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Yezin Agricultural University, 29 August 2019

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in Myanmar

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CONTENTS

Background

Myanmar is among the highly vulnerable countries to climate change and extreme weather conditions. Based on the the Long-Term Climate Risk Index (CRI), Myanmar is one of the three most affected countries over the past two decades (1999 to 2018). In more recent years, the change in the climate has been characterized by changing rainfall patterns, increasing temperatures and extreme weather throughout the country. Rising temperature in the atmosphere also causes sea level rise and affects low lying coastal areas. The impact of climate change has led to massive displacement of people and the destruction of livelihoods, crops and other food sources.

Realizing the impact of climate change as a global and national challenge, FAO has been implementing a GEF funded project "Sustainable Cropland and Forest Management in Priority Agro-Ecosystems of Myanmar (SLM-GEF)" since July 2016 to address the negative impact of climate change. This five-year project (2016-2021) is funded by Global Environment Facility (GEF) and is being jointly implemented with the Ministry of Natural Resources and Environmental Conservation (MoNREC) and the Ministry of Agriculture, Livestock, and Irrigation (MoALI). The main aim of the project is to build capacity of farming and forestry stakeholders to mitigate climate change and improve land conditions. This is done by adopting policies and practices related to climate smart agriculture (CSA), sustainable forest management (SFM) and sustainable land management (SLM).

A National Climate Smart Agriculture Center (NCSAC) has been established and operationalised at Yezin Agriculture University (YAU) with the support from the project in order to coordinate development, packaging and promotion of best practices and to conduct advocacy activities related to CSA. The Center was jointly inaugurated by His Excellency Dr. Aung Thu, the Union Minister of MoALI and Ms Xiaojie Fan, the FAO Representative in Myanmar on 17 August 2018. A CSA Technical Support Group (TSG) has been formed representing a national cohort of Myanmar's best experts associated with CSA/SLM approaches to coordinate among the relevant stakeholders, make strategic decisions and guide effective operationalization of the CSA Center. The TSG comprises of 26 members representing DoA, DAR, DoP, DALMS, FD, I/NGO's, YAU and FAO. Since its establishment, the Center has successfully organized several awareness raising events, training and demonstration activities aiming for CSA promotion. The center also provided library services, measured greenhouse gas emission using gas chromatography machine and organized a firtst national workshop on "Promoting Climate Smart Agriculture in Myanmar" on 14 Sep 2018 at YAU.

A second national workshop on "Green Ecology in Myanmar" was co-organized by FAO and NCSAC/YAU on 29 Aug 2019 at YAU considering the need to focus on landscape approach. This workshop was jointly opened by Dr Aung Thu, The Union Minister for MoALI; Ms Xiaojie Fan, the FAO Representative in Myanmar and Dr Nang Hseng Hom, the Rector of YAU. More than 175 participants representing relevant Government Departments from MoALI and MoNREC, YAU, State Agriculture Institutes, International organizations/INGOs/NGOs (Cesvi, AVSI, COLDA, IIRR, Helvetas, SwissAid, IRRI, JICA, JIRCAS, ICRAF, IWMI), UN Agencies (FAO, WFP and UNOPS) and Donors participated in the workshop. A total of 14 papers related to four sub-themes of the workshop: CSA/SLM/SFM concepts/techniques, water-saving techniques and irrigation, agroforestry and agro-ecology, were presented by various speakers representing YAU, IIRR, ICRAF, IWMI and FAO. This was followed by a group discussion and presentations on issues/challenges, opportunities and recommendations for promoting CSA/SLM/SFM concepts/techniques, water-saving techniques and irrigation, agroforestry and agro-ecology in Myanmar.

Mr. Xavier Bouan, the Senior Technical Advisor of the SLM-GEF Project, closed the workshop by summarizing the key findings of the workshop and extending vote of thanks to all the participants for their active participation and genuine contributions.

The workshop was successful and very useful in terms of sharing ideas, experiences, research findings and extension tools/models on the topics related to promoting CSA/SLM/SFM concepts/techniques, water-saving techniques and irrigation, agroforestry and agro-ecology in Myanmar.

A panel of the following Editorial Board reviewed the relevant papers based on their background.

- Dr Shwe Mar Than, Deputy Director, ACARE (Advanced Centre for Agricultural Research and Education), MOALI (Two papers: 1 and 2).
- Dr Htay Htay Oo, Professor, Department of Agronomy, Yezin Agricultural University, Myanmar (Three papers: 3, 6 and 7).
- Dr Yarzar Hein, Associate Professor, Department of Agricultural Economics, Yezin Agricultural University, Myanmar (Two papers: 4 and 5).
- Dr Yu Yu Min, Professor & Head, Department of Microbiology, Yezin Agricultural University, Myanmar (One paper: 8).
- Dr Nyo Mar Htwe, Deputy Director, ACARE (Advanced Centre for Agricultural Research and Education), MOALI (Three papers: 9, 10 and 11)

This was followed by the overall review of all the papers and entire proceedings by the International Climate Smart Agriculture Specialist (Mr Jitendra P. Jaiswal) and former National Climate Smart Agriculture Specialist (Ms Khin San Nwe) of SLM-GEF Project, FAO Myanmar.

The Cover design, layout and formatting of the proceedings have been done jointly by Dr Yarzar Hein, Nyo Mar Htwe, Yezarni Ko Ko Htwe (from YAU) and Soe Moe Naing (from FAO). The invaluable contributions of all concerned in oragnising and making this workshop successful and preparing the proceedings are highly acknowledged.

The detailed workshop agenda has been presented in Annex 1.

Opening session

Welcome address and opening speech by Dr Aung Thu, Union Minister, MOALI

Honorable guests from FAO, Donor agencies, representative from Ministry of Natural Resources and Environmental Conservation, representative from Ministry of Agriculture, Livestock and Irrigation, Ladies and Gentlemen, very good morning! I have a rare privilege to welcome all of you to this important event organized by Food and Agriculture Organization of the United nations, in collaboration with Global Environment Fund (GEF) and Yezin Agricultural University (YAU). Special welcome goes to FAO Representative in Myanmar, delegates who have travelled all the ways from various counters.

We are here today to share the knowledge of Climate Smart Agriculture (CSA), Sustainable land Management (SLM), Sustainable Forest Management (SFM) concept or techniques and agroforestry, water saving techniques and irrigation, agroecology that are very important to our agriculture and the livelihoods of many households.

Myanmar is highly vulnerable to climate change and some studies point out that Myanmar is 2nd most vulnerable country in the world, in terms of vulnerability from extreme weather events related to climate change. This is a serious threat to Myanmar's sustainable development. Now a day, Myanmar is exposed to cyclones, floods, heavy rains, droughts, extreme temperatures, which are becoming more frequent and more severe with the changing climate.

According to floodlist news, several states and regions in Myanmar were hit by heavy monsoon rainfall and flooding, beginning with Kachin and Rakhine states and Sagaing Region in this year. By 23 July, over 40 000 people were displaced and staying in 186 evacuation centres in Kachin, Rakhine, Chin, and Mon states, as well as Bago, Sagaing, Mandalay and Magway regions. According to a UN report, as of 04 August, around 26 000 remained displaced, mostly in Sagaing, Mandalay, Bago and Magway regions and Kayin state. A total of 728 000 hectares of agricultural land has been hit by flooding so far this year, and of that number, 16 000ha of crops were destroyed. Moreover landslide in Paung township, Mon state occurred during August and it's killed over 40 people.

As we all know that the interaction of climate change and agriculture is a two way direction. Agriculture sector suffers from the negative impacts of climate change as mentioned in previously. And also, agriculture contributes the Green house gas (GHG) emission, especially non carbon dioxide gases such as methane and nitrous oxide gas, which have more serious effects on atmosphere. Approximately, agriculture and land use change contribute 29 percent of total global emission annually.

From those points of view, today workshop discussion on different technical session can find out the possible solution to adaptation and mitigation measures of Myanmar agriculture and land use sector.

Ladies and gentlemen!

Enhancing food security requires the transition to agricultural production systems while contributing to climate change adaptation and mitigation. So, today discussion on effective and efficient use of natural resources such as fresh water, land, soil nutrients and genetic resources are most important to cope with current climate change issues in our country.

I would like to take this opportunity to express my sincere thanks to the responsible persons from MONREC, GEF, FAO and YAU. All of them have been working with us since the beginning of the planning stage and they are still here today for all of us, even though they are both very busy with their responsibilities. I am confident of the results of today's discussions will be valuable and important initiative for our future CSA in Myanmar.

I wish you all have great times.

