significant potential for further

growth of the maize sector, but there are scale-up challenges, in terms of backward–forward linkages of sector stakeholders, equity and efficiency trade-offs, client orientation and efficiency of agricultural R&D. Innovations at various levels is the key for future growth and maize sector trajectories.

K. Srinivas (NAARM, India) made a presentation on “Assessments of the maize situation, outlook and investment opportunities in Asia”. Despite the growth of maize sector in the study countries in Asia, significant differences were observed (e.g. with respect to the share of area under hybrids, which is very high in Bangladesh, but comparatively low in India). Based on different estimations of future demand and production of maize, some countries (e.g. India) might potentially become a more important maize exporter, whereas other countries (e.g., China) might still remain a net importer, due to the fact that the demand-growth exceeds the production growth rate.

Hassnain Shah (PARC, Pakistan), in his presentation on “Competitiveness of maize production in Pakistan” highlighted that Pakistan has potential to increase the maize area under hybrids. Seed production in the country is currently not sufficient to satisfy demand. Pakistan could establish itself as a maize exporter due to comparative advantages in maize production. This would, however, require appropriate technology and policy support.

Monayem Miah (BARI, Bangladesh) presented a paper on “Maize production in Bangladesh: way towards self-sufficiency”. Maize production in Bangladesh increased significantly due to the widespread adoption of hybrids, especially since the beginning of the 2000, driven by the increasing demand from the poultry and fish feed industry. Maize productivity is already the highest in the region, with an average yield of around 7 t/ha. However, poultry feed producers are concerned that maize exports would increase the domestic price of maize, and therefore, their production costs, whereas maize producers see benefits from exports. Currently, Bangladesh is still a net-importer, but there would be the potential for export, if new areas are brought under maize cultivation.

Technical Session 5: Biotechnology for maize improvement in Asia

Co-Chairs: *H.S. Gupta* (BISA, India)
Umi Kalsom Abu Bakar (MARDI, Malaysia)

Rapporteur: *J.L. Karihaloo* (APAARI)

Saturnina C. Halos (Department of Agriculture, Philippines) in his **keynote lecture** on “Insect-resistant and herbicide tolerant GM maize in Philippines: present status and prospects”, explained in detail the history and development of GM maize cultivation in the Philippines. Introduction of GM maize in farmers’ fields started in the year 2002; currently yellow corn GM hybrids having traits for insect resistance (IR) and/or herbicide tolerance (HT) are under commercial cultivation over an area of 700,000 ha. Till date, four IR, two HT and six stacked IT/IR GM events have been approved by the biosafety regulatory authorities. These traits are significant since Asian corn borer is a serious pest of maize in the Philippines and weeding is a major production expense. The adoption ranged up to 65 per cent of all yellow maize grown in a region. Post-approval conditions laid out by the regulatory authorities include implementation of the approved insect resistance management strategy (IRM), adoption of soil and water conservation when farming GM maize in sloping

areas, and monitoring of GM maize adoption. Socioeconomic analysis revealed that higher yields and incomes, availability of financial assistance, effective pest resistance, good produce quality and lesser cultivation expense were the major reasons given by farmers for adoption of GM maize. The increased income made by farmers was used for day-to-day expenses, children's education, home improvement and farm development, thus helping to bring them out of poverty. Majority of GM maize farmers expressed that they would continue to grow GM maize. The new traits that the farmers wanted in maize hybrids are resistance to other insect-pests, drought tolerance and overall weather resilience, efficient use of inputs, and good quality produce.

Jan Samson (DuPont-Pioneer) made a presentation on “Developing resilient maize for Asia against biotic and abiotic stresses”, emphasizing on an integrated approach that combines improved hybrids, native trait variation and transgenic traits in tackling abiotic and biotic stresses affecting maize productivity. Climate change will also lead to increase in biotic stresses, which warrants multiple approaches including crop modelling and transgenic strategies. Marker-assisted selection, doubled haploids, precision phenotyping, including digital imaging, high-density genotyping and DNA sequencing are important in modern maize breeding programs. Understanding the growers' needs, innovative technology options, multi-year on-farm testing before product commercialization, and integrated solutions for local needs were emphasized.

In a presentation on “Molecular marker-assisted breeding for tropical maize improvement”, **Raman Babu** (CIMMYT) elaborated the work of CIMMYT in association with regional and national research systems, on an array of genome-wide association studies (GWAS) that have resulted in identification of reliable marker-trait associations for a range of abiotic and biotic stress tolerance traits along with important nutritional quality traits in tropical maize germplasm. Also, whole genome-based ‘genomic selection’ (GS) models have been trained for rapid improvement and prediction of complex traits such as drought and heat tolerance. Recent developments with respect to various molecular breeding tools and strategies and their applicability to maize breeding programs, especially in Asia, were also presented. Various challenges/bottlenecks that impede the adoption of such modern breeding tools in the tropics, and opportunities to overcome these challenges, were highlighted.

Lijuan Yu (YAAS, China) made a presentation on “Genome-wide analysis of phosphate transporter gene family in maize”, in which she detailed genome-wide search in maize through which 40 potential phosphate transporter (PT) family genes were found. Phylogenetic analysis assigned the 40 PT paralogues into four clusters; in addition, around 250 putative *cis* elements were found in the 2-kb upstream region of these PT genes, of which a majority were Pi-response and other stress-related *cis* regulatory elements. *ZmPht1;6*, one of the PTs, was found to mediate Pi uptake. The results from this study could be useful in elucidating the roles of PTs in the growth, development, and stress response in maize.

Dung Do Van (NMRI, Vietnam), in his presentation on “Deciphering genomic regions associated with waterlogging and drought tolerance traits in tropical maize using multiple connected populations”, reported evaluation of a set of ~800 F2:3 families derived from eight biparental populations for their *per se* performance under waterlogging, drought and

optimal conditions at CIMMYT-Hyderabad during 2013-2014. The nested association design of the eight populations with two common drought tolerant parents and eight waterlogging tolerant lines enabled joint linkage and linkage-disequilibrium analysis for uncovering/validating potential regions for abiotic stress tolerance. QTL mapping carried out using ~870 polymorphic SNPs in the eight populations revealed a total of 20 QTL for grain yield (GY) and other associated traits of waterlogging and drought tolerance. Out of the 11 QTL detected for drought tolerance, two were identified in more than one population. Several waterlogging QTL were also detected in this study, nine of which overlapped with the regions identified for GY, brace roots and lodging percent under waterlogged conditions in an independently derived recombinant inbred line population and offer potential introgression opportunities into Asian elite germplasm.

Vignesh M (IARI, India) presented a paper on “Enrichment of kernel β -carotene in maize hybrids using marker-assisted backcross breeding strategy”, highlighting the variability of β -carotene among diverse inbreds and their utilization in the biofortification program. Molecular marker-assisted introgression of *crtRB1* 3’TE favourable allele from CIMMYT-HarvestPlus genotypes into seven elite Indian inbreds that are parents of four commercial maize hybrids, viz., Vivek QPM-9 (VQL1 \times VQL2), Vivek Hybrid-27 (V335 \times V345), HM-4 (HKI1105 \times HKI323) and HM-8 (HKI1105 \times HKI161) was undertaken. While the parental inbreds possessed low β -carotene (1.4 $\mu\text{g/g}$), the *crtRB1*-introgressed progenies revealed β -carotene ranging from 9.7–17.0 $\mu\text{g/g}$. Recovery of ~90 per cent recurrent parent genome in the introgressed progenies led to high phenotypic resemblance with their recurrent parents. Improved inbreds were crossed to reconstitute the hybrids which possessed enhanced kernel β -carotene ranging from 11.5–20.55 $\mu\text{g/g}$, as compared to their original hybrids (mean: 2.2 $\mu\text{g/g}$). The reconstituted hybrids evaluated at diverse locations exhibited grain yield at par with the original hybrids, offering significant promise for further deployment.

Technical Session 6: Strengthening maize seed systems in Asia

Co-Chairs: *Subash Dasgupta* (FAO RAP, Thailand)
N.N. Singh (TAAS, India)

Rapporteur: *A.R. Sadananda* (CIMMYT)

David Spielman (IFPRI, USA) gave a **keynote lecture** on “Measurement of growth of Asia’s maize seed system”. Maize seed industry in Asia has grown over the years, but its continued growth requires a new discourse, greater regulatory capacity, better metrics, better data and more insightful analysis. Empirical measurement of the growth of maize seed industry in Asia is hindered by lack of required data. A list of 25 indicators was presented that can potentially aid in determining the seed industry performance, innovation, structure and regulation. Data on these indicators will also help in setting the research priorities and encourage the maize seed industry growth. The importance of analysing the varietal turnover rate to estimate in turn the impact of innovations was emphasized.

Ian Barker (SFSA) gave an account of the efforts being made by the Syngenta Foundation for Sustainable Agriculture to foster the nascent seed markets in Africa, including seed replanting guarantee and weather-linked insurance schemes. Delivery of research products targeted for small and marginal farmers remains a challenge due to the remoteness and lack of infrastructure in

stress-prone and outlying areas. The Affordable, Accessible Asian drought-tolerant maize (AAA) project, is an example of a successful public-private partnership (PPP) project in Asia, with well-defined target region, product profile, and delivery models, with the goal of supporting the small-scale maize farmers in Asia with climate-resilient maize.

A.R. Sadananda (CIMMYT) made a presentation on “International Maize Improvement Consortium (IMIC) in Asia: Partnership with seed companies for client-oriented product development and delivery”. IMIC-Asia, launched in 2010, has been structured for developing client-oriented products, and for reducing the timeline for product deployment and impacts in the farmers’ fields. Current activities of IMIC-Asia includes development of improved inbred lines and marketable hybrids, collaborative product testing, training and testing services. Future expansion plans could include doubled haploids (DH), marker-assisted breeding, pre-breeding and customized training programs on prioritized areas.

D.B. Bhandari (Nepal), one of the pioneers of community-based seed production in Nepal, made a presentation on “Strengthening the local seed systems and disadvantaged communities: Success and evolution of the first community-managed seed production company in the hills of Nepal”. The Sindhu-Tuki community-based seed producer (CBSP) group was formed in 2005 with 100 farmers; this evolved into the Sindhu-Tuki Seed Producers Cooperative Ltd. in 2008 with 92 members, and finally into Hariyali Seed Company Pvt. Ltd. (HSCPL) in 2010 with 346 members. HSCPL helped in production of quality seed and in enhancing the adoption of improved maize varieties. HSCPL intends to enter into hybrid maize seed production, with the support of CIMMYT. It has initiated its own research activities and establishment of seed production farm(s) and better infrastructure for seed quality testing, seed processing, and packaging.

Chutima Koshawatana (FCRI, Thailand) made a presentation on “Maize seed village: A self-reliance production for Thai farmers” highlighting about yet another successful community based seed production initiative. Maize seed village was established with an objective to disseminate Nakhon Sawan 3 hybrid and strengthen self-reliance on maize seed production. She narrated the efforts in developing model farmers and model farms, with effective seed production and inventory management, in the northern region of Thailand.

Technical Session 7: Regional Assessment of maize in South Asia and Oceania: Country Reports

Co-Chairs: *Bhag Mal* (APAARI)
Hassnain Shah (PARC, Pakistan)

Rapporteurs: *P.H. Zaidi* and *K. Seetharam* (CIMMYT)

In this Technical Session, maize program leaders/representatives of seven countries from South Asia and the Oceania presented an overview of maize program of respective countries, including the progress made so far regarding varietal development and deployment, quality seed production, development of agronomic management practices, adoption of improved technologies and their impact, maize processing, value addition and product development, public-private partnerships and successful examples in maize R&D, and the way forward.