Dr Aung Thu

Union Minister

Ministry of Agriculture, Livestock and Irrigation

Opening Remark by Ms Xiaojie Fan, FAO Representative in Myanmar

Your Excellency Dr Aung Thu, The Union Minister for Agriculture, Livestock and Irrigation (MOALI), Your Excellency, U Hla Kyaw, Deputy Minister of MoALI, Honorable Members of Parliament, Permanent Secretaries, Director Generals and senior officials from partner ministries, Rectors of YAU, University of Forestry and Environment Science, and University of Veterinary Science, Representatives from international partners, NGOs, CSOs, and colleagues from FAO.

Good morning, Mingalaba!

It is my great pleasure to welcome you all to this ***"National Workshop on Green Ecology in Myanmar"*** **–** jointly organized by Yezin Agriculture University and FAO. This workshop is being organized to share knowledge and experiences on concept and practices applicable to Myanmar, including **Climate Smart Agriculture**, **Sustainable Land management, Sustainable Forest Management**, **agro-forestry**, **water management, agro-ecology, etc**.

Throughout the long history of our partnership, FAO has been working closely with the government of Myanmar contributing to its livelihood improvement and economic development, towards achieving the **Global Sustainable Development Goals**. Taking this opportunity, I want to express our sincere appreciation to MoALI, MoNREC and all other partners for your collaboration and great support to FAO over the years, without which we would not have achieved what we have today.

As we all know, Climate Change is becoming a global challenge and it is affecting all four dimensions of food security: **food availability**, **food accessibility**, **food utilization** and **food systems stability**.

To assist countries in developing and transforming agricultural systems that both limit their impact on and are resilient to climate change, FAO promotes **Climate Smart Agriculture** (CSA) around the world. CSA is an integrated approach that helps to guide actions and develop agricultural strategies to effectively support development and ensure food security under the threat of climate change, taking into consideration the social, economic and environmental context.

Additionally, in the recent years, FAO has also been promoting the concept of **agro-ecology** as an **integrated approach** that simultaneously applies **ecological & social concepts** to the design and management of food & agricultural systems.

FAO has been organizing a series of international and regional multi-stakeholder meetings to identify needs and priorities to scale up agro-ecology as a strategic approach to achieve Zero Hunger and the SDGs. We are also ready to support countries in developing a policy environment and frameworks to promote agro-ecological approaches.

Now more specifically in Myanmar, you may know that the country is highly vulnerable to climate change and extreme weather conditions, and Myanmar ranks among the top three countries mostly affected by weather related events. This has significant negative impact on agricultural production that potentially can lead to food insecurity.

However, as we all known and have seen, the government of Myanmar is making all possible efforts to mitigate and adapt to the impact of climate change. By signing the Paris Agreement, Myanmar has sent a very clear signal about pursuing a low carbon development path. This is further backed up by significant national initiatives, such as **Myanmar National Climate Change Policy** and sector strategies like **Myanmar Climate Smart Agriculture Strategy**.

Realizing the global and national challenges, FAO Country Office in Myanmar has set Enhancing Resilience to CC and Sustainable Natural Resource Management as one of our top three priorities in the Country Programming Framework from 2017 - 2023. In this regard, we have committed ourselves to support Myanmar in mitigating the looming threats of climate change and in promoting risk sensitive development within agriculture, including the support in developing the **Agriculture Sector Action Plan on Disaster Risk Reduction (AAPDRR)** that is soon to be launched by MoALI and FAO.

Through the GEF funded project "Sustainable Cropland and Forest Management in Priority Agro-Ecosystems of Myanmar", jointly implemented with MoALI and MoNREC, we have been working on building the capacity of farming and forestry stakeholders to mitigate climate change and improve land condition, by adopting Climate Smart Agriculture (CSA), policies and practices relating to sustainable forest management and sustainable land management.

In order to coordinate development, packaging and promotion of best practices and to conduct advocacy activities related to CSA, this project has supported establishment and operationalization of the **National Climate Smart Agriculture Center** at Yezin Agriculture University (YAU). Once again, I want to thank Your Excellency Dr Aung Thu for opening the National CSA Center on 17th August 2018.

In the last one year, the Center has successfully organized several awareness raising, training and demonstration activities aiming for CSA promotion. The center also provides library services and measures greenhouse gas emission using gas chromatography machine.

On the above, I would like to publicly congratulate the CSA Center for all progresses accomplished so far.

Excellences, colleagues and friends,

I would like to conclude here by ensuring, once again, FAO's commitment to work and collaborate closely with MoALI, MoNREC and all other partners, both national and international, in promoting climate smart agriculture and green ecology in Myanmar, for the achievement of our joint goals for the sustainable development of the country.

On behalf of FAO, I would like to extend our best wishes for a successful workshop with active participation and effective contributions from all of you.

Thank you.

Ms. Xiaojie Fan

FAO Representative in Myanmar

Words of Acknowledgement and Objective of the Workshop
By Dr Nang Hseng Hom, Rector, Yezin Agriculture University

Your excellency Minister Dr Aung Thu, Members of Nay Pyi Taw Council U Aye Maung Sein, Chairman of Agriculture, Livestock Breeding and Rural Development Committe Pyithu Hluttaw U Yan Linn, Chairman of Farmers' and Workers' Affairs Committe Pyithu Hluttaw U Kyaw Myint, Chairman of Farmers Affairs Committee, Amyotha Hluttaw U Ba Myo Thein, Chairman of Agriculture, Livestock and Fisheries Development Committee Amyotha Hluttaw U Aung Kyi Nyunt, FAO representative of Myanmar Ms Xiaojie Fan, representatives from NGO/INGO, representatives from YAU, ACERE, Director Generals of MONREC and MOALI, Professors from University of Forestry and Veterinary, distinguished guests, and ladies and gentlemen, I wish you all Mingalapar. It is really a great honor and privilege for me to express my sincere thanks to you all for your kind presence in this auspicious occasion.

First and foremost, we would like to express our deep felt thanks to his excellency Dr Aung Thu, Minister for Agriculture, Livestock and Irrigation for inaugurating the second Workshop on Green Ecology in Myanmar 2019, as our honorable chief guest. Our warmest thanks are due to Parliamentary Representatives of Upper House and Lower House, for their kind presence in this workshop, even though there are very tight schedule of their duties and responsibility in the parliamentary sessions. We would like to convey our highest thanks to Ms Xiaojie Fan, FAO Representative of Myanmar for her encouraging opening remarks and valuable support in facilitating the successful convening of this workshop.

We would like to briefly state today workshop's background and objective. With the purpose of building the capacity of farming and forestry stakeholders to mitigate and adapt climate change, and improve land conditions in Myanmar, Food and Agriculture Organization of United Nations (FAO), Ministry of Natural Resources and Environmental Conservation (MoNREC) and the Ministry of Agriculture, Livestock, and Irrigation (MoALI) jointly are currently implementing "Sustainable cropland and forest management in priority agro-ecosystems of Myanmar (SLM-GFF) Project". As a component of this project, National Climate Smart Agriculture Center was established in 2018, last year. By acting as the national CSA knowledge repository and a focal point for the advancement of knowledge, NCSA Center organizes today Green Ecology workshop with three objectives:

Sharing knowledge and experiences on different approaches and methods used locally or internationally relevant to promote CSA/SLM/SFM in Myanmar

Sharing best practices of CSA/SLM/SFM, both technical and regulatory issues, based on national and international experiences

Discussion on the opportunities and challenges related to CSA/SLM/SFM promotion in Myanmar and suggest possible solutions

With these objectives, we do believe that the appropriate solutions to adaptation and mitigation measures of Myanmar agriculture and land use sector will be find out as a **result of this Green Ecology Workshop.**

In here, we are appreciative of the roles played by the international and national resource persons for their well-prepared and resourceful papers on country' experience and lessons which will be of a great value for the consideration of sustainable cropland and forest management in priority agro ecosystems of Myanmar. We also like to thank the rest of the participants for taking their time to come here and their valuable contribution to the success of this workshop. Finally, our warmest and sincerest thanks to responsible persons of FAO-SLM project and our Technical Support Group Members of NCSA Center, and the supporting staffs from YAU who worked together so hard to make this very important workshop a reality.

Thank you so much!