Bangladesh – Md. Abu Alam Mondal (BARI)

Maize is number three crop in Bangladesh, and is largely used as feed for poultry, fish and cattle. Grown round the year, maize area has been expanding in the country. Traditionally grown during winter/dry season (0.312 m ha), but spring season maize area is also increasing (0.045 m ha). Maize hybrid seed requirement is 6,500 tons; local production is only 1,000 tons, and the rest is imported from other countries, mainly India. BARI hybrids contributed 260 tons in terms of total seed. BARI has strong collaboration with CIMMYT, working on various projects, such as Heat Tolerant Maize for Asia (HTMA) and Cereal System Initiative for South Asia (CSISA). Major challenges and future thrusts are: (a) developing and deploying stress resilient germplasm, especially for drought, waterlogging, heat and salt stresses; (b) nutritionally enhanced/biofortified maize, and (c) strengthening public-private partnerships.

Bhutan – Dorji Wangchuk (RNR RDC)

Maize is used as a staple food crop in Bhutan; over 80 per cent of maize produced is used as food. Maize program in Bhutan is still at a development phase, with germplasm introduced from CIMMYT and other sources. Attempts are being made to establish a formal maize seed sector, and to adopt community-based seed production (CBSP), which has been successful in Nepal. While most maize varieties in Bhutan are OPVs, recent emphasis has been on hybrids. Future thrusts include: (a) strengthening local seed system; (b) enhancing germplasm base, especially stress resilient germplasm; recently joined HTMA project, led by CIMMYT; and (c) improve maize processing and diversify products.

India – O.P. Yadav (IIMR-ICAR)

In India, maize is the number three crop after rice and wheat in terms of area and production and number two, only after wheat in terms of productivity. It is largely used as feed (52%) followed by food (23%) and other industrial uses. Remarkable gains (62%) in maize production happened during 2003-2013, due to increase in both productivity (27%) and increase in area (28%). The present focus is on high-yielding single-cross hybrids; more than 100 hybrids have been released in India since 2000, suitable for different states of India. New hybrids combine traits of high yield and resistance to major biotic stresses. High emphasis is also placed on agronomic research including planting crop geometry, nutrient management and conservation agriculture practices. Emphasis is also on quality seed production, and facilitating small/medium enterprises. Future priorities include: a) effectively meeting the increasing maize demand (@15%/year for poultry itself); b) more emphasis on single-cross hybrids; c) strengthening and liberalizing seed sector; d) emphasis on elite hybrid-oriented, stress resilient germplasm; e) enhancing capacity on DH and molecular breeding technologies; f) emphasis on biofortified maize, including QPM, provitamin A, methionine, low phytic acid, Fe and Zn; and g) upscaling hybrid adoption.

Nepal – K.B. Koirala (NMRP-NARC)

Maize plays a key role in the food and nutritional security of Nepal. Maize is mainly used as food (55%), followed by poultry feed (20%) and livestock feed (15%). Maize OPVs cover about 90 per cent area, but recent emphasis is on hybrids. There is a large yield gap that needs to be addressed for enhancing national maize productivity. Major production constraints are abiotic

stresses (drought, heat, cold and low N) and biotic stresses (insect-pests, GLS and leaf blights). NMRP-NARC has active collaboration with CIMMYT, through various projects, including HTMA, HMRP and CSISA, with particular emphasis on developing and deploying stress resilient and nutritionally enriched maize. Future priorities are: (a) human resource development in maize R&D; (b) elite and stress resilient germplasm; (c) strengthening seed system; and (d) strengthening public-private partnerships.

Pakistan – Mian Muhammad Shafique (MMRI)

Maize is the third most important crop in Pakistan, after wheat and rice, and is grown for feed (35%), food (23%) and industrial and other uses (31%). Punjab and KPK are the two major maize growing states. Over 80 per cent maize is grown in autumn (July-Nov) and the rest in spring season (Feb-June), but the spring maize area is increasing largely because of high yields. Over 80 per cent of maize seed is imported and is sold at high price. The focus of crop improvement program is on developing high yielding germplasm, and identifying donor lines for major stresses, such as drought and heat, and for major diseases and insect-pests, besides standardization of single cross seed production, and strengthening seed system. Future priorities include: a) introduction of new elite stress tolerant exotic germplasm, and their use in breeding program; b) accelerated development of productive inbred lines using DH technology; c) research on genetically modified maize; d) strengthening local seed system; and e) capacity building.

Sri Lanka – W.M.W. Weerakoon (FCRDI)

Maize is the second most important crop after rice. As of now, the country is self-sufficient with regard to maize, but production needs to be doubled as the demand is increasing especially for poultry feed. About 95 per cent of the hybrid maize seed is imported. The focus is on hybrid development, using germplasm from CIMMYT and local germplasm, and also introduction and testing of ready hybrid combinations from CIMMYT. Emphasis is also being placed on agronomic innovations and policies for enhancing productivity per unit area. Technologies are being introduced to address water scarcity and other issues, such minor-tank based farming, irrigation scheduling based on pan evapotranspiration, and optimization of planting dates etc. Future priorities include: a) developing and deploying elite stress tolerant germplasm, especially for drought and heat stress; b) enhancing private sector involvement in agriculture R&D; c) acquiring technology and resources for DH-based breeding; d) introduction of farm machinery to reduce the cost of cultivation; and e) achieving self-sufficiency in hybrid seed.

Papua New Guinea (PNG) – Julie Sip (NARI)

Maize is an important crop for PNG, grown by 94 per cent of the rural population, and is used as an animal feed, for starch production, and as food. PNG, however, lacks technical expertise/capacity on maize breeding, and seed production and delivery system. Pools, populations and inbred lines are introduced from CIMMYT and Thailand, but most research is done on agronomic research and testing at different locations. Future priorities include: a) developing a maize improvement policy for PNG to promote domestic production as a component of grain industry; b) improve productivity and efficiency of seed systems; and c) strengthening the breeding program, to develop germplasm with resilience to abiotic and biotic stresses.

Technical Session 8: Regional Assessment of Maize in East Asia, South East Asia and West Asia: Country Reports

Co-Chairs: *John McMurdy* (USAID)
Pichet Grudloyma (NSFCRC, Thailand)

Rapporteur: *Genevieve Renard* (CIMMYT)

In this Technical Session, maize program leaders/representatives of seven countries from East Asia, South East Asia and West Asia presented overview of maize program of respective countries, and highlighted the challenges to the maize sector, and the institutional priorities.

China – Juanghua Wang (CAAS)

Maize is the most widely grown crop in China. Maize area increased from 25 million ha to 33 million ha, and the corresponding production increased from 130.2 million tons to 210.0 million tons over the last one decade. Due to suitable climatic conditions, maize is planted in all seasons and in almost every province in China. However, major maize area in China is in a broad diagonal belt from northeastern to the southwestern provinces, including Shandong, Jilin, Hebei, Heilongjiang, Liaoning, Henan, and Sichuan provinces. China's feed maize demand was estimated at about 130 million tons in 2013, which was about 62 per cent of overall maize demand. Industrial use of maize has also experienced fast expansion in the last decade. In China, significant increases in maize yields occurred from the 1950s to 2010s, in four stages, namely OPVs, double-cross hybrids, single-cross hybrids, and stress tolerance. A total of 331 maize varieties were registered to meet the demand for maize production between 2004 and 2013. However, the key varieties/hybrids in China have not changed too much in the past decade. Bottlenecks for improving maize production and yields in China include water shortages, poor soil quality, climate change (low and high temperatures), and lack of useful genetic variability. Therefore, the emphasis is on improving resource use efficiency, protecting environmental quality, and research innovation. Future work for maize production, research and development in China will require a multi-disciplinary approach involving breeders, soil scientists, agronomists, farmers, ecologists, policy-makers, and social scientists.

Indonesia – Muhammad Azrai (ICERI)

Maize is one of the strategic commodities for agricultural development in Indonesia, especially for food and feed. The use of maize in the food and feed industry in Indonesia is around 41 per cent, and 59 per cent, respectively. Demand for maize continues to increase, but the production is unstable. The challenges for maize sector in Indonesia are climate change, abiotic and biotic stresses, and conversion of optimal land for non-agricultural purposes. Intensive diffusion and adoption of superior, climate-resilient maize varieties, cultivation practices and post-harvest technologies should be undertaken to improve national maize production and farmers' welfare. CIMMYT has tremendous impact on maize R&D in Indonesia through various collaborative projects (e.g., AMBIONET, AMNET, AMDROUT, AAA). Priorities for maize R&D include: a) developing and deploying climate-resilient maize varieties; b) improving facilities and infrastructure for maize seed production and marketing; c) new models of cultivation, plant protection, and post-harvest technologies with greater effectiveness and efficiency; d) policies and programs for increasing

maize farmers' income and living standards through improved productivity, value-addition, and better use of maize for food, feed and industries; and e) increasing the competence of human resources.

Philippines – Roger V. Navarro (PhilMaize)

Maize is the second most important crop in the Philippines, next to rice. Around 1.8 million farmers rely on maize production for livelihood. Yellow maize is predominantly used for livestock and poultry feed; this accounts for almost 70 per cent of the national maize annual production. White maize is produced and utilized as food at a smaller scale: usually for household consumption and as an alternative for rice in the southern part of the country. About 15 per cent of Filipinos eat white maize as staple. White maize production has gone down in the past 10 years (1.2 million ha white maize), while yellow maize area is growing. The introduction of GM maize (yellow) in 2003 is a major milestone in the Philippines. In 2013, the Bureau of Plant Industry estimated that around 728,076 hectares was devoted to GM yellow maize production in the country, placing the Philippines as one of the biggest users of GM maize in Southeast Asia. Some important challenges to maize sector include: a) lack of effective post-harvest facilities; b) building the competitiveness of maize industry; and c) improving the economic well-being of the white maize-growing farmers.

Thailand – Pichet Grudloyma (NSFCRC)

Maize growing area in Thailand is estimated at around 1.206 million hectares with a total production of 5.063 million tons and an average yield of 4.41 tons/ha in 2013. Maize R&D in Thailand is carried out actively by both public and private organizations. In the public sector, the Department of Agriculture (DOA) and Kasetsart University (KU) devote 30 per cent of their research effort to population improvement and 70 per cent to hybrid development. The private sector mainly focuses on developing proprietary hybrids. Much of private research, however, depends heavily on public sector maize germplasm, especially stress tolerant materials. Currently, Thailand does not permit any commercialization, importation, transit and exportation of GM crops, except for research purposes at the laboratory and greenhouse levels, although GM maize grain and its processed food products are permitted. Constraints for improving maize yields include abiotic stresses (drought, waterlogging, low soil fertility) and biotic stresses, especially diseases (downy mildew, southern rust, Northern Corn Leaf Blight, MDMV). The success of Thailand's maize production is based on the success in developing hybrid maize seed industry through PPPs. Maize breeders from the public and private sectors have the opportunity to discuss, share experiences, working procedures, management and problem-solving through the working season.

Vietnam – Mai Xuan Trieu (NMRI)

The importance of maize is rapidly rising in Vietnam, second only after rice. In 2013, maize area, average yield and total production reached up to 1.172 million ha, 4.43 tons/ha and 5.2 million tons, respectively. However, the volume meets only 70 per cent of the domestic demand, as about 850,000 ha of maize is grown in the mountainous and rainfed areas where yield is reduced by about 40 per cent due to drought. Ninety per cent of maize production in Vietnam is used as animal feed and only 10 per cent for human consumption

(waxy corn, sweet corn) and other industrial products. Domestic maize hybrids in Vietnam account for around 36 per cent to 40 per cent of the annual seed market, and the rest is from foreign companies. Key constraints for maize sector are: a) lack of application of agricultural mechanization, especially on sloping-land areas; b) inadequate capital investment for purchase of inputs, such as fertilizers, and for post-harvest services; and c) irrigation is costly and insufficient to ensure water requirements. Opportunities and priorities for maize R&D include: a) increasing maize-growing area; b) improving productivity, grain quality and efficiency of maize production; and c) addressing constraints in maize development, through improved technologies, strengthening research infrastructure, institutional reorganization, human resource development, and domestic cooperation.

Iran – Rajab Choukan (SPII)

Maize is one of the major crops in Iran, with a cultivated area of over 450,000 ha, out of which about 270,000 ha are for grain and 180,000 ha for silage. Seventy per cent of maize is used for poultry and animal feeding, 20 per cent in food industry, 5 per cent in industrial products and the rest (5%) for seed, etc. Local production is about 1.852 million tons of grain maize, which can meet only 32 per cent of local demand. According to the new maize development program, self-sufficiency in grain maize is targeted to be raised from 32 per cent in 2013 to 38 per cent in 2018 and 51 per cent in 2025. Water is the major factor limiting maize development and productivity in Iran. Given the growing demand on water resources, greater production will need to come from higher productivity rather than from net increase in cropland area. Use of new improved hybrids alongside improved management options is important. Emphasis is on development of improved, climate-adapted germplasm, diversification of genetic base of improved hybrids, and facilitating farmers' access to and trust in the new germplasm/technologies.

Turkey – Rahime Cengiz (MRS)

Maize is the third most widely cultivated crop in Turkey, following wheat and barley. It is successfully raised both as the main season crop and second crop. Seventy-eight per cent of maize production is used in poultry industry. Maize production reached 6 million tons in 2013, with an average yield of 8.95 t/ha, attributed to high-yielding hybrids and solid foundation of agronomic management. Seed production rights of new hybrids developed by public sector institutes are assigned to seed companies in the domestic private sector. However, the number of domestic varieties is lower than the number of varieties registered by the foreign-invested private sector in Turkey. Future thrusts and institutional priorities for maize R&D include: a) increasing the number of domestic hybrid maize varieties in a short time; b) developing and deploying climate resilient maize varieties, especially against abiotic stresses (drought, high temperature) and biotic stresses (diseases and insect-pests); c) developing varieties with high feed quality (high oil and methionine); d) Generating homozygous maize lines using DH technology at low cost and in a shorter time; e) effectively using DNA markers in genomics-assisted maize breeding; f) registering new hybrid maize varieties with high silage quality value and delivering them to the farmers; g) developing high-yielding maize hybrids with grain quality based on the preferences of maize-processing industrial enterprises (oil, chips, starch, nuts, etc.).

Technical Session 9: Precision-conservation agriculture for enhanced input-use efficiency

Co-Chairs: *D.P. Biradar* (UAS Dharwad, India)
Tien-Jung Yu (CoA, Chinese Taipei)

Rapporteur: *M.L. Jat* (CIMMYT)

M.L. Jat (CIMMYT) in his **keynote lecture** on “Conservation agriculture based management practices for sustainable maize systems: Learnings from South Asia” emphasized that in South Asia, the world’s most populous region, owing to natural resource degradation and emerging climatic extremes, maize has emerged as a potential driver of change. He highlighted that CA-based management practices have positive effects on yield and income in maize systems in general but the rainfed maize systems had more benefits. He further highlighted that no-till without surface residues is not useful in the medium-term, and in the long-run it could be rather detrimental. While presenting a time series analysis, he highlighted that the yield benefits of CA are more prominent after 2-3 years and hence long-term and systems approaches are important to critically analyze the real benefits of CA. The success of CA depends on layering of adapted component technologies for genotypes, water nutrient, weed, pest management, etc. on the foundations of the key elements of CA. He also emphasized that defining ‘recommendation domains’ of the CA-based management systems to diverse farm typologies is critical for scaling-up and scaling-out the CA-based management technologies. He also highlighted that lack of quality human resources on the ground is one of the major bottlenecks in the uptake of CA-based management systems; hence, capacity development at different levels and scales is critical.

Kaushik Majumdar (IPNI, South Asia) summarized the recent advances in precision nutrient management in smallholder maize systems of South Asia. He highlighted that maize is a nutrient-responsive crop; hence, appropriate nutrient management would be critical for sustainable intensification of maize-based systems. He emphasized that the “4R Nutrient Stewardship” principles provide an opportunity for more precise determination of source, rate, time and method of fertilizer application in smallholder maize systems, and consequently economic, social and environmental benefits to the society beyond the immediate gains of productivity increase. He shared the recent experiences on “Nutrient Expert” decision support tool for site-specific nutrient management (SSNM) in maize across South Asia. “Nutrient Expert”, which has been recently developed by IPNI and CIMMYT in close collaboration with NARES and other institutions, helps implement precision nutrient management in smallholder maize system in Asia and beyond. Its large-scale adoption and implementation in smallholder maize system can increase productivity and profitability and reduce environment footprint of applied nutrient. The presentation highlighted that integration of socioeconomic determinants in fertilizer recommendation would be critical for their adoption in smallholder systems. Development of system-based management option is more pertinent as compared to crop-specific approaches.

Mulugetta Mekuria (CIMMYT) shared the experiences from the “Sustainable intensification of maize-legumes based systems in Eastern and Southern Africa (SIMLESA) project”, funded by ACIAR. The multi-commodity and multi-institutional SIMLESA project focuses on systems integration and multi-stakeholder innovation platforms for sustainable agricultural intensification (SAI). Enhanced productivity is an integral part of sustainability. As part of SAI, resource-conserving technologies can help preserve diversities in cropping patterns and can have “win-win”

outcomes in terms of improving yields and reducing risks while reducing labour costs and input use, and sustaining the natural resource base. The main lesson from SIMLESA to help guide the Asian maize sector development is that many goals of increasing yields, reducing risk, enhancing profitability and conserving resources can be achieved simultaneously without too many trade-offs through effective application of CA-based SAI strategies, comprehensive integration of disciplines to generate relevant solutions, bringing on board functional stakeholders through innovation platforms, mainstreaming gender, inclusive strategies and value chain analysis tools to create improved farmer-to-market linkages.

Dongxing Zhang (CAU, China) in her presentation on “Performance of a precision planter with row cleaners and depth control units for no-till sowing of maize” mentioned that no-till planting is becoming popular and gaining ground in China. However, precise crop establishment and crop geometry is still an issue of concern. In this direction, the team in China have developed a precision planter with row cleaners and depth control units. This adjustable planter is useful under different kinds of maize (varying seed size) under different soil moisture contents. The planter has a huge potential for precision maize planting under no-till conditions for improving yields and resource use efficiency.

Chaohai Li (HAU, China), in her presentation on “Influence of soil compaction stress on root endogenous hormone and protective enzyme activities in maize”, emphasized that soil compaction is a major cause of soil health deterioration and crop yield losses in China. Based on specific studies, she observed that high soil compaction could cause destruction of the balance of the root senescence. Her results clearly showed that maize plants were not passively tolerant to soil compaction stress, but were actively building new balance to reduce the injury by the soil compaction stress.

Technical Session 10: Nutritional enhancement of maize

Co-Chairs: *Kevin Pixley* (CIMMYT)
Sain Dass (IMDA, India)

Rapporteur: *Raman Babu* (CIMMYT)

Fan Xingming (YAAS, China) gave a **keynote lecture** on “Development of biofortified maize in Southern China”. Nutritionally enhanced maize is given high importance in China. A high-oil maize hybrid, Yunrui-8, developed by the team at YAAS is being cultivated in 0.5 million hectares in southern China. Hybrids with stacking of several nutritional quality traits, such as QPM, high provitamin A and high oil, are being developed by the YAAS team. Dairy, poultry and piggery industries recognize the importance of such value-added products, resulting in premium pricing. Molecular marker-assisted breeding was effectively implemented for rapid incorporation of genes such as *opaque2* and *CrtRB1* in developing nutritionally enriched maize. In collaboration with China Agricultural University (CAU), a high provitamin A hybrid, YR506 has also been recently developed, especially for southern China; the hybrid yields on an average 10 t/ha, which is 8 per cent more than the commercial hybrid checks.

Willy Suwarno (BAU, Indonesia) made a presentation on “Provitamin A enrichment in maize”. Repeatability for carotenoid traits is high and $G \times E$ is low, indicating minimum effect of environment on expression of carotenoid related traits. The target of 15 ppm of provitamin

A has been achieved in some CIMMYT lines and populations. Three hybrids with >7 ppm provitamin A have already been officially released for commercial cultivation in Zambia in 2012. Native genomic variation in two high impact genes, *LcyE* (*Lycopene epsilon cyclase*) and *CrtRB1* (*Beta-carotene hydroxylase*) have been identified that influence favourably provitamin A concentrations in maize endosperm. *CrtRB1* was found to confer 2-10 fold favourable effects on provitamin A concentration across diverse genetic backgrounds, and is being routinely used by CIMMYT under the HarvestPlus breeding program.

Dharam Paul Chaudhary (IIMR, India) made a presentation on “Exploitation of natural variability in maize for major micronutrients”. Comprehensive screening for carotenoids and kernel micronutrients (Fe and Zn) has been initiated at the Indian Institute of Maize Research (IIMR), India. Preliminary evaluations indicated significant genetic variability among both normal and QPM germplasm for micronutrient concentrations. Kernel colour intensity and total carotenoid contents showed significant positive correlation whereas no significant correlation was observed between kernel colour and beta-carotene concentrations. Eight QPM lines and five normal lines have been identified with above-average micronutrient concentrations that could serve as potential donors upon validation in the biofortification breeding programs.

Harakotr B (KKU, Thailand) presented a paper on “Evaluation of coloured waxy maize germplasm for high anthocyanin concentration and anti-oxidant capacity”. Adequate genetic variability exists for a range of anti-oxidants and their activity levels in waxy maize germplasm. Large genetic variances and low $G \times E$ indicated possibility of evaluation at fewer locations/seasons for these traits to identify superior genotypes. Five lines have been identified with superior concentrations of anthocyanin and high anti-oxidant capacities in tropical Thailand germplasm that could potentially be utilized in developing superior waxy maize hybrids.

Eakrin Sarepoua (KKU, Thailand) made a presentation on “Effects of genotypes and growing conditions on phytochemicals and anti-oxidant activity of corn silk”. Corn silk, which is otherwise considered as a waste product could be potentially used as therapeutic remedy for various illnesses, such as kidney and prostate disorders, cystitis, edema and obesity. Total phenolics, anthocyanin and flavonoid contents have been evaluated in corn silks of baby corn and waxy corn germplasm. Significant genotypic variation exists for such traits, although high $G \times E$ was observed for most traits. High mean temperature and solar radiation were found to be associated with increase in bio-active components and their anti-oxidant levels in corn silks.

Technical Session 11: Adapting maize production to the changing climate

Co-Chairs: *Etienne Duveiller* (CIMMYT)
K.B. Koirala (NARC, Nepal)

Rapporteur: *Tek Sapkota* (CIMMYT)

Alok K. Sikka (ICAR, India) delivered a **keynote lecture** on “Climate resilient agriculture: A national initiatives in India”. He highlighted the climate change situation in South Asia and its current and potential effects on Indian agriculture. Warming, temperature extremes and strong variability in rainfall are likely to impact food and livelihood security of the burgeoning population in India which is dependent on agriculture. Climate risks are best

addressed through incorporation of adaptation, mitigation and other resilient practices in agriculture which can enhance the adaptive capacity of the system to changes induced by climate change and variability. In the last decade, several important national initiatives to address climate change effect on agriculture were taken up in India to evolve appropriate adaptation and mitigation strategies. The National Initiative on Climate Resilient Agriculture (NICRA) launched by the Indian Council of Agricultural Research (ICAR) provided the much needed impetus to climate change research in a network mode, particularly in harnessing the genetic resources that can confer tolerance to various climate stresses amply supported with the establishment of the state-of-the-art research facilities. The core component of NICRA is technology demonstration in 100 most climate-vulnerable districts to identify climate-resilient practices and technologies through participatory demonstrations in farmers' fields, which can be mainstreamed for upscaling under the National Mission for Sustainable Agriculture throughout the country. The conceptual and implementation framework of NICRA can be replicated to usher in climate resilient agriculture production systems in other parts of South Asia, in interface with initiatives such as CCAFS.