Dr Nang Hseng Hom
Rector
Yezin Agricultural University

Papers presentation and discussions

Session 1

CSA/SLM/SFM concept/techniques and agroforestry

Climate-smart villages in Myanmar as platform to promote CSA

Wilson John Barbon[1], Chan Myae[2], Su Myat Noe[3], Julian Gonsalves[4]

Abstract

The manifestations of climate change differ across different agro-ecosystems in Myanmar. Climate change impacts and local responses are different from each agro-ecology, so it is crucial that adaptation measures recognize the value of targeted, location specific, community-based strategies and processes. The climate-smart village approach is one platform that can facilitate community-based adaptation in agriculture. With support from CCAFS in 2017 and with International Development Research Center (IDRC)-Canada in 2018, IIRR is implementing 4 climate-smart villages (CSVs) representing 4 major agro-ecological regions of Myanmar namely the central dry zone, mountain highlands, upland-plateau and delta. In this action research, we seek to demonstrate and test the different socio-technical methodologies in facilitating CSVs in Myanmar. Our initial findings have shown that by using socio-technical methodologies—we ensure active participation by farmers including women in the process of community-based adaptation as well as ensure the effectiveness of CSA technologies and practices. These methodologies also allowed for initial out-scaling through awareness building of key stakeholders in Myanmar.

Keywords: *CSA, climate-smart village, socio-technical methodologies*

1. Introduction

In Myanmar, climate variability is experienced in most parts of the country with some parts receiving excessive rain, and others have to deal with drought periods during the cropping cycles. A severe flood was occurred in 2008 because of Cyclone Nargis which stroke down the Ayeyarwaddy and Yangon regions; an estimate of 140 000 people were killed and 2.4 million people were severely affected during that time. Regarding also with drought, a significant drought occurred in Myanmar during 2010 which was the most severe in several decades. The extreme temperature also recorded 47.2 °C at Myinmu station in dry zone area on 14 May 2010. Temperature has been higher in each year and monsoon approaches rain lately every year, causing severe shortage of water in many parts of Myanmar.

The effects of climate change being location specific, community-based and needs driven approaches which feature increased levels of community participation and engagement are needed in arriving at scalable models. Therefore, it is crucial that adaptation measures recognize the value of targeted, location specific, community-based strategies and processes. This needs to be provided special attention in implementing community-based adaptation (CBA) processes in Myanmar.

It is important for large-scale initiatives to consider local priorities and integrate lessons from successful adaptation efforts, relying on lessons derived from site-specific research located in areas where out-scaling is envisaged. This is particularly important in a country like Myanmar with a diversity of ethnic groups, climate zones and agroecosystems. There is increasing mention in the literature about the important contribution of community-based and led initiatives in effective adaptation efforts of smallholder farmers (Heltberg, Siegel, &

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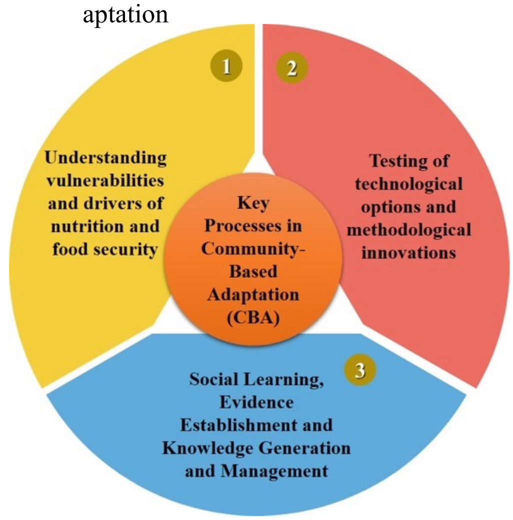
Jorgensen, 2009; Kansiime, 2012; Reid et al., 2009). Despite this growing recognition and the potential value of community-based adaptation processes, the replication and increased practice of these processes is still relatively uncommon.

There is a complementary need to ensure that CBA processes in the field of agriculture create co-benefits that will address what is referred to as the current "development deficit" (Parry et al., 2009). CBA processes should contribute in sustaining ecosystems, creating stable incomes, achieving a sustainable food system that nourishes people and strengthening local institutions of governance.

CBA is understood by IIRR and its partners as a process of resilience building, which relies on an initial phase of identifying vulnerabilities, mapping of CSA options (both processes and technologies) and associated participatory action research aimed at deriving a portfolio of scalable technological options and social learning processes which address climate and livelihood risks and local needs. Such portfolio of CSA options usually address multiple household needs of livelihood, nutrition and income needs. Adaptation is not accomplished in a single intervention rather it is a continuum, requiring an overarching approach that range from those that address the underlying drivers of vulnerability to those designed exclusively to respond to climate change impacts (ODI, 2010). With a portfolio approach, diversification and intensification objectives can be achieved, especially for small holder and those with marginal landholdings.

Figure 1 shows the key steps that IIRR follows in facilitating community-based adaptation in agriculture. Our approach is not of one-size fits all approach but takes on a location-specific approach where the basis of adaptation is the understanding of how climate change affects the local agriculture systems. We also take on a portfolio approach—developing a menu of technological options (point 2 in the diagram) where people can choose those that they think works well with their own context. Finally, we take on a social learning guided by evidence and knowledge generated from the testing of adaptation options.

Figure 1. Key processes in Community-based Adaptation



In its work in the Philippines, IIRR has learned the importance of establishing proof of concept sites where scale is demonstrated and an evidence base is established for purposes of supporting wider uptake of the CBA approach. In Myanmar, to promote the out-scaling of CBA in agriculture, IIRR believes that we need implement an approach that deal with context specificities of various agro-ecological regions as well as socio-cultural differences. Like in the Philippines, we refer to this proof of concept sites to demonstrate context specific community-based adaptation in agriculture as climate-smart villages.

2. Materials and methods

2.1 The climate-smart village (CSV) approach

CSVs are on-site, on-location platforms where discovery, learning and sharing happens. CSVs serve as basis for field level advocacy for promoting CBA processes. These are intentionally designed to be low cost and typically feature local teams and local institutions in order to enhance their role as "lighthouses" to support wider uptake.

CSVs are the platforms (venue and location) for climate change adaptation wherein location-specific strategies for addressing climate risks and challenges are tested, developed and subsequently scaled up. This is done by establishing the necessary evidence base through participatory and collaborative approaches and associated action research. The process involves not only farming communities but also the local governments, and the local research community. Unlike the "Millennium Villages", a demonstration of input-intensive integrated rural development—The CSV is a demonstration of how (process) to assist local communities adapt to climate change. CSVs recognize the fact that individual action is not enough in coping with climate change. They provide the platform for multi-stakeholder participation and collaborative work in targeted, clearly delineated geographic areas ("territories" or "small landscapes").

2.2 Climate-smart villages in Myanmar

In 2016, IIRR, with support from CGIAR-CCAFS,Climate Change, Agriculture and Food Security (CCAFS) program conducted a rapid scoping study of 4 various agro-ecologies in Myanmar. The goal of this study was to get an overview of the agriculture systems in those agro-ecologies (the central dry zone, mountain highlands, upland-plateau and delta) such as crops grown, crop calendar, markets, extension and impacts of climate change. This study provided the basis of the potential of establishing CSVs in Myanmar to promote climate resilience in agriculture. This is very unique to Myanmar where the country has diverse agro-ecologies therefore, it is important to adopt a more localized approach to agriculture development programs. IIRR believes that the CSV approach could be the localized approach to be used for agricultural development.

In Myanmar, with support from CCAFS and the International Development Research Center in Canada, IIRR is conducting a 3-year participatory action research to establish 4 climate-smart villages. This research is to develop a process of establishing CSVs in Myanmar, demonstrate CSA in the 4 agro-ecologies and identify the pathways to bring CSVs to scale—replicate the CSVs by NGOs and government agencies all over Myanmar. Below summarizes the profile of the 4 CSVs established in Myanmar.

As noted in this table, this represents the diversity of agro-ecologies and its corresponding agriculture systems. For instance, the agriculture system in Chin state, given their isolation is more driven by household food security, while farmers grow cash crops such as elephant foot yam, farmers grow other crops mainly so they can have food This is different from the agriculture systems in Delta and dry zone where production is driven my markets. The agriculture system in Shan is driven both for food consumption and markets as they are close to the trading centers.

Each of these CSVs also experience climate change differently. It is in this context that IIRR presents the importance of localized climate change adaptation in agriculture that is systems-oriented rather than crop or commodity-oriented approaches. The systems-oriented approach takes into consideration the soil, water, climate variability and extension services—all determine the outcome and quality of agriculture production. In the CSVs, IIRR is demonstrating a systems-approach to building resilience in agriculture. In this paper, IIRR will present the different socio-technical methodologies that it has developed to facilitate the process of adaptation in agriculture that is localized and systems-oriented.