Hanuman Singh Jat (CIMMYT) presented the scope and implications of maize-based cropping systems diversification for better resilience of crop production systems in the Indo-Gangetic Plains (IGP). He highlighted the salient features of crop production systems in IGP, emphasized on the need for cropping system diversification, and indicated opportunities for system diversification in western and eastern IGP. Diversification is required to enhance food security, to conserve water and other ecological resources and to adapt to climatic variability. Summarizing some of the initiatives and success examples from NW India, he mentioned that global and regional demand for maize, field scale water balances, landscape scale hydrology and appropriate policy measures are major drivers for diversification of the existing rice-wheat cropping system in IGP.

T. Satyanarayana (IPNI) in his presentation on "Using ecological intensification (EI) to improve maize yields while minimizing adverse environmental effects" elaborated the importance and approaches for EI to improve maize yield while minimizing adverse environmental effects. By highlighting the challenges of maize production, he put EI practices into context under IPNI's maize initiative. Started in 2009, IPNI's maize initiative challenged scientists around the world to use the best science available to create new management systems for maize. He emphasized that EI may be location specific and as a practice it is a way to bridging the yield gap i.e. the difference between the yield under optimum management and the average yield achieved by farmers. He summarized preliminary results of the work on EI in India and concluded that EI increases yield significantly over farmers' practice (FP). Performance indicators, such as water productivity, agronomic efficiency and partial factor productivity, were also higher in EI based maize production compared to FP. It was suggested that life cycle analysis of GHG quantification may further help in holistic comparison of such production systems.

Tek Sapkota (CIMMYT) made a presentation on "Environmental footprint of maize-based cropping systems under different crop establishment methods in north-west India" Under the CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS), CIMMYT is monitoring GHG emission from various cropping systems under different tillage, residue and nutrient management in different agro-ecologies in South Asia. He briefly summarized

the results of the work done under CCAFS on quantification of greenhouse gases (GHGs) emission (CO_2 and N_2O) in maize-wheat-mungbean (MWM) and maize-maize-sesbania (MMS) cropping systems under three tillage and crop establishment methods i.e. conventional tillage (CT), bed planting (BP) and no-tillage (NT). Irrespective of cropping systems, both CO_2 and N_2O emissions in summer maize season were significantly higher in CT as compared to BP and NT, while emissions during winter and spring crop seasons were not significantly different among cropping systems as well as crop establishment methods. The system level global warming potential based on soil flux (without considering photosynthetic uptake) ranged from 33 to 69 $\text{Mg CO}_2\text{-eq ha}^{-1}$ with no significant difference among tillage/crop establishment methods and between the two cropping systems.

Suphakarn Luanmanee (NSFCRC, Thailand) presented the “Effect of fertilizer management and cropping system on soil quality, greenhouse gas emission and maize productivity”. She described the maize production scenario in Thailand, and shared the results of a long-term research trial; the trial showed that maize-mungbean system was more productive, cost-effective and is more easily adopted by farmers than other cropping systems. Also, application of chicken manure together with inorganic fertilizer improved the soil fertility and increased production, but also increased environmental footprint of production. Therefore, organic agriculture is not necessarily environment-friendly as it may lead to higher foot print in absolute terms as well as in terms of unit food production per unit of environmental foot prints.

Technical Session 12: Enhancing gender equity and social inclusiveness

Co-Chairs: *Nora Lapitan* (USAID)
Olaf Erenstein (CIMMYT)

Rapporteur: *Surabhi Mittal* (CIMMYT)

In her keynote lecture on “Amplifying outcomes through addressing inequality: The role of gender transformative approaches in agricultural R4D”, **Paula Kantor** (World Fish Center) emphasized on the need to understand the people’s role in technology adoption, and how different social groups are to be benefitted from technology. Increasing agreement on the relevance of gender and social equality to agricultural development outcomes has not come with the same consensus regarding how to intervene in the sector to foster equality. The guiding principles of agriculture research for development (AR4D) and AR4D’s focus on capacity development can contribute to this debate and to advancing gender integration in the sector, if the ‘social threads’ within its principles are developed more thoroughly. She articulated how the social dimension of AR4D could be further developed through the conceptualization and operationalization of gender transformative approaches. There is a need to unlock the social constraints that exist around women’s participation in AR4D. Doing so can make the most out of synergies between enhanced social equality and capacities to innovate.

Yamuna Ghale (SDC, Nepal) made a presentation on “Community based seed production systems in the hills of Nepal”, highlighting the experiences and learning on gender equity and social inclusion (GESI). She emphasized on the need to demystify certain myths related to the role of poor, smallholders and women in agricultural research and development. She stressed that poor and smallholder producers can meaningfully contribute to quality seed production, and need not be mere technology recipients. It is important to have women’s participation in the crucial processes of planning, implementation and monitoring of research

and development process. Having an inclusive team of service providers and beneficiaries is necessary in decision making process.

Maitrayee Mukhopadhyay (KIT, Netherlands) presented interesting information about gender relations in agriculture in the changing contexts of migration, economic liberalization, and livelihood options of the poor, which requires social inclusion and the need to include youth. She emphasized on the need for AR4D to be more attentive to, and invest in the way gender analysis is incorporated into the research framework itself, and as well take some steps to build an agenda of gender specific research. Including gender in the core business of agricultural research requires pursuing a twin strategy: (1) mainstreaming gender analysis in on-going agricultural research; and (2) undertaking gender-focused research in agriculture.

Surabhi Mittal (CIMMYT) presented the results from a study on the utility of information and communication technologies (ICT), especially mobile phones, for women engaged in agriculture. The problem of lack of adequate and reliable information is particularly pertinent among women; also, the information needs for female farmers can vary widely as they are engaged in multiple roles in agriculture in order to support male farmers in their family farms. Thus, ICT-based agro-advisories could make women feel empowered. Women farmers have valued these services and have shown interest in knowing more about new technologies. It is still a long way to tap the power of ICTs in parts of a country like India where direct involvement of women in agriculture could be limited. However, women in the male-headed households feel that their participation in family agriculture has improved with increased information flow.

Recommendations

1. There is considerable scope for doubling maize production in the next decade. Asia will be the niche for maize production considering the emerging demands and potential for future expansion, as reflected by the recent growth trends in both area and production. Also, there exist tremendous opportunities for productivity increases by harnessing innovations in genetic improvement and agronomic management. Concerted efforts are, therefore, needed to integrate the novel breeding techniques for improved genetic gains (especially under stress-prone environments), accelerate the development and deployment of high-yielding climate resilient maize genotypes, strengthen the maize seed sector and to provide access to quality seed through public-private partnerships (PPPs). Opportunities also exist to out-scale innovations such as conservation agriculture and climate-smart agriculture practices (CSAPs) in maize based cropping systems, and adoption of progressive policies for value chains in order to link farmers to markets so as to benefit producers, consumers and the value chain facilitators.
2. There is an urgency to widen the genetic base of the existing elite maize germplasm through multi-institutional efforts and enhanced exchange of germplasm. The standard material transfer agreement (SMTA), adopted by the International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA) under FAO, needs to be modified for effective multilateral exchange of germplasm/breeding materials among the partner institutions. Collecting and characterizing maize landraces from genetic diversity-rich and hitherto unexplored areas, and pre-breeding efforts need to be intensified as a matter of priority. In order to achieve

this, innovative measures with increased long-term funding have to be ensured by the National Agricultural Research Systems (NARS) and the International Research Centers (IRCs).

3. Importance of maize in the Asian cropping systems has grown rapidly in the recent past, with several countries registering impressive growth in both production and productivity. There is a scope for further expansion of maize area in the region. Tremendous opportunities exist for outscaling innovations in crop improvement, management and crop diversification. International and national institutions engaged in maize research and development are also laying emphasis on foresight, technology targeting, partnerships involving all stakeholders and capacity development to effectively upscale and outscale innovations for greater impact. Such innovations include climate-resilient and nutritionally enriched single-cross maize hybrids, quality protein maize (QPM), genetically modified (GM) maize, conservation agriculture (CA), small farm mechanization, transplanted maize, winter and spring maize, specialty maize (baby corn, sweet corn, popcorn, etc.), and above all maize processing and value-addition, including biofuel production.
4. Concerted and accelerated breeding efforts using novel techniques, such as double haploids, molecular marker-assisted selection and precision phenotyping, are needed for developing improved maize varieties (especially single-cross hybrids) with high yield, stress resilience and better nutritional quality (especially QPM, provitamin A enrichment, and improved fodder quality), and adaptability to diverse agro-ecologies. Elite lines need to be recycled keeping in view the heterotic relationship so as to develop superior hybrids.
5. The Philippines have significantly moved forward with regard to deployment of insect-resistant and herbicide-tolerant genetically modified (GM) maize, while Vietnam has recently declared its intention to deploy GM maize for the benefit of maize farmers in the country. Other countries in Asia (especially the large maize producing countries like China, India and Indonesia) will need to assess the opportunities that GM maize offers to the smallholder farmers, through technologies that can reduce cost on inputs and ensure resilience.
6. In order to enhance maize production and productivity, sustainable cropping/farming systems need to be developed and adopted. Efficient input-use systems and conservation agriculture practices need to be scaled-up and scaled-out. Improved management practices (such as sustainable intensification, site-specific nutrient management and soil health, pest and weed control, and small-scale low-cost farm implements/machinery) need to be promoted through participatory research, involving smallholder farmers.
7. Malnutrition is pervasive with high intensity in South Asia. Hotspots of such micronutrient deficiency need to be identified and regional trait priorities determined for biofortification. QPM has been demonstrated to be nutritionally superior to conventional maize in maize-based human diets, particularly for young children and lactating mothers. It is an important potential tool for combating protein malnutrition in countries where maize is a staple food. The value of nutritional stacks in maize was also appreciated by the participants and recommended it as a high priority. High oil, quality protein and enhanced provitamin A are some of the most preferred traits for immediate germplasm development. High

methionine, high zeaxanthin (deep orange), high vitamin E, low lignin (forage maize) are some of the desired traits for which preliminary genetic leads are available but are yet to be channelized into varietal development. Molecular breeding for developing nutritionally enriched maize varieties has to be given high priority, whereas high QPM varieties/hybrids need to be promoted through appropriate intervention through pricing based on value added products.

8. Post-harvest processing, value addition, product packaging, storage and marketing need to be given high priority to strengthen maize value chains and to enhancing income as well as livelihoods of smallholder farmers. Increasing interest of consumers in nutritionally enriched and specialty maize products warrants greater attention from research, development and policy point of view. In this context, needed efforts on public awareness will have to be made to ensure much greater use of maize as food in Asia.
9. Availability of quality seed of improved maize varieties/hybrids is one of the key factors determining production and productivity. Therefore, urgent attention is required to producing better quality seed through strong public-private-producer partnerships. For this, there is a need to assess the regional, inter-country and intra country demand of hybrid seeds vis-à-vis availability and to develop a strategy to produce enough seed by empowering private seed sector. Empowering the farming communities to produce good quality seeds of improved varieties (especially hybrids) and linking them to the markets assumes special significance in the existing scenario. Fortunately, the maize seed industry in Asia has grown over the years. However, the industry requires better statistics, more insightful analysis and better seed quality monitoring/ regulatory system. Delivery of improved maize seeds at the door step of farmers at affordable price is a major challenge that has to be addressed by building strong publicprivate partnerships. Hence, a Mission Mode approach on maize seed production in the Asian region is the need of the hour.
10. Agricultural research for development (AR4D) on maize in Asia should adopt a more holistic approach, requiring greater inter-institutional linkages/partnerships among various stakeholders, public-private partnerships and above all strong commitment of scientists (including social scientists), extension specialists and the farmers. The role of youth as service/knowledge providers to farmers has to be appreciated and strengthened henceforth to bridge the existing yield gaps. This in turn warrants greater thrust on human resource development and capacity building, through vocational training and use of modern information and communication technologies (ICT) for disseminating information.
11. As a long-term strategy for sustainable intensification, balancing demand-supply vis-à-vis natural resources, “A Maize Atlas for Asia” should be developed so as to define the current and potential maize production systems’ domains and targeting portfolios of technologies and innovations with the present and projected resource scenarios.
12. Smallholder farmers, especially women, should be at the centre-stage of agricultural research and development agenda, especially to address the existing constraints to household nutrition security and enhanced production and income. In this regard, women empowerment through improved access to agricultural inputs at affordable cost,

availability of microfinance/credit at low interest rates, crop insurance, and access to low-cost, small-scale farm machinery would ensure improved agricultural production and household nutrition security. Hence, gender programs at the national, regional and global level will have to be promoted through higher commitment and policy support to gather both qualitative and quantitative data on gender dynamics, drudgery and technological options. There is also a need to understand the social constraints that exist around women participation in agriculture, especially in the changing context of migration, economic liberalization and the positive shift towards gender and social inclusion.