2.3 Socio-technical methodologies in the climate-smart villages

The CSVs in Myanmar was introduced in 2016 through CGIAR-CCAFS and IIRR. CCAFS supported the Ministry of Agriculture, Livestock and Irrigation (MOALI) in the formulation of the Myanmar CSA Strategy. This document laid out the long term as well as short-term strategies and priorities to promote climate change adaptation in Myanmar agriculture. One of the strategies identified is the establishment of CSVs. With support from CCAFS and IDRC-Canada, IIRR ventured into establishing CSVs in 2017, starting with 2 CSVs initially and then in 2018 added 2 more CSVs resulting a total of the current 4 CSVs in Myanmar.

The work of IIRR in the Myanmar related to CSVs involved using a variety of socio-technical methodologies. Table 2 below summarizes the different socio-technical methods that IIRR has used to facilitate the establishment of the Myanmar CSVs.We refer to these as socio-technical methodologies because it is a combination and complementation of agriculture research (technical) and social

Table 1. Profile of the Myanmar climate-smart villages

Name of Village	Saktha	Htee Pu	Ma Sein	Taung Kamau
Agro-ecology	Highlands	Dry Zone	Delta	Upland
Major crops	Rice, corn, vegetables	Groundnut, pigeon pea, green gram	Rice	Rice, millets. corn
Township (Tsp)	Hakha	Nyaung-Oo	Bogale	Nyaung-Shwe
State/Region	Chin	Mandalay	Ayeyarwaddy	Shan
Total households	200	275	103	94
Total Population	865	11 180	453	405
Female	445	603	249	215
Male	420	577	214	190
Distance from Tsp. nearest	32 km	35 km	11 km	20 km
Ethnic Group	Chin	Burmese	Burmese	Pa-o

Table 2. Summary of Socio-technical methodologies in the Myanmar CSVs

Steps in the CSV establishment	Methods	Purpose	Socio	Technical
Social preparation	Opening wedge activities	To build community trust and initial interest to participate	·	
Assessment of agriculture systems and climate change risk	Household surveys	To facilitate targeting and monitoring outcomes	·	
	Participatory vulnerability assessments and gender analysis	To collectively identify and analyze climate risks to agriculture and gender	·	·
		To build awareness of climate change risks		
Identification of options for adaptation	Focus group discussions (sector based)	To develop a menu of options based on local knowledge	·	·
	Secondary research	To identify latest technologies and practices developed by scientists		·
Multi-location and participatory testing of identified options	Participatory varietal selection	To field test new varieties of major crops		·
		To characterize new varieties vis a vis specific climate condition		
	Crop trials	To field test introduced crops to the system		·
	Demonstration	To field test integrated systems (e.g. trees, small livestock, gardens)		·
	Setting up adaptation fund	To support strategic adaptation options	·	
Farmer to farmer learning	Farmer learning groups	To share knowledge and materials	·	
	farmer field days	To develop farmer specialists		
Scaling out CSVs	Roving workshops	To build awareness of policy makers and NGOs	·	

mobilization and organizing (socio). We believe in the importance of this complementation because for adaptation to be sustainable—the subjects (farmers, households and villagers) has to own this process of adaptation. True resilience cannot be given to farmers, true resilience has to be built within the farmers' mindset and expressed in their attitude and practices towards farming. This cannot be achieved by just doing hard agriculture research. This is where the value of social mobilization, social learning and organizing comes in in order to achieve sustainability.

On the technical side of these methodologies, we worked with different research organizations within the CGIAR system and the Department of Agriculture Research (DAR) through their field research stations located near the CSVs. This way we ensure that whatever technologies and practices farmers are learning in their field by testing of various options—those are backed by researches of scientists, specialists and practitioners.

3. Results and discussions

After almost 3 years of working in the 4 CSVs and implementing these combinations of socio-technical methodologies, the followings are our initial results.

3.1 Social preparation

One of the key questions we asked in the beginning of this work is how and where do we find the village to be designated as a CSV in Myanmar. Based on the experience and performance of the other CCAFS CSVs in Southeast Asia, we used the following criteria to narrow down the list of villages we will consider as CSVs.

a) Representing a key agro-ecological region of Myanmar and have high risk to climate change impacts,

b) Accessibility of the CSV to facilitate visits by other farmers, government officials, researchers, donors and partners,

c) Manageable size in terms of population; we considered households to be between 100-250 households,

d) Least served by NGOs or government programs on agriculture. This is to ensure equity of services, and

e) Presence of a local organization who will be willing to be trained to implement the CSV approach.

After the CSVs were identified, we conducted initial activities called as "opening wedge activities". These are activities that engage farmers in onsite testing of technologies identified based on the needs identified during the scoping missions. The primary purpose of these activities is to build good will and trust between the community members and the facilitators of the CSV activities. As the opening wedge activities IIRR implemented crop trials of new varieties as well as for new crops, introduction of diverse fruit trees into homesteads and introduction of boundary planting of legumes trees such as Cassia siamea. These activities are to be understood as exploratory range of diversified options that illustrate a portfolio of (diversified) CSA options. These activities are more social activities of trust building rather than hard agricultural research.

3.2 Assessment of agriculture systems and climate change risks

The process of identifying the CSVs and the implementation of the "opening wedge activities" took at least one cropping season of 2017. In 2018, with commitment and participation already established in the social preparation, IIRR conducted the next step in the CSV process—the assessment of agriculture systems and climate change risks. There are two main methodologies used for the assessment and those are: participatory vulnerability assessment (PVA) and the household surveys.

The PVA took 2-3 days for facilitating various participatory tools such as community mapping, seasonal calendar, timeline, problem tree analysis and focus group discussions. The information and analysis gathered in the PVA are: description and characterization of the agriculture production systems (e.g crops grown, cropping calendar, issues and concerns in production), climate change risks (e.g. changes that affected production) and finally the role of men and women in the agriculture, food security and nutrition.

While conducting PVAs, household level surveys were also conducted to gather individual data related to livelihoods, wealth estimates, household coping strategy, household food security and diet diversity and household gender dynamics. The information gathered in the surveys were sed to better inform the design of the support IIRR will provide to the CSVs. From the assessment findings a profile of the climate-smart village was developed. The summary of the villages situation are as follows.

3.2.1 Htee Pu climate-smart village (dry zone)

Half of the 275 households in Htee Pu CSV are engaged in farming as a form of livelihood. Another 15 percent households works in livestock rearing such as goat, cattle, and pig. Htee Pu farmers are primarily growing pigeon pea, tomato, sesame, and groundnut, which they plant during the rainy season. However, agriculture in this village faces several challenges that are aggravated by climate change. Htee Pu CSV is in Myanmar's Dry Zone, where desertification is prevalent. Desertification is driven by deforestation, soil erosion, and salinization. Deforestation occurs because of the high demand for fuel wood and other forest products. Soil erosion is intensified due to strong rainfall and rapid surface runoff. Rainfall in the Dry Zone is not only stronger than in other areas, but also highly variable. This leads to droughts and floods that limit crop production and quality and exposes farmers to various pests and diseases.

3.2.2 Ma Sein climate-smart village (delta)

Rice cultivation is the main livelihood of Ma Sein CSV residents. They also plant coconut and betel nut trees in their cultivated lands, which cover 397 hectares. Those without access to the lands, are engaged in backyard animal husbandry, small-scale fishing and aquaculture, and betel nut and coconut trading, among others. Ma Sein CSV is in Ayeyarwaddy Region, a low-lying, flood-prone area in Myanmar. Aside from floods, the people in this region regularly face storms and other natural disasters. The constant exposure of Ayeyarwaddy to these disasters contributes to its high landless rates, recorded at 50 percent for poor households and 24 percent for non-poor households in 2017. Gender issues also prevail in the region, specifically in Ma Sein CSV, where only 17 out of the 249 women are actively engaged in development issues such as village development and social welfare.

3.2.3 Saktha climate-smart village (mountain highlands)

This CSV is situated in Hakha Township in Chin State, which is considered as the poorest state in Myanmar. One of the drivers of poverty in this state is a lack of access to markets, which is exacerbated by a lack of road infrastructures and poor quality of available roads. These roads are often blocked due to landslides during the monsoon season. This inadequacy of infrasttracture hinders the delivery of agricultural extension services to Saktha CSV such as planting materials and inputs. These services are critical to Saktha CSV, wherein more than 90 percent of the households work in the agricultural sector. The sector, though, now faces intensified floods, droughts, and rain infestations, among others, leading to food insecurity.