13. Conducive policy environment as well as enhanced investment (at least double) on maize research for development are the key factors for the growth of maize and related value chains in Asia. Besides addressing specific issues concerning Asian maize industry, there is a need to catalyze the stakeholders in the region to scale-up and scale-out innovations in maize-based cropping systems. This will require innovative institutional reforms such as public-private-producer partnerships.
14. To strengthen maize research for development in Asia, there is also a need to establish maize innovation platforms and initiate regional and sub-regional networks focused on prioritized areas, identified during the Conference. It was recommended that such networks should target improving maize genetic base through pre-breeding; doubled haploid technology for enhancing genetic gains and breeding efficiency; accelerated development of improved single-cross maize hybrids using genomics-assisted breeding and precision phenotyping; adopting GM maize technology, strengthening maize seed sector and deploying climate resilient maize germplasm through public-private partnerships; sustainable intensification of maize-based cropping systems, conservation agriculture, precision nutrient management, small farm mechanization and climate-smart production practices; and strengthening maize value chains through innovative policies and socio-economic interventions.
15. Participants strongly emphasized on the need to work together in a network mode to derive synergies among the international and national agricultural research institutions and to facilitate improved germplasm development in the Asia-Pacific region. To this effect, a “Value Added Maize Network for Asia” (VAMNET) was proposed keeping in view the benefits of earlier networks such as TAMNET (Tropical Asian Maize Network) and AMBIONET (Asian Maize Biotechnology Network). Facilitation role of CIMMYT to establish such a network was recognized. NARS participants assured their full support to such an initiative.

Welcome Remarks

Dr. Anan Suwannarat

Director General, Department of Agriculture, Government of Thailand
Bangkok, Thailand

Dr. Hiroyuki Konuma, Assistant Director General, FAO Regional Office for Asia and the Pacific; Dr. Simon Hearn, Chairman of APAARI; Dr. Raj Paroda, Executive Secretary, APAARI; Dr. Thomas Lumpkin, Director General, CIMMYT; Dr. B.M. Prasanna, Director, Global Maize Program, CIMMYT; Distinguished Guests, Ladies and Gentlemen!

It is indeed an honour and great pleasure for me to address the Opening Session of the 12th Asian Maize Conference and Expert Consultation. First of all, I would like to thank the organizers for this opportunity given to the Department of Agriculture (DOA), Govt. of Thailand to co-organize this very important Conference.

The theme “Maize for Food, Feed, Nutrition and Environment Security” is very relevant and timely as this is in line with the priority policies of the Ministry of Agriculture in most of the governments in the Asia-Pacific Region. This is so, in recognition to the enormous value of the maize crop as a food and feed crops. It also contributes to the environmental security when it is used as a renewable energy crop, however, without competing with food security.

Looking through the outline of every technical session, I am very much impressed on the very knowledge rich coverage of this conference. Nevertheless, the list of resource speakers who are world renowned for their significant contributions in enhancing the production and productivity of the maize sector is really very encouraging for us to participate in this worthwhile Conference.

Convening such a Conference, I am sure, takes a lot of effort and hard work, particularly in bringing all the prominent personalities in the field of agricultural research and development from the Asia-Pacific region. I, therefore, would like to convey our congratulations and appreciations to the Organizing Committee under the dynamic leadership of Dr. Raj Paroda, Executive Secretary, APAARI and his able staff, and to all the sponsors for all the support given that made this Conference a reality. We really feel grateful to Dr. Paroda for bringing to us a forum where we will have a good comprehension on the regional priorities and niches for enhancing maize production and productivity, where we could exchange views and experiences on cutting-edge maize technologies among the maize research and development community. This Conference would also provide us with a platform for synergies among institutions and stakeholders, whereby we could develop an innovative and impact-oriented regional strategy for the adoption of resilient technologies, market opportunities, networks, investment priorities, and policy advocacy.

At this point, on behalf of the Department of Agriculture, I would like to express our very warm welcome to all of you, and our good wishes for your pleasant and productive stay here in Bangkok, Thailand. Although your schedule may be too busy for the next three days of the Conference, I hope you would have the chance to feel the Thai warm hospitality and enjoy the beauty of Thai culture and be charmed with the uniqueness of Bangkok.

Having these thoughts, I now declare the 12th Asian Maize Conference and Expert Consultation now open.

Thank you very much for your attention.

Introductory Remarks

Dr. Raj Paroda

Executive Secretary, Asia-Pacific Association of Agricultural Research Institutions (APAARI)
Bangkok, Thailand

Mr. Hiroyuki, Konuma, Dr. Simon Hearn, Dr. Thomas Lumpkin, Dr. Annan Suwannarat, Dr. B.M. Prasanna, distinguished invitees, guests, ladies and gentlemen!

It gives me a great pleasure to welcome you all to the 12th Asian Maize Conference and Expert Consultation on “Maize for Food, Feed, Nutrition and Environmental Security”. It is heartening to see nearly 300 participants from 30 countries worldwide, especially from the Asia and the Pacific, participate in this important Conference. I am convinced that a gathering of such a diverse array of participants, including renowned scientists, policy makers, agribusiness entrepreneurs, farmers, and representatives of funding agencies will give a strong impetus for strengthening maize research and development in Asia.

The importance of maize for food, feed and nutritional security worldwide, and Asia in particular, has grown manifold, and is well-recognized by this august group. No other cereal crop is used for as diverse an array of purposes as maize, including food, feed, fodder, biofuel and industrial purposes, and in as diverse regions in the world as in Africa, Asia, and Latin America. Although developed countries, particularly the USA, contribute predominantly to maize production, demand for maize in the developing world is expected to surpass the demands for both wheat and rice by the year 2020. While global maize production has increased by 3.70 per cent per year during 2001-02 to 2012-13, the growth rate was 5.60 per cent per year in Asia during the same period. Despite impressive progress in maize growth rates in several countries, Asia remains a major destination of maize imports. The ‘maize-livestock revolution’ has arisen from a combination of population increase, changes in the diet of millions of people towards dairy and meat, increasing urbanization and growth in disposable incomes. The continent accounts for one-third of global import trade in maize. It is predicted that its size will increase due to increased demand of maize in China and in other countries.

The rapidly changing demand for maize in Asia has opened new opportunities for agricultural transformation and income growth in the region. How will Asian countries better tap this huge potential? This will depend on the agility of our institutions to develop and deploy improved technologies, especially quality seed with relevant traits for the farmers, and agronomic management practices that can increase maize productivity per unit area, per unit input and per unit time. This also requires creation of an appropriate institutional and policy environment that ensures smallholders farmers access to information, new seeds, complementary inputs and reliable markets.

The Intergovernmental Panel on Climate Change (IPCC) in its Fifth Assessment Report further highlighted the impacts being felt in South Asia due to the changing climate. Maize in Asia, which is largely dependent on rainfall, especially during the monsoon season, is vulnerable to the highly variable rainfall incidence, including the extremes. The frequency of heat wave attacks during the crop growth period has increased since the middle of the 20th century in large parts of Asia. Also, Asia is increasingly witnessing the spectre of floods causing severe losses to agriculture, property and livelihoods. The key challenge is to improve productivity of major crops like maize in the face of the changing climates and the huge risks associated with such changes. According to a recent analysis, climate change is already adversely affecting yields of maize in the Asian region, and the predicted losses by 2080 will be, on average, more than 15 per cent. There is no other way to tackle this challenge than through intensive development and deployment of climate resilient varieties and climate-smart production practices that enable the smallholders to adapt to the changing climate. Without this, the food and feed security of Asia will be at huge risk.

Despite the challenges, farmers in Asia have demonstrated time and again their enormous strength and adaptive capacity. They recognize the immense potential of maize in improving their livelihoods, as this is a crop that can be grown throughout the year, and can fit into diverse cropping systems. It has relatively lower water requirement as compared to rice and wheat, and enables farmers to incorporate the short-duration hybrid maize varieties in cropping systems involving rice, wheat, potato, legumes, oilseeds or vegetable crops, thereby improving productivity, profitability and sustainability of farming systems. However, the use of conventional farming practices based on extensive tillage, especially when combined with removal or *in situ* burning of crop residues, has accelerated erosion while the soil resource base has been steadily degraded. Despite the availability of improved crop varieties with increased yield potential, optimum maize production is still not attained in several Asian countries generally because of poor crop management. Cropping systems will thus have to be more robust and sustainable. New agricultural practices will not only have to prevent further soil degradation but also improve the resilience of the system while reducing production costs. While conservation agriculture principles are applicable to a wide range of crop production systems, application of conservation agriculture will vary with climate, biophysical soil characteristics, system management conditions, and farmers' circumstances. Therefore, specific and compatible management components (e.g., rotation crops, soil and nutrient management strategies, pest and weed control, appropriately scaled implements) need to be identified through adaptive research with active farmer involvement.

Critical for improving the maize yields in several Asian countries is improving smallholder farmers' affordability and access to quality seed of improved varieties, especially high-yielding, climate-resilient hybrids. Maize has spurred a vibrant seed industry in Asia, and has attracted significant levels of private sector investment in hybrid maize research, seed production and seed marketing. Over the last few decades, the seed companies have established wide networks for marketing and distribution of improved maize seed. These networks are vital in ensuring national, regional and global food security. However, we do need to carefully assess the regional, inter-country and intra-country imbalances in terms of smallholder farmers' access to improved seed at affordable costs, and identify possible solutions to address this important constraint. Empowering the local communities to learn and to produce seed of

improved varieties, including hybrids, and connecting them with appropriate markets assumes importance.

I sincerely urge the participants of the Conference to critically address the constraints to increased maize production and productivity in Asia, including the ways and means to enhance the affordability and access to improved technologies, reduce post-harvest losses, improve value-addition and effective marketing channels, and ultimately the income and livelihoods of the people who matter the most – the smallholder farmers. Future research, therefore, should take a more holistic approach that requires not only intensified public-private partnerships, inter-institutional linkages, and collaboration among biophysical scientists, but also more active involvement of social scientists, extension specialists and the farmers. Research-extension-farmer linkages should be fostered for effective technology transfer and adoption.

I am sure that the research managers, scientists and other stakeholders representing various disciplines and programs would deliberate and exchange the views and will come out with a road map that will lead to sustainable growth in maize production, and enhanced productivity of maize in the smallholder farmers' fields in the Asian countries. I wish the 12th Asian Maize Conference and Expert Consultation a great success and the participants a pleasant stay in Bangkok.

Thank you!

Introduction of the Theme

Dr. Thomas Lumpkin

Director General, International Maize & Wheat Improvement Center (CIMMYT)
Mexico

When talking about agriculture in Asia, maize is not a crop that automatically springs to mind. Across the continent to eat is to eat rice or wheat. Meals are simply not acceptable without these staples. That being said, a booming poultry industry and rapid expansion of livestock rearing is driving a massive expansion of maize cultivation in Asia.