3.2.4 Thaung Kamau climate-smart village (uplands)

Taung Khamauk is the village under Tone Lae village tract, Nyaung Shwe Township which is situated in the southern part of Shan State and it is about 1-hour drive from Nyaung Shwe. There are total 94 households and 405 people in the village and all belong to the Pa-o ethnic group. The village is situated above 3 000 feet elevation above sea level. Most (80 percent) of the village members depend on agriculture and livestock rearing for their livelihoods. Agricultural season regularly starts with rainy season in May. There is only one cropping season in this village because of lack of water resources. Variability in the rainfall is the main climate change risk affecting the village. Heavy rainfall also led to soil erosion and degradation. Lack of rainfall is also becoming more frequent and severe in these days, and the onset of rainfall is becoming unstable which leads to shifting of the sowing time resulting to low yields and crop failures.

The household surveys also indicated interesting information about the nutrition and food security in the CSVs. One of the indicators used for nutrition and agriculture was the Household Diet Diversity

Table 3. List of Identified options for adaptation for the 2019 season

OPTIONS IDENTIFIED (technologies and practices)	
Farms	Homesteads/HH
SAKTA CSV (mountain highlands), Chin State	
Climate Change Effects: Heavier rainfall causing floods and landslides, Increased temperatures, Cooler winters, Stronger winds, Erratic rainfall patterns (longer monsoon), Food insecurity during non-production months, Crops losses (poor germination, low yields, crop death, pest and diseases), Animal losses due to diseases	
Diversifying upland rice varieties in the CSV	Vegetable gardening with RTB
Promotion of Tarpegu and Upland 2 rice varieties	Rearing pigs and chickens
PVS trials for other rice varieties	Pig/Chicken Propagation Centers
Seed production and banking for Tarpegu and Upland 2	
Diversifying varieties of millets and corn	
PVS Trials for millets and corn	
Seed production and banking of Yezin 1 and Ekary varieties	
Fish propagation in 'forest' ponds with fish propagation centers	
Integration cash crops such as EFY	
Promotion of Alnus nepalensis planting in farms	
HTEE PU CSV (dry zone), Mandalay Region	
Climate Change Effects	
Increasing variability of rainfall (some seasons very wet, some seasons very dry), Increasing temperature, Climate extreme events such as long dry season, Degradation of soil from lack of organic matter, soil erosion from rainfall and high temperatures, Pest and diseases, Delays in planting, Lower yields, Crop death, Animal diseases	
Promoting Climate-smart agronomic practices in farms	Vegetable gardening with fruit trees
Crop rotation	Rearing goats and chickens
Mulching	Bagan Goat and Chicken Propagation Centers
Cover cropping	
Integrated Pest Mgt	
Intercropping of pigeon pea, corn and groundnut	
Dryland horticulture	
Boundary planting of Cassia to improve soil organic matter and as wind breaks	
Revaluing millets and sorghum for other applications	
PVS Trials for millets	
PVS trials for sorghum	
Seed propagation for sorghum	
Seed propagation and banking for groundnut, pigeon pea, sorghum	
MA SEIN CSV (delta), Ayeyarwaddy Region	
Climate Change Effects	
Climate variability, some seasons have too much rain, some have less rains, increasing temperatures, Saline intrusion due to sea level rise, Climate extremes such as cyclones (deadliest was Cyclone Nargis, Crop losses due to flooding, Difficulty of drinking water, Low income	

OPTIONS IDENTIFIED (technologies and practices)	
Farms	Homesteads/HH
Organic matter improvement of rice farms using sun hemp, Gliricidia and Sesbania	Diversification of homestead-based low-input production of:
Diversifying rice varieties for flood tolerance and saline tolerance (PVS for Rice Varieties)	Betel leaves. Testing trichodarma+EM5 for fungus mgt
Coconut husk fiber processing (e.g. coco coir)	Duck rearing for eggs. Testing for locally grown feeds
	Fish production in backyard runnels
	Low input pig/chicken production with homestead fodder production (Tricanthera, RTBs)
	Homestead Fruit trees and pineapple
	Pig propagation center
	Fish propagation centers
TAUNG KHAMAUK (upland), Shan State	
Climate change effects	
Heavy rainfall, Longer monsoon season, too less rainfall, increasing variability of rainfall, Pests and diseases to crops, Low yield, Diseases in cattle and animals	
Improving access to climate-smart crop varieties	Homestead food production
PVS Trials for upland rice	Sweet corn and corn
PVS trials for groundnut	Vegetables
PVS for Millet	RTB
Crop trials for soybean, sunflower, wheat, Niger seeds	Fruit trees (e.g jackfruit)
Trials of soil management practices	Low-input chicken and pig production with alternative feed system
Integration of Gliricidia, sun hemp, lime and compost	Pig/Chicken propagation centers
Trials of water management practices	
Integration of avocado fruit trees in the farms	

Score developed by FANTA/USAID. In the 4 CSVs, it was found that there is good diversity in the diets of the villagers, scoring an average of 6 food groups out of the standard 12 food groups needed for a good diet. However, while this is a good score, we also learned that these food groups consumed are mostly cereals, oils and fats and vegetables. The least consumed food groups are white roots/tubers, milk and other fruits. The surveys also revealed that in those CSVs—agriculture production is mostly for selling in the markets except for Saktha in Chin state where production is mainly for home consumption.

3.3 Identification and selection of option for CSA

IIRR worked with the farmers and other members of the village to identify solutions to the challenges they identified. These solutions are referred as the options for CSA. As mentioned in the beginning, IIRR is trying to develop a portfolio or a menu of options to which farmers can choose.

IIRR developed and facilitated systematic and elaborated "participatory scoring tool" to identify and prioritize the identified options. At the beginning of this exercise a set of criteria was developed together with the villagers that includes whether it is ecologically sustainable, whether it is affordable, whether it responds to climate variability and whether it offers opportunities for women to engage. During the discussions, the participants in the CSV also identified key objectives in identifying the options. These objectives are:

- Minimize losses of primary crops due to climate risks (very wet, very dry, very cold, very hot, seasonal changes),
- Increase diversity of sources of income and food,
- Achieve security in access to food during non-production months, and
- Increase the contribution and participation of women to livelihoods and community development initiatives.

Several focus group discussions were conducted guided by the "participatory scoring tool" separate discussions for farmers and women were organized to ensure that what the CSV will identify are owned by both men and women in the CSV. Out of these processes in the CSV, these are the CSA options we identified per CSV:

3.4 Multi-location and participatory testing of options

As part of this research, IIRR has setup an adaptation fund which allocates a specific lump sum of funds available for the CSV. The purpose of this fund is to catalyze implementation of the options. Asking farmers to change technologies and practices in farming is difficult without any support and incentive to do so. The farmers in the CSV are one of the poorest in Myanmar and will not have sufficient assets and resources to do experimentation and trials. IIRR has received positive feedback from the CSV as it allows them to determine how the fund will be used in a way they think will help them effectively. In 2018 cropping season, the multi-location testing and trials of the adaptation options produced significant learning in terms of adaptation within the CSV. Some of those findings are:

Saktha CSV: The upland rice varieties developed and tested in the Aungban Research Station of DAR performed very well in highland conditions. Chin farmers want to cultivate more.

Saktha CSV: There is a big potential for upland aquaculture using seasonal ponds called "forest ponds". This offers co-benefits that include additional sources of income and food and at the same time harvest water for use during the dry months.

Htee Pu CSV: Farmers find integrating fruit trees (mostly seintalone mango) into farms as a climate-smart technique because fruit trees are more resistant to climate variability. There is also a developing resurgence and acceptance of sorghum production, a crop with fodder and food potential.

MaSein CSV: Homestead-level production offers great opportunities for diversifying from rice-based production system. Homestead production in the delta includes betel production, small livestock and aquaculture.

These lessons and findings were results from the 2017-2018 cropping season where farmers work with IIRR to test adaptation options.

3.5 Social learning via farmer to farmer approaches

In order to share the experiences and good practices derived from the testing, IIRR also facilitated to organize farmer field days in the CSVs. Farmer field days are leading to the emergence of farmer specialists in the CSV that has become a resource person for a specific crop/variety. Farmer field days also opened up opportunities for the villagers and the local NGO partners to engage with the local government extension offices to get technical support and to scale out the practices or options. During the field days, the villagers learned about the options for them in terms of:

Varieties of crops they have tested are suitable and performing well in their farms.

Challenges that farmers experienced during the testing of these options. These are also opportunities to innovate in the next season.

Potential support from other agencies including government to further support the initiative.

Aside from the farmer field days, IIRR also conducted a training course for local NGO partners working at the national level and at the regional/ state level. The goal of this training course is to raise their awareness as well as to provide them basic guidance and a framework to follow for them to design and implement their climate-smart villages project. This is one pathway of out-scaling CSVs in Myanmar being pursued by IIRR.