Anan Suwannarat, Raj Paroda, Simon Hearn, Hiroyuki Konuma, B.M. Prasanna, esteemed colleagues:

Asia has made great strides in the last few decades to pull itself out of poverty. Yet, despite the rapid economic growth, 12.7 per cent of the region's population, 526 million people still suffer from food insecurity. Based on current crop yields, feeding more than 9.5 billion people by 2050 and perhaps 12.3 billion by 2100 will not be a trivial task. In Asia alone, the demand for maize is expected to double by 2050. The increase in yield will have to happen while using fewer nutrients, less water and land. Sustainably increasing maize production will have a crucial impact on food security and livelihoods across the continent.

The 12th Asian Maize Conference is an important part of international collaborative efforts by the agricultural research community to address these challenges and improve the lives of farmers.

In the context of Asia's rich agricultural history, maize is a fairly new crop to the region, and was probably brought by the Portuguese in the 16th century, and until recently maize was not an important crop on the continent.

Maize's rising popularity can largely be attributed to changing diets, especially the increasing demand for meat, poultry and dairy products. Today, more than 70 per cent of maize is used as poultry feed, due to its high cost-nutrient efficiency. This rising demand has also resulted in a high imports in some countries. For example, in 2011, China, Asia's largest maize producer, became a net importer of maize for the first time in 14 years.

Unless we take action, demand will outstrip supply.

The production of maize across the continent is becoming highly sophisticated and standardized. However, we need to recognize the numerous issues the crop faces and the actions we need to take to fix them;

- Soil erosion caused by hillside maize production
- The vulnerability resulting from monocropping and the potential of epidemic diseases, such as we have seen in eastern Africa with maize lethal necrosis

- Fertilizer use inefficiency and pollution
- Rising temperatures and increasing extreme weather events from climate change

To begin to combat these challenges, we need to include some focus on crop rotations, diversification and other improved agronomic practices that use conservation agriculture techniques to sustain soils and protect the crop from diseases.

We need better policies that help regulate markets, so as to protect smallholder farmers from high risk and financial vulnerability.

We need to promote better uses of the maize crop, including industrial uses, to stabilize the market.

We have already made great strides bringing the benefits of ICT to both men and women farmers, but we now need to reach even more smallholder farmers with modern communication technologies.

And, we need to widen maize's genetic base in order to reduce the risk of catastrophic diseases and make maize more adaptable to a range of environments due to the increased variability that is coming with climate change.

This Conference is a chance for us to look holistically at four distinct but interlinked areas of importance for maize production in Asia: food, feed, environmental and nutritional security.

Malnutrition and undernutrition are at unacceptable levels in some parts of Asia. Efforts to enhance the nutritional value of rice and wheat will not be enough to help the 526 million people living on the continent who suffer from food insecurity. We need to bring the same successes we have seen in Africa with Provitamin A enriched maize and quality protein maize to Asia. The nutritional quality of maize should not just be enhanced for animals. Dual purpose maize is one way to balance the benefits for both food and fodder. One crucial step in this process will be to further improve the biofortification of quality protein maize with more essential amino acids, and thus bring even further benefits to the people that eat it.

Dr. Paroda, Dr. Prasanna – On behalf of CIMMYT and the CGIAR Research Program on Maize, I would like to congratulate you and your teams for your very hard work over the past few months – I know that there have been some sleepless nights for you and others.

We have a unique opportunity here to mobilize our collective resources to help smallholder farmers and achieve a great impact on maize-based farming systems in Asia. This will require a close partnership with an array of institutions to develop and deploy hybrids and other high-yielding and climate-resilient improved maize germplasm, promote adoption of conservation agriculture in maize-based systems, connect small farmers to innovation and recommendations based on global knowledge via computers and cell phones.

Asia has had a wheat green revolution.

And Asia has had a rice green revolution.

Asia is now having a maize green revolution and we are here to support it.

Thank you!

Chairman's Remarks

Dr. Simon Hearn

Chairman, Asia-Pacific Association of Agricultural Research Institutions (APAARI)

As one of the co-organizers, I consider it a privilege to welcome you all on behalf of APAARI. For us, it is a unique opportunity to have participation of many NARS leaders, maize experts and stakeholders to discuss various important research and development related issues concerning maize in Asia.

Maize is a major food, feed and industrial crop around the world. It is a source of food security in several developing countries. Together with rice and wheat, maize provides around 30 per cent of the food calories to more than 4.5 billion people in 94 developing countries. Also, it is a preferred staple food for 900 million poor people. The area, production and productivity of maize have increased several-fold over the last 50 years; much of that growth has occurred in the developing world. In Asia, maize has recorded the fastest annual growth (around 4%), as compared to other cereals. Eight major maize-producing countries in Asia – China, India, Indonesia, Nepal, Pakistan, Philippines, Thailand, and Vietnam together produce 98 per cent of Asia's maize and 26 per cent of global maize. Despite increased production, increasing demands of food, feed, and industry will require more investments in maize research for development.

In order to meet global demands, we will need 70 per cent more food by 2050 which implies the need for increasing the productivity significantly. At the same time, maize production and productivity in several Asian countries is severely constrained by lack of improved seeds and other critical inputs, lack of training and knowledge transfer for the resource-poor farmers, and abiotic and biotic stresses which are rapidly increasing under changing climate scenario.

In recent years, the importance of maize in Asia's cropping systems has grown rapidly, with several countries registering impressive growth in production and productivity rates. There is tremendous scope for further expansion of maize area in the region. As Asia's agribusiness and food processing industries and economies continue to grow, the opportunities for the use of maize as food, feed, fodder and for industrial uses will increase significantly. The growing needs of the poultry sector, the expansion of maize seed sector and increasing interest by consumers in nutritionally enriched and specialty maize products require greater attention both from the research and development viewpoints.

In order to meet the current and future demand of maize in Asia, concerted efforts need to be made towards integrating novel breeding techniques for improved genetic gains especially under stress-prone environments; developing high-yielding and climate-resilient maize varieties; production and access of quality seeds; introducing precision-conservation agriculture and climate smart practices for sustainable intensification of maize-based cropping systems; empowering

local stakeholders through cutting-edge technologies; and implementing innovative policies for stronger maize value chains and services for client communities.

There are tremendous opportunities for innovations in crop improvement, management and diversification. Also, there is need for capacity development of stakeholders to effectively out-scale innovations for greater impact. Innovations include single cross maize hybrids, quality protein maize (QPM), genetically modified (GM) maize, conservation agriculture (CA), small farm mechanization, transplanted maize, winter and spring maize area development, baby corn, sweet corn and biofuel production.

There is an urgent need for conducive policy support/environment and enhancing the investments significantly on maize research for development. The specific issues concerning Asian maize industry need to be addressed in order to harness the emerging opportunities. There is also a great need to catalyze stakeholders in the region to outscale innovations in maize-based cropping systems through building new public-private-partnerships (PPPs). The 12th Asian Conference and Expert Consultation on Maize being jointly organized by APAARI, CIMMYT, FAO and DOA, Thailand has brought together the key Asian maize experts to discuss the current status, explore future opportunities and challenges for enhancing food, feed, nutrition and environmental security in Asia.

The overall goal of the Conference and Expert Consultation is enhancing food, feed, nutrition and environmental security in Asia. The specific outputs expected from the Conference include: i) identification of national and regional priorities for enhancing maize production and productivity, ii) sharing of experiences and knowledge on innovations relating to sustainable maize production and utilization among diverse stakeholders, iii) awareness for promoting the use of maize for diverse purposes, iv) identification of synergies and convergence opportunities among maize R4D stakeholders in Asia, v) developing a regional maize strategy for sustainable food and nutritional security in Asia.

I am sure the deliberations in the 12th Asian Maize Conference and Expert Consultation will provide an insight of the current problems being faced by all concerned with maize production and utilization in different maize growing countries and devise suitable strategies and road map for effectively addressing these problems in a time-bound manner in order to contribute towards food, feed, nutrition and environmental security in Asia.

I wish the Conference a great success.

Thank you

Chief Guest's Address

Mr. Hiroyuki Konuma

Assistant Director-General and FAO Regional Representative for Asia and the Pacific
Bangkok, Thailand

Dr. Anan Suwannarat, Director General, Department of Agriculture, MOAC; Dr. Raj Paroda, Executive Secretary, APAARI; Dr. Thomas Lumpkin, Director-General of CIMMYT; Dr. Simon Hearn, Chairman, APAARI & Principal Adviser, ACIAR; Dr. B.M. Prasanna, Director, Global Maize Program, CIMMYT; Excellences, Respected Participants, Ladies and Gentlemen!

First of all, I wish to welcome you all to this 12th Asian Maize Conference and Expert Consultation on “**Maize for Food, Feed, Nutrition and Environmental Security**” jointly organized by APAARI, CIMMYT, Government of Thailand (DOA, MOAC) and FAO. I am very honoured to be the Chief Guest and to make a keynote speech at the onset of this important event, where the focus will be on maize, a crop with a multiple importance in our life, but yet often forgotten. Indeed, maize sector has been doing very well. We have a tendency to forget the importance sometimes, if we are doing too well.

Before I begin my speech, I would like to express my deep appreciation to **APAARI, CIMMYT and the Department of Agriculture, Ministry of Agriculture and Cooperatives, Government of Thailand** for their valuable partnership and excellent organization of this important event. I also wish to thank each one of you for participating in this Conference despite of your busy schedule in your home country.

Ladies and Gentlemen,

According to recently revised FAO's Global Perspective Study “World Agriculture Towards 2030/2050”, despite of sharp decline in cereal crop annual productivity growth in the past two decades between 1987 and 2007 if compared with that of the Green Revolution period, maize was the only major cereal crop which recorded nearly 2 per cent annual productivity growth during that period as against only about 1 per cent annual growth of rice and wheat. We all are aware that this was largely contributed by the success of agricultural research, effective agricultural extension and outreach efforts, and public and private-sector partnership for the expansion of hybrid maize varieties. On the other hand, the same study report projected that the future annual yield growth of maize would decline to 0.56 per cent during the period 2005/07-2050 as the yields are nearing to ceilings obtained from past research benefits. Thus, future development of maize sector is dependent crucially on future progress in varietal improvement and agricultural research. Indeed, this is one of the key reasons which facilitated the organization of this meeting.

In 2013, the world recorded the bumper harvest of maize with a world record exceeded 1 billion metric tons; the first time in the history. It would likely be renewed this year with

a little higher new production record. At the same time, the international market benchmark price of maize declined sharply with a historic record in the past several years at 164 US\$ per tonne in September 2014, down by 22 per cent from that of one year ago or over 50 per cent down from the price 2 years ago. The Chicago Board of Trade (CBOT) maize future for December 2014 delivery price was quoted at much lower price of US\$ 130 per tonne. We anticipate that this trend might continue for next several months as the harvesting of 2014 maize crop is underway in USA, the largest maize producer which shares one third of the total world maize outputs, with nearly 12 million tonnes (or 3.4%) increase over the record crop last year with estimated yield increase by 8 per cent. This is good news for consumers, but a bad news for producers.

Concerning the trade, the world trade of maize is expected to down sharply by 4.5 per cent (5.3 million tonnes) in 2014/15 season from that of previous season which will be the biggest drop in the past two decades if happens. This would be contributed by the decrease of maize import by European Union (EU) countries (over 30% decrease from previous season) resulted from a good production prospect in EU and more importantly a large availability of feed wheat. Indeed, wheat would be competing with maize for animal feed in EU countries.

Let's look at the future outlook of maize production and utilization. The OECD-FAO Agriculture Outlook 2014-2023 which was published recently, indicated that world utilization of coarse grains, mainly maize, is projected to increase by 20 per cent in next 10 years by 2023. This would be driven largely by the expansion of demand for animal feed, which holds the largest share of the total utilization. Indeed, at present, about 58 per cent of maize is utilized for animal feed, while nearly 16 per cent is used for human food and remaining 26 per cent for other uses including largely for bio-ethanol production. In USA, about 36 per cent of maize produced in the country in the current season is used for bio-ethanol production. The OECD-FAO Outlook Study estimates that in developing countries (excluding China), about 40 per cent of coarse grains (mainly maize) would remain to be used for food, 50 per cent for animal feed and around 10 per cent for other uses in 2023. On the other hand, in developed countries, about 8 per cent would go for food, 50 per cent for animal feed, nearly 30 per cent for biofuel and 12 per cent for other uses in 2023. In China alone, about 10 per cent of maize is expected to be used for food, nearly 70 per cent for animal feed and remaining 20 per cent for other uses in 2023. In general, the share of maize utilized for animal feed has been increasing in China and other middle income countries in accordance with changing dietary patterns of increasing number of middle income people who tend to consume more meat, milk, eggs and other livestock and fish products. On the other hand, sharp increase of the use of maize for biofuel in developed countries is anticipated as explained earlier, while maize would remain as an important human food resource of the poor in many developing countries.

In this context, I would like to highlight four key points for discussion. These are enhancing food production, feed production, addressing nutritional problem and environmental sustainability.

In spite of concerted efforts over the past half century, problems of food security and nutrition could not be solved entirely. This is evident in the latest released figures on the status of poverty and malnutrition in Asia and the Pacific. This region still holds the highest concentration of two thirds of world undernourished people. Even if we achieve MDG target

to halve the proportion of chronic hunger to 12 per cent by next year, there will be still remaining 12 per cent who are the most vulnerable and disadvantaged group in our society and the largest portion of them are living in rural areas and engaged in agriculture directly or indirectly. In Asian context, maize is often seen as a poor people's food or the staple food for those living in highlands and mountains. There are many people in rural areas and among indigenous tribes who are mostly dependent on maize for their food security and livelihoods. It is encouraging that farmers are increasingly shifting their interest on maize and bringing more areas under maize cultivation, a trend that was not visible even two decades back, except in very few countries. Maize is not only more productive than rice and wheat but also superior in terms of nutrition and prices. As I see it, more awareness and motivational programs are needed to convince people to eat more maize in addition to our efforts in technological advancement with the ultimate goal to reduce pressure on rice production and consumption. Maize is a well-researched crop compared to rice and wheat in terms of technological advancement but problem remains on how these technologies can be successfully tailored to fit within the real needs of smallholder farmers, and their cropping patterns and crop rotation.

My second point is feed production. As we all know, maize production has been increasing due to its high demand mainly as poultry feed or livestock feed rather than human food. Besides, it is also used as feed in aquaculture. Expansion of maize cultivation will continue in future due to its nutritional advantage over other feeds and also cost effectiveness. Economic development, demographic changes, income rises, and food diversity will increase demand for more fish and meat. For that purpose, we have to produce more animal feed to meet the ever increasing demand of meat and fish products. Maize could be good option for this purpose over other animal feeds. In addition to food and feed, maize has a wide range of industrial applications such as materials for manufacturing of ethanol and molecules.

Third point is nutrition problem. As I mentioned earlier, maize is nutritionally superior to any other cereal crop grown in this region. In view of this, its promotion in this region is a matter of urgency in order to reduce malnutrition problems of the children within the shortest possible time. Maize grains are rich in vitamins A, C and E, carbohydrates, and essential minerals, and contain 9 per cent protein. They are also rich in dietary fiber and calories which are good source of energy. Our efforts to include maize as food for children should be doubled than before in order to reduce under-nutrition of our children. Use of maize as a key ingredient of winning food or complimentary food for young children as a nutrition supplement should be further promoted.

Fourth and the last point is sustainability and environmental security. For Asia, increasing productivity of crops largely remains as one of the key options to enhance food security and reduce hunger and malnutrition. But, it has to be achieved in environmentally sound way. This is the challenge that we have to address in the years ahead. We know that excessive uses of natural and external resources to increase production and productivity of rice and wheat during the green revolution period had brought negative impact to natural environments, which are beyond recovery in some areas. Yields of these crops are now increasing at a much slower pace that poses serious threat to food security. We need to make a drastic mid-course correction in how we use resources in efforts to sustain continued growth of agricultural production. Obviously, future food production in this region should come from an environmentally sustainable way

that brings minimum disturbance to already fragile environments. FAO is promoting the “Save and Grow” approach to improve the situation. I think this is an appropriate forum to look into this issue in more details.

Ladies and gentlemen,

The four issues (enhancing food production, feed production, nutritional problem and environmental security) that I briefly discussed constitute the goal of this Conference and expert consultation. This event is, therefore, structured with following five broad objectives to achieve this goal: i) to assess the regional priorities and niches for enhancing maize production and productivity, ii) to share experiences and the latest information/knowledge on cutting-edge maize technologies among the maize research and development community, iii) to create general awareness and provide a platform for synergies among institutions and stakeholders for better use of maize as food, feed and industrial crop in Asia, and iv) to develop an innovative and impact-oriented regional strategy and road map through access to and accelerated adoption of resilient technologies, market opportunities, networks, investment priorities, and policy guidelines.

Finally, we have to keep in mind that maize is a unique crop that stands out among the cereals because of its higher productivity, diversified uses and low prices. It is being used for production of biofuels and, in some countries, biotech seeds are largely used in maize production. All of these issues have to be taken into account in spreading this crop in the Asian region. But, food security should come first as the priority. Public-private partnerships, international exchanges of information, germplasm and technologies, adoption of value chain approach in the context of Asian transition can make difference in our future efforts. There are numerous other ways and means that will come out from the Conference, I hope.

I also wish to re-emphasize the importance of agricultural research, as future development of maize sector deeply depended crucially on future progress in varietal improvement and agricultural research.

Let me once again say that I feel very much honoured to be invited to the Conference. I look forward to receiving a concrete conclusion and recommendations that would come out through your deliberations and joint efforts.

With these words, let me thank you once again and wish the Conference all success.

Program

Day 1 : 30 October, 2014

08:45 - 10:00 Opening Session

Venue: Grand Ballroom

08:45 - 08:55	Welcome	Anan Suwannarat (DG, DOA-Thailand)
08:55 - 09:10	Introductory Remarks	Raj Paroda (Executive Secretary, APAARI)
09:10 - 09:25	Introduction of the Theme	Thomas Lumpkin (DG, CIMMYT)
09:25 - 09:35	Chairman's Remarks	Simon Hearn (Chairman, APAARI)
09:35 - 09:55	Address by Chief Guest	Hiroyuki Konuma (ADG, FAO RAP)
10:00 - 10:30	<i>Group Photograph & Tea/Coffee break</i>	

10:30 - 11:40 Plenary Session 1: Keynote presentations

Venue: Grand Ballroom

Co-Chairs : Nick Austin (ACIAR, Australia)
Thomas Lumpkin (CIMMYT)

Keynote Lectures:

10:30 - 10:55	Maize research-for-development scenario: Challenges and opportunities for Asia	B.M. Prasanna (CIMMYT)
10:55 - 11:20	Maize in Asia: Drivers of change	Subash Dasgupta (FAO RAP)
11:20 - 11:40	General discussion and concluding remarks by Co-Chairs	

11:40 - 13:00 Plenary Session 2

Venue: Grand Ballroom

Panel Discussion:

Doubling Asia's maize production in the next decade

Moderator : Raj Paroda (APAARI)
Panelists : S.K. Vasal (Mexico)
Md. Rafiqul Islam Mondal (BARI, Bangladesh)
Nguyen Van Bo (VAAS, Vietnam)
Edwin C. Villar (PCAARRD, Philippines)
Clive Murray (SFSA)

13:00 - 14:00	<i>Lunch</i> <i>Venue: Cattleya</i>	
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14:00 - 16:00 Parallel Technical Sessions

Technical Session 1 : Enhancing genetic gains in maize breeding
Venue: Grand Ballroom

Co-Chairs : S.K. Vasal (Mexico)
Suwit Chaikattiyod (DOA, Thailand)

Keynote Lecture:

14:00 - 14:25 Strategies for germplasm enhancement of maize Walter Trevisan
(GEM Program, USA)

Speakers:

14:25 - 14:50 High throughput and precision phenotyping for improving abiotic stress resilience of maize Jose Luis Araus
(Univ. of Barcelona, Spain)

14:50 - 15:15 Seeds of Discovery: Characterizing and utilizing maize genetic resources for germplasm diversification Kevin Pixley
(CIMMYT, Mexico)

15:15 - 15:40 Water Efficient Maize for Africa (WEMA): A model partnership for tropical maize improvement Kiru Pillay
(Monsanto, South Africa)

15:40 - 16:00 General discussion and concluding remarks by Co-Chairs

Technical Session 2 : Maize for fodder/feed, specialty corn, value-addition and processing
Venue: Canna Room

Co-Chairs : Eskandar Zand (AREEO, Iran)
Sergie Bang (NARI, PNG)

Keynote Lecture:

14:00 - 14:25 The rapid growth of the poultry industry in Asia: Implications for research and development Christian Bober (CIMMYT, India)

Speakers:

14:25 - 14:45 The fodder value of maize stover vis-à-vis other cereals residues and opportunities for improvement through crop breeding and value addition Michael Blummel (ILRI)

14:45 - 15:05 Breeding purple waxy corn for health and wellbeing Kamol Lertart (KKU, Thailand)

15:05 - 15:25 Development and commercialization of value-added food products of Quality Protein Maize for nutrition security Usha Singh (RAU, India)

15:25 - 16:00 General discussion and concluding remarks by Co-Chairs

16:00 - 16:30 *Tea/Coffee break*

16:30 - 18:15 Parallel Technical Sessions

Technical Session 3: Stress resilient maize for Asia

Venue: Canna Room

Co-Chairs : Inia B. Seruiratu (MoA, Fiji)
Md Rafiqul Islam Mondal (BARI, Bangladesh)

Keynote Lecture:

16:30 - 16:55 Abiotic stress resilient maize for adaptation to climate change in the Asian tropics PH. Zaidi (CIMMYT, India)

Speakers:

16:55 - 17:10 Multi-trait selection index for excess water tolerance in maize at seedling stage M. Shalim Uddin (BARI, Bangladesh)

17:10 - 17:25 Understanding of Curvularialunata pathogenicity differentiation induced by resistance varieties Jie Chen (SJU, China)

17:25 - 17:40 Effect of Maize Dwarf Mosaic inoculating at various growth stages on yield of Nakhon Sawan 3 Siwilai Lapbanjob (NSFCRC, Thailand)

17:40 - 17:55 Temporal variation of stem borer damage in maize at Chitwan, Nepal Buddhi B. Achhami (NMRP, Nepal)

17:55 - 18:10 Genetic analyses of resistance to stored grain weevil (*Sitophilus oryzae* L.) in maize Rajkumar Zunjare (IARI, India)

18:10 - 18:15 General discussion and concluding remarks by Co-Chairs

Technical Session 4: Socioeconomics and innovative policies for enhanced maize production and impacts

Venue: Grand Ballroom

Co-Chairs : Raghunath Ghodake (NARI, PNG)
David Spielman (IFPRI, USA)

Keynote Lecture:

16:30 - 16:55 Policy frameworks for effective innovation, dissemination and adoption of maize technologies in Asia Katinka Weinberger (CAPSA, Indonesia)

Speakers:

16:55 - 17:15 Scaling maize innovations in a changing Asia Olaf Erenstein (CIMMYT)

17:15 - 17:35 Assessments of the maize situation, outlook and investment opportunities in Asia K. Srinivas (NAARM, India)

17:35 - 17:50 Competitiveness of maize production in Pakistan Hassnain Shah (PARC, Pakistan)

17:50 - 18:05 Maize production in Bangladesh: way towards self-sufficiency Monayam Miah (BARI, Bangladesh)

18:05 - 18:15 General discussion and concluding remarks by Co-Chairs

18:15 - 19:00 Poster Session

(Posters accepted under Technical Sessions shall be displayed all through the day for review by delegates, as well as for evaluation by a panel)

19:30 Dinner hosted by FAO
Venue: Cattleya

Day 2 : 31 October, 2014**08:30 - 09:30 Plenary Session 3: Keynote presentations***Venue: Grand Ballroom*