4. Conclusion

In this paper, IIRR echoed the same message that many authors concluded about the location-specificity of community-based adaptation. This is even more important in agriculture, where production depends on the agro-ecological context. This research seeks to demonstrate and test the different socio-technical methodologies in facilitating climate-smart villages in Myanmar as a platform that government and development organizations can adopt to promote climate resilience in agriculture in Myanmar. The initial findings have shown that by using socio-technical methodologies—active participation by farmers including women can be ensured in the process of adaptation. Additionally, effectiveness of CSA technologies and practices can also be ensured. These methodologies also allowed for initial out-scaling through awareness raising of key stakeholders in Myanmar. In the succeeding activities of the action research, IIRR will setup mechanisms for spontaneous horizontal exchanges. Moreover, IIRR will also strengthen the evidence-base of the CSVs to influence policies and programs leading to sustainability and wider uptake of climate resilience in agriculture in Myanmar.

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Factors influencing adoption of soil conservation practices in Hakha township, Chin State of Myanmar

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Abstract

The study attempted to determine the factors influencing adoption of soil conservation practices in Hakha Township, Chin State. The specific objectives of the study were to find out the socioeconomic status of farmers and their current farming system, to assess the extent of soil conservation practices and factors influencing on adoption of soil conservation practices; and to identify the limitations for adoption of soil conservation practices by farmers. The necessary data were collected from 110 respondents in which 68 adopters and 42 non-adopters from 5 villages in Hakha Township by using simple random sampling method through personal interview with a set of structured interview schedule. The Chin State and Hakha Township were purposively selected for the study. Thirteen explanatory variables were used for the probit regression model. Among them, family labor, farm income, degree of slope land and risk orientation behavior were positively influenced the adoption of soil conservation practices. Soil conservation practices such as terracing, constructing the contour bunds, crop residues management, intercropping with leguminous crops, practicing minimum tillage, leaving long fallow land period, growing hedgerows, windbreaks planting, mulching and composting were used by the adopters. A majority of adopters (61.8 percent) used terracing and crop residues management as soil conservation practices. But both adopters and non-adopters had some limitations for adopting the soil conservation practices. To overcome the limitationfor adoption of soil conservation practices, appropriate intervention should be practiced.

Keywords: *Adoption, soil conservation practices, Chin State, probit regression model, limitations*

1. Introduction

Land degradation in the form of soil erosion and nutrient loss is a crucial factor affecting farming productivity and agricultural development in the highlands. Due to torrential rain, hilly regions may suffer landslide and torrential waters from the mountain. Hurni (1986) stated that the high intensity of rains, intensive deforestation and improper agricultural practices, overgrazing, and demographic pressure on resources resulted in severe land degradation. Land resources have faced increasing land degradation due to soil erosion (FAO, 1986). Since 1945, land degradation has affected 1.2 billion hectares of agricultural land worldwide, and about 80 percent of this degradation has happened in developing countries (Hailu, 2008). The undulating land composed mainly of sandy loam with low fertility is exposed to severe erosion under the rain and strong winds (UNDP, 2011). The induced soil erosion problem is one of the major threats in ensuring food security. Soil erosion is the most serious in the hills. The main causes of soil loss are due to the cultivation on the steep and unprotected slopes; overgrazing and unselective felling of forest trees.

Soil conservation practices play a very important role for sustainable agriculture in conserving the water resources and the maintenance of a stable ecosystem. Farouque and Tekeya (2008) stated that soil fertility improvement and conservation practices will be a beneficial approach to improve crop yield and preserve soil fertility over the long term. The transfer of technology through agricultural extension about crop farming practices, appropriate cropping patterns, the supply and proper use of agricultural inputs, and the systematic practices of plant

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protection included the improved soil conservation practices are being undertaken. The uptake of sustainable soil management technologies depended on the households' adaptive economic capacity. Ervin (1982) affirmed that farmers' perception positively affected the adoption and effort of soil conservation.

Soil erosion is one of the major problems in ensuring the food security of Chin State because the soil is very soft and vulnerable to erosion. In addition, 80 percent of farming are under shifting cultivation (Thein, 2012). It has resulted in the loss of soil, nutrient depletion, which leads to land degradation. Taungya farmers reduced their fallow land periods for their subsistent living that create a very high rate of deforestation and soil erosion. This, in turn, results in low productivity of agriculture, food insecurity and poverty. Moreover, shifting cultivation release greenhouse gases such as carbon dioxide and also gives a negative impact on climate change. FAO (n.d) described that the main negative impact on climate change is the green house gases that emanate directly and indirectly due to the burning of non-renewable resourses (carbon bound in mineral oil or coal). Nowadays, the present agricultural policy of the Ministry of Agriculture, Livestock, and Irrigation (MOALI) is focusing on increasing production and productivity and promoting sustainable and climate-smart agriculture. Thus, farmers need to manage soil fertility degradation by developing alternative strategies that include physical measures, biological measures, and other effective approaches. Shifting cultivation should consider the most ecologically effective approach such as slash & mulch instead of slash & burn and appropriate traditional & improved management practices such as terracing, constructing the contour bunds, crop residues management, mulching and growing the cover crops, etc. If available alternative appropriate or improved farming practices used correctly, the present productivity level and income can be considerably increased or doubled which can then lead to increased soil fertility for sustainable agriculture in Chin State. Therefore, the study was conducted to understand thefactors influencing adoption of soil conservation practices in Hakha Township, Chin State. The specific objectives of the study were:

(1) To find out the socioeconomic status of farmers and their current farming system,

(2) To assess the extent of soil conservation practices and factors influencing on adoption of soil conservation practices between adopters and non-adopters, and

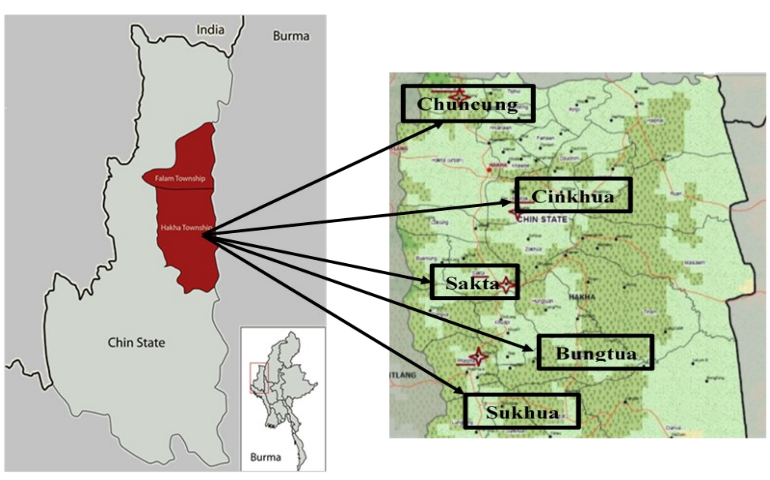
(3) To identify the limitations for adoption of soil conservation practices by farmers

2. Research methodology

2.1 Description of the study area

Hakha, the capital of Chin State, is situated in the Northern Chin State and has 30 village tracts. The total area of Hakha Township is about 12.50 square miles (4 281 km2). It has a population of about 48 352. Hakha has very steep mountains and hills that form continuous ridges with

Figure 1. Map of the Study Area



very narrow valleys and vegetation, and their mountain has altitude ranging from 3 000 to 8 000 feet. It is located at 6 125 feet above sea level. The sad story of landslides had happened in the Hakha Township in 2015.