Co-Chairs : William Dar (ICRISAT)
Simon Hearn (APAARI)

Keynote Lecture:

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|---------------|--|-------------------------------|
| 08:30 - 08:55 | Present and potential impacts of changing climate on maize-based cropping systems in Asia: Strategies for adaptation | Clare Stirling (CIMMYT-CCAFS) |
| 09:00 - 09:15 | General discussion and remarks by Co-Chairs | |
| 09:15 - 09:45 | <i>Tea/Coffee break</i> | |

09:45 - 12:00 Parallel Technical Sessions**Technical Session 5: Biotechnology for maize improvement in Asia***Venue: Grand Ballroom*

Co-Chairs : H.S. Gupta (BISA, India)
Umi Kalsom Abu Bakar (MARDI, Malaysia)

Keynote Lectures:

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|---------------|---|--|
| 09:45 - 10:10 | Insect-resistant and herbicide-tolerant GM maize in Philippines: present status and prospects | Saturnina C. Halos (Department of Agricultural Biotechnology, Philippines) |
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Speakers:

- | | | |
|---------------|--|-----------------------------|
| 10:10 - 10:30 | Developing resilient maize for Asia against biotic and abiotic stresses | Jan Samson (DuPont Pioneer) |
| 10:30 - 10:50 | Molecular marker-assisted breeding for tropical maize improvement | Raman Babu (CIMMYT, India) |
| 10:50 - 11:05 | Genome-wide analysis of phosphate transporter gene family in maize | Lijuan Yu (YAAS, China) |
| 11:05 - 11:20 | Deciphering genomic regions associated with waterlogging and drought tolerance traits in tropical maize using multiple connected populations | Dung Do Van (NMRI, Vietnam) |
| 11:20 - 11:35 | Enrichment of kernel β -carotene in maize hybrids using marker-assisted backcross breeding strategy | Vignesh M. (IARI, India) |
| 11:35 - 12:00 | General discussion and concluding remarks by Co-Chairs | |

Technical Session 6: Strengthening maize seed systems in Asia

Venue: Canna Room

Co-Chairs : Subash Dasgupta (FAO RAP)
N.N. Singh (TAAS, India)

Keynote Lectures:

09:45 - 10:10 Innovation, competition, and industry performance: Better metrics for measuring the growth of Asia's maize seed system David Spielman (IFPRI)

Speakers:

10:10 - 10:30 Strengthening the maize seed sector in marginal markets in Asia Ian Barker (SFSA)

10:30 - 10:50 International Maize Improvement Consortium (IMIC) in Asia: Partnership with seed companies for client-oriented product development and delivery A.R. Sadananda & B.S. Vivek (CIMMYT, India)

10:50 - 11:10 Strengthening the local seed systems and disadvantaged communities: Success and evolution of the first community-managed seed production company in the hills of Nepal D.B. Bhandari (Hariyali Seed Cooperative Ltd., Nepal)

11:10 - 11:30 Maize seed village: A self-reliance production for Thai farmers Chutima Koshawatana (FRECRI, Thailand)

11:30 - 12:00 General discussion and concluding remarks by Co-Chairs

12:00 - 13:00 Plenary Session 4

Venue: Grand Ballroom

Panel Discussion:**Ensuring a vibrant maize seed sector in Asia through public-private partnerships**

Moderator : Marco Ferroni (SFSA)
Panelists : Arvind Kapur (Rasi Seeds, India)
Shilpa Divekar Nirula (Monsanto)
Fan Xingming (YAAS, China)
John McMurdy (USAID)
Bijendra Pal (Bioseed)

13:00 - 14:00 *Lunch*
Venue: Grand Hall 1

14:00 - 16:30 Parallel Technical Sessions**Technical Session 7: Regional Assessment of Maize in South Asia and the Oceania: Country Reports**

Venue: Grand Ballroom

Co-Chairs : Hassnain Shah (PARC, Pakistan)
Bhag Mal (APAARI)

14:00 - 14:20 Bangladesh Md. Abu Alam Mondal (BARI)

14:20 - 14:40	Bhutan	Dorji Wangchuk & Tirtha Katwal (RNR-RDC)
14:40 - 15:00	India	O.P. Yadav (DMR-ICAR)
15:00 - 15:20	Nepal	K.B. Koirala (NMRP-NARC)
15:20 - 15:40	Pakistan	Mian Md. Shafique (MMRI)
15:40 - 16:00	Sri Lanka	W.M.W. Weerakoon (FCRDI)
16:00 - 16:20	Papua New Guinea	Julie Sip (NARI)
16:20 - 16:50	General discussion and concluding remarks by Co-Chairs	

Technical Session 8: Regional Assessment of Maize in East Asia, South East Asia and West Asia: Country Reports

Venue: Canna Room

<i>Co-Chairs</i> : John McMurdy (USAID) Pichet Grudloyma (NSFCRC, Thailand)		
14:00 - 14:20	China	Mingshun Li (CAAS)
14:20 - 14:40	Indonesia	Muhammad Azrai (ICERI)
14:40 - 15:00	Philippines	Roger V. Navarro (PhilMaize)
15:00 - 15:20	Thailand	Pichet Grudloyma (NSFCRC)
15:20 - 15:40	Vietnam	Mai Xuan Trieu (NMRI)
15:40 - 16:00	Iran	Rajab Choukan (SPII)
16:00 - 16:20	Turkey	Rahime Cengiz (MRS)
16:20 - 16:50	Discussion and concluding remarks by Co-Chairs	
16:50 - 17:15	<i>Tea/Coffee break</i>	

17:15 - 18:15 Plenary Session 5

Venue: Grand Ballroom

Panel Discussion:

Interface with farmers and entrepreneurs on opportunities for enhanced maize production and utilization in Asia

Moderator : Mark Holderness (GFAR)		
Panelists : Esther Penunia (AFA, Philippines) Ambika Pandey (Hariyali Seed Cooperative Ltd., Nepal) Md. Abdul Mazid (BRAC, Bangladesh) Yash Sahrawat (YPARD, India) Taweesak Pulam (Sweet Seeds Co. Ltd., Thailand) Baldev Singh (AIAMMA, India)		
18:15 - 18:30	Borlaug Institute for South Asia (BISA): A new initiative for food security	H.S. Gupta (BISA)

18:30 - 19:30 Poster Session

(Posters accepted under Technical Sessions shall be displayed all through the day for review by delegates, as well as for evaluation by a panel)

19:30 Dinner hosted by DOA, Thailand
Venue: Grand Hall 1

Day 3 : 1 November, 2014

08:30 - 10:30 Parallel Technical Sessions

Technical Session 9: Precision-conservation agriculture for enhanced input use efficiency

Venue: Grand Ballroom

Co-Chairs : Alok K. Sikka (ICAR, India)
Tien-Jung Yu (COA, Chinese Taipei)

Keynote Lecture:

08:30 - 08:55 Conservation agriculture based management for sustainable maize systems: Learnings from South Asia M.L. Jat (CIMMYT, India)

Speakers:

08:55 - 09:15 Precision nutrient management in smallholder maize systems: recent advances Kaushik Majumdar (IPNI, South Asia)

09:15 - 09:35 Sustainable intensification of maize-based systems: Lessons from SIMLESA Mulugetta Mekuria (CIMMYT, Zimbabwe)

09:35 - 09:50 Performance of a precision planter with row cleaners and depth control units for no-till sowing of maize Dongxing Zhang (CAU, China)

09:50 - 10:05 Influence of soil compaction stress on root endogenous hormone and protective enzyme activities in maize Chaohai Li (HAU, China)

10:05 - 10:30 General discussion and concluding remarks by Co-Chairs

Technical Session 10: Enhancing nutritional quality of maize

Venue: Lilavadee Room

Co-Chairs : Kevin Pixley (CIMMYT)
Sain Dass (IMDA, India)

Keynote Lecture:

08:30 - 08:55 Development of biofortified maize in southern China Fan Xingming (YAAS, China)

Speakers:

08:55 - 09:15 Provitamin A enrichment in maize Willy Suwarno (BAU, Indonesia)

09:35 - 09:50 Biofortification potential of QPM and normal maize for major micronutrients Dharam Pal Chaudhary (DMR, India)

09:50 - 10:05	Evaluation of colored waxy corn germplasm for high anthocyanin concentration and antioxidant capacity	Harakotr B. (KKU, Thailand)
10:05 - 10:20	Effect of locations and varieties on yield, phytochemicals and antioxidant activity in corn silk	Sarepoua E. (KKU, Thailand)
10:20 - 10:30	General discussion and concluding remarks by Co-Chairs	
10:30 - 11:00	<i>Tea/Coffee break</i>	

11:00 - 13:00 Parallel Technical Sessions

Technical Session 11: Adapting maize production practices to the changing climate

Venue: Grand Ballroom

Co-Chairs : Etienne Duveiller (CIMMYT)
K.B. Koirala (NMRP-NARC)

Keynote Lecture:

11:00 - 11:30	Climate resilient agriculture: a major national initiative in India	Alok K. Sikka (ICAR, India)
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Speakers:

11:30 - 11:50	Building resilience to climate and non-climate drivers of change through systems diversification with maize: Scope and implications in the western and eastern IGP	Hanuman Sahay Jat (CIMMYT-India)
11:50 - 12:05	Using ecological intensification to improve maize yields while minimizing adverse environmental effects	T. Satyanarayana (IPNI, India)
12:05 - 12:20	Environmental footprint of maize-based cropping systems under different crop establishment methods in north-west India	Tek Sapkota (CIMMYT, India)
12:20 - 12:35	Effect of fertilizer management and cropping system on soil quality, greenhouse gas emission and maize productivity	Suphakarn Luanmanee (NSFCRC, Thailand)
12:35 - 13:00	General discussion and concluding remarks by Co-Chairs	

Technical Session 12: Enhancing gender equity and social inclusiveness

Venue: Lilavadee Room

Co-Chairs : Nora Lapitan (USAID)
Olaf Erenstein (CIMMYT)

Keynote Lecture:

11:00 - 11:30	Amplifying outcomes through addressing inequality: The role of gender transformative approaches in agricultural R4D	Paula Kantor (WorldFish, Egypt)
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Speakers:

11:30 - 11:50	Community based seed systems in hills of Nepal	Yamuna Ghale (SDC, Nepal)
11:50 - 12:10	Gender roles or production relations? Gender equity and social inclusion through agriculture research	Maitrayee Mukhopadhyay (KIT, Netherlands)
12:10 - 12:30	ICT for gender empowerment	Surabhi Mittal (CIMMYT, India)
12:30 - 13:00	General discussion and concluding remarks by Co-Chairs	

08:30 - 13:00 APAARI General Assembly Meeting*Venue: Tulip Room***10:30 - 11:00 Group Photograph & Tea/Coffee Break***Note: Participation only by APAARI Members and Special Invitees*13:00 - 14:00 *Lunch**Venue: Cattleya***14:00 - 15:15 Plenary Session 6: Keynote presentations***Venue: Grand Ballroom*

*Co-Chairs : Nguyen Van Bo (VAAS, Vietnam)
B.M. Prasanna (CIMMYT)*

Speakers:

14:00 - 14:30	Nutritionally enriched maize: adoption and impact in Asia	S.K. Vasal
14:30 - 15:00	New developments in production of doubled haploids in maize breeding	Albrecht Melchinger (Univ. of Hohenheim, Germany)
15:00 - 15:30	General discussion and remarks by Co-Chairs	
15:30 - 16:00	<i>Tea/Coffee break</i>	

16:00 - 18:00 Concluding Plenary Session*Venue: Grand Ballroom*

*Co-Chairs : Raj Paroda (APAARI)
Thomas Lumpkin (CIMMYT)*

Presentation of key recommendations from Technical Sessions

Presentation of Best Poster Awards

Presentation of Plaques & Mementoes

Concluding remarks by Co-Chairs

19:30 Dinner hosted by COA, Chinese Taipei
Venue: Grand Hall 2

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