2.2 Method of data collection and analysis

The Chin State and Hakha Township of Myanmar were purposively selected for the study. Both primary and secondary data were used for this study. A total sample household of 110 included 68 adopters and 42 non-adopters from five purposely and randomly selected villages of Cinkhua, Chuncung, Sukhua, Sakta and Bungtuah for the study. An adopter was determined if a farmer had adopted at least one kind of any strategy of soil conservation practices such as terracing, constructing the contour bunds, windbreaks planting, crop residues management, intercropping with leguminous crop, practicing minimum tillage, leaving long fallow land period, growing the hedgerows, mulching and composting. If not, the farmer was considered to be a non-adopter. Secondary data were gathered from village level government and published and official records of the Department of Agriculture, NGOs and INGOs in Chin State. Compared mean statistics and paired-sampled t-test, descriptive statistics, and chi-square tests were used to describe the distribution of socio-economic characteristics, farm and institutional characteristics, and farmer's perception and attitude towards soil conservation practices and shifting cultivation. Farmer's perception and attitude were computed by index using a set of questionnaires based on their knowledge as follows:

Perception / Attitude Index =(Sum of Scores - minimum possible score) / Difference between maximum and minimum possible score

(Hubert and Schultz, 1976)

The scoring system by the orientation of the statement measured by the agreement statement such as agree, undecided and disagree with a 3-point Likert scale. According to Moulik and Rao (1973); and Ningareddy (2005), it was scored 3, 2, 1 for positive statements and 1, 2, 3 for negative statements. Three different ranges of indices were categorized by frequency distribution as high (0.70 to 1.00), medium (0.35 to 0.69) and low (0.00 to 0.34) level. The higher index describes more affirmation on perception and a more favorable attitude towards the soil conservation practices and shifting cultivation by farmers. The probit regression analysis was used to describe the factors influencing on the adoption of soil conservation practices as follows:

$$Yi = \beta0 + \beta1X1 + \beta2X2 + \beta3X3 + \ldots + \beta11X11 + b1D1i + b2D2i + \varepsilon i$$

Where; Yi = Adoption (1 = if any strategy of SC practices was adopted, 0 = if otherwise)

β0 = intercept, X1= Age, X2= Education, X3 = Family labour, X4 = Total cultivated land size (Ac),

X5= Annual farm income (MMK), X6 = Farm distance from home (Min), X7 = Degree of slope land, X8 = Index for perceived usefulness of soil conservation practices, X9 = Index for ease of usefulness of soil conservation practices, X10= Risk orientation index, X11= Economic orientation index, D1i = Access to training for soil conservation practices, D2i = Access to credit, Ɛi = Error term

3. Results and discussion

3.1 Characteristics of household heads

The data related to the characteristics of the household heads in the study area are shown in Table 1. Among demographic characteristics, age is one of the most important factors in the decision-making for adopting a technology or an innovation. The average age of adopters was 53.29 years old, and that of non-adopters was 48.21 years old. An average age of adopters and non-adopters were statistically different at 10 percent level. In this study, the farmers were categorized into young (up to 35 years), medium (36-50 years) and old age of farmers (above 50 years). Among them, the majority of farmers were in the age group of medium, and old age. The result found that the majority of adopters were older farmers. This could be expected that older farmers used soil conservation practices because they had more experience about their farm conditions and in resource management that would make them more willing to adopt soil conservation practices.

The level of education of the farmers is also important for the decision-making of the adoption of conservation technology. The adopters' average

Table 1. Characteristics of household heads in the study area

Items	Adopters (n = 68)	Non-adopters (n = 42)	t-test	Significant level (2-tailed)
Age of household head (Year)	53.29	48.21	1.922*	0.057
Up to 35 (Young)	6 (8.80)	8 (19.00)		
36-50 (Medium)	22 (32.40)	17 (40.50)		
Above 50 (Old)	40 (58.8)	17 (40.50)		
Education (schooling year)	6.69	5.45	1.858*	0.066
Illiterate (0)	8 (11.80)	6 (14.30)		
Primary (1-6)	25 (36.80)	23 (54.80)		
Middle School (7-9)	17 (25.00)	9 (21.40)		
High School (10-11)	17 (25.00)	3 (7.10)		
Graduate (>11)	1 (1.50)	1 (2.40)		
Farming experience	27.22	24.07	1.097 ns	0.275

Note: * Significant at 10 percent level. ns not significant. Value in parentheses indicates percentage.

schooling years was 6.69 years while for non-adopters' the average schooling years was 5.45 years. The difference between the average schooling years of adopters and non-adopters was significantly different at the 10 percent level. The majority of adopters and non-adopters found to have primary, middle and high school education level, but 11.8 and 14.3 percent of the adopter and non-adopter farmers respectively were illiterate. The results of significant illiteracy percent reflected the high rate of illiteracy in the study area.

The farming experience is the number of years that the farmers practiced in farming as a mean of living. An average farming experience of adopters was 27.22 years, and that of non-adopters was 24.07 years. The results found that the difference between the average farming experience of adopters and non-adopters was not statistically different in the study area.

3.2 Socioeconomic characteristics of households

The socioeconomic characteristics of households are shown in Table 2. Family size would affect the amount of labor available for farm activities, household activities, and demand for food. The average number of family members for adopters was 5.39 persons while those for the non-adopters w as 4.98 persons. The family size ranged between 1 and 12. The family size was categorized into small (1-3 persons), medium (4-6 persons), and large family (7-12 persons). The average number of family members was not significantly different between the adopter and non-adopter categories. The results showed that the majority of households had medium and large families.

The availability of family labor plays a major role in the influential adoption and extent of use of soil conservation technologies. The number of family labor in adopter households had a mean of 3.35, while non-adopters had a mean of 2.40. The difference between the average number of family labors by adopters and nonadopters households was significantly different at the 1 percent level. The results revealed that adopters had more family labors than non-adopters.

Total cultivated land holding by adopters was an average of 2.17 acres, while those for non-adopters was an average of 1.76 acres. The average acre of cultivated land of adopters and non-adopters was not significantly different from each other. The majority of farmers occupied below 1.28 acres of land (small size landholding). According to this result, most of the farmers usually owned small size cultivated landholding that would be at least 0.5 acre.

3.3. Income of households in the study area

The income source of rural households was composed of different income-generating activities

Table 2. Socioeconomic characteristics of households in the study area

Items	Adopters (n = 68)	Non-adopters (n = 42)	t-test	Significant level (2- tailed)
Family size (no.)	**5.39**	**4.98**	**1.016** ^{ns}	**0.312**
1-3 (Small)	12 (17.6)	5 (11.9)		
4 – 6 (Medium)	37 (54.4)	31 (73.8)		
7- 12 (Large)	19 (27.9)	6 (14.3)		
Family labor (no.)	**3.35**	**2.40**	**4.335** ***	**0.000**
Total cultivated land (acre)	**2.17**	**1.76**	**1.431** ^{ns}	**0.155**
0.5-1.28	28 (41.2)	20 (47.6)		
1.28-2.75	20 (29.4)	14 (33.3)		
> 2.75	20 (29.4)	8 (19.0)		

Note: *** Significant at 1 percent level. ns: not significant. Value in parentheses indicates percentage.

(Figures 2 (a) and 2 (b)). Farm income was considered as the most important from the sale of crops and livestocks. Non-farm income involved non-farm wages, salaries, pensions, and interest received by farm families. Off-farm income obtained from wages from working on other farms. A remittance was a transfer of money from a person working outside the country or internationally. If the households' income was decomposed, the major income of adopters and non-adopters obtained from farming, i.e., 64 percent of total income in adopters, and 68 percent of total income in non-adopters were farm incomes.

3.4. Farming system in the study area

Farming is mainly practiced on steep, high-altitude and cool monsoon forest areas because the villages were located in the hilly region. Traditional livelihoods are rooted in agriculture; usually, paddy, maize, and elephant foot yam, upland shifting cultivation (taung-yar) or mobile farming, raising fowls and livestock. Other crops grown were cabbage, cauliflower, mustard, onion, garlic, potatoes, sweet potatoes, banana, grape, chili, ginger, cowpea, yard-long bean, green gram, pigeon pea, millet and radish. Some farmers had an orchard with bananas, avocados, grapes, and so on. The majority of farmers grow rice, maize for home consumption, but those with larger holdings, some may sell. The other crops were elephant foot yam, millet, pulses, some vegetables, and culinary crops that are grown either in-home garden or in the taung-yar field. Today elephant foot yam has become popular and are grown in commercial scale. The growing seasons were in the winter and rainy season.

3.5 Extent of soil conservation practices by adopters in the study area

A total of 52.5 percent of adopters used terracing as a soil conservation practice, which was followed by crop residue management (48.5 percent), composting (16.2 percent), having long fallow land period (14.7 percent), intercropping with pulses (8.8 percent), practicing minimum tillage (8.8 percent), contour bund construction (7.4 percent), windbreaks planting (5.9 percent), mulching (5.9 percent) and hedgerow planting (4.4 percent) (Table 3). The majority of adopter farmers used terracing and crop residues management on their farms.

3.6 Farm characteristics in the study area

Farm characteristics are presented in Table 4. The average acre of eroded farms and average farm distance were not significantly different between adopters and non-adopters. The farm distance from home was an average of 45.00 minutes for adopters, whereas those of non-adopters was 41.1 minutes by walking.

Soil fertility level of the farm in the study area was categorized into very fertile, fertile, moderate and poor soil according to respondents' expertise judgment and response. Adopters' lands were classified as very fertile soil (7.4 percent), fertile soil (30.9 percent), moderately fertile soil (51.5 percent) and poor soil (10.3 percent) while farm plots of non-adopter were classified as

Figure 2 (a). Income decomposition of adopters (n=68)

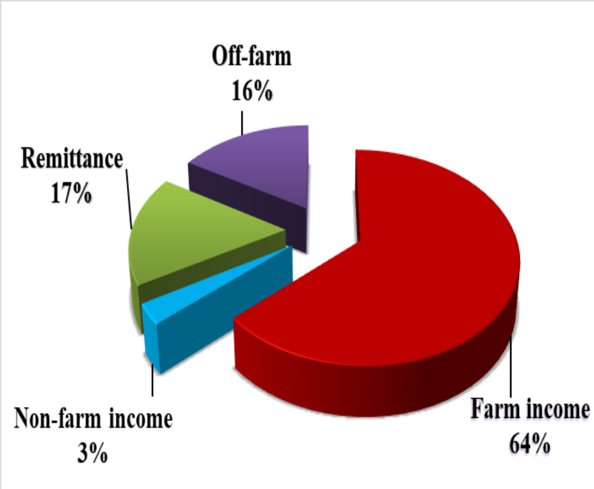


Figure 2 (b). Income decomposition of non-adopters (n=42)

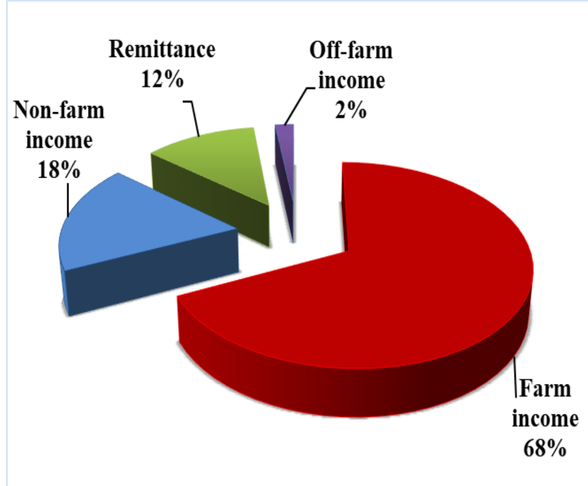


Table 3. Soil conservation practices done by adopters in the study area

No.	Items	Frequency	Percentage	Rank
1	Terracing	36	52.9	1st
2	Crop residues management	33	48.5	2nd
3	Composting	11	16.2	3rd
4	Long fallow land period	10	14.7	4th
5	Intercropping with pulses	6	8.8	5h
6	Minimum tillage	6	8.8	5th
7	Contour bunds construction	5	7.4	6th
8	Windbreaks planting	4	5.9	7th
9	Mulching	4	5.9	7th
10	Hedgerow	3	4.4	8th

Table 4. Farm characteristics in the study area

Items	Adopters (n=68)	Non-adopters (n=42)	T-test	Significant level (2- tailed)
Farm distance (minutes by walking)	45.00	41.10	0.518^{ns}	0.606
Degraded land (ac)	0.28	0.31	0.394^{ns}	0.694
Fertility level				
Very fertile	5 (7.4)	2 (4.8)		
Fertile	21 (30.9)	9 (21.4)		
Moderate	35 (51.5)	25 (59.5)		
Poor	7 (10.3)	6 (14.3)		
Slope condition				
Steep/mountain (>30⁰)	30 (44.1)	10 (23.8)		
Gentle (10-30⁰)	32 (47.1)	28 (66.7)		
Flat (6-9⁰)	6 (8.8)	4 (9.5)		

Note: ^{ns} is not significant. Value in parentheses indicates percentage.

very fertile soil (4.8 percent), fertile soil (21.4 percent), moderately fertile soil (59.5 percent) and poor soil (14.3 percent) in their field respectively.

The slope of farm plots in this study area was categorized into steep/mountain, gentle, and flat according to its topography, and respondents' expert judgment and responses. Adopters occupied steep/ mountain land (44.1 percent), gentle land (47.1 percent), and flat land (8.8 percent) while non-adopters occupied steep/mountain land (23.8 percent), gentle land (66.7 percent) and flat land (9.5 percent), respectively. The result found that the majority of adopters occupied steep land than non-adopters. According to this result, this might be farmers who cultivate on the steep slope fields adopted conservation practices to control soil loss.

3.7 Farmer's attitude toward shifting cultivation in the study area

Farmers' attitude toward shifting cultivation was measured by 10 statements in a 3-point Likert scale as indicated in Table 5. Figure 3 reveales the attitude level towards shifting cultivation by farmers from 10 statements, which were 30.9 percent of adopters as more favorable attitude, favorable (47.1 percent) and less (22.1 percent) favorable attitude towards shifting cultivation while non-adopters had more favorable (35.7 percent), favorable (33.3 percent) and less (31 percent) favorable attitude towards shifting cultivation. The results showed that adopter farmers had more knowledge about the shifting cultivation that it caused climate change and land degradation than non-adopters.

3.8 Farmer's attitude towards soil conservation practices in the study area

Farmers' attitudes towards soil conservation practices measured by a 3-point Likert scale in 11 statements (Table 6). The results in Figure 4 is the summary of the attitude level towards soil conservation practices from 11 statements, that 47.1 percent of adopters had a more favorable attitude towards soil conservation practices, followed by a favorable attitude (32.4 percent) and less (20.6 percent) favorable attitude towards soil conservation practices while non-adopters had a more favorable (35.7 percent), favorable (28.6 percent) and less (35.7 percent) favorable attitude towards soil conservation practices. According to this result, adopters had a more favorable attitude towards soil conservation practices than non-adopters because they knew that wheather the soil conservation practices are easy or not there aresome benefits to the crop production.

3.9 Perceived usefulness of soil conservation practices by farmers

Farmer's perception of the usefulness of soil conservation practices in the study area was measured by a 3-point Likert scale in 8 statements (Table 7). The result in the Figure 5 demonstrates the summary of index for perceived usefulness from 8 statements, among which 89.7 percent of adopters had a high affirmation, followed by medium (10.3 percent) affirmation on perception of usefulness of soil conservation practices while non-adopters had high (83.3 percent), medium (14.3 percent) and low (2.4 percent) affirmation on usefulness of

Table 5. Farmer's attitude towards shifting cultivation in the study area

Items	Mean
1. Due to slash and burn, shifting cultivation release CO_2 and soil fertility degradation.	2.46
2. Yield decline due to shorten fallow period.	2.48
3. It is difficult to change alternative practices.	2.44
4. It leads to occur heavily soil degradation.	2.51
5. It is easy to practices.	2.04
6. It is labor consuming.	2.45
7. It is not eco-friendly.	2.32
8. It does not support sustainable agriculture.	2.61
9. It should change to alternative practices for development of farming system.	2.68
10. It may cause negative impact on climate change.	2.63

Figure 3. Attitude towards shifting cultivation of farmers in the study area

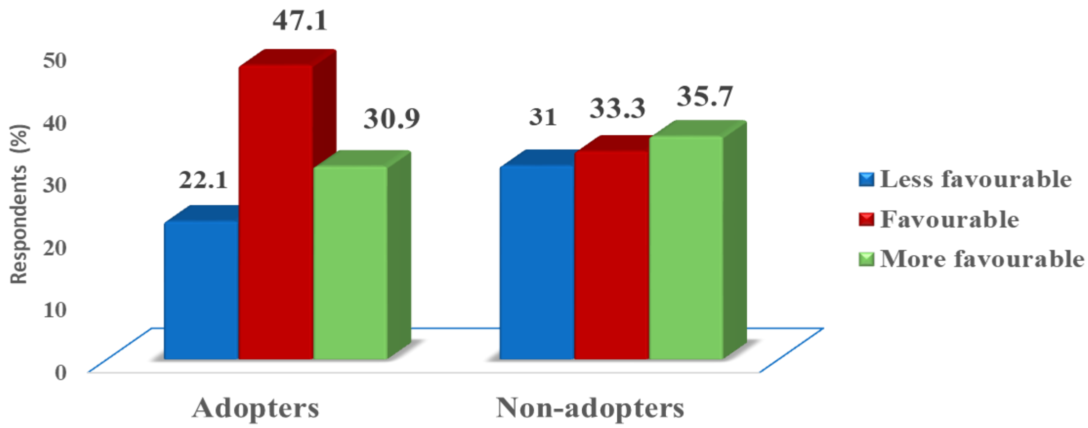


Table 6. Farmer's attitude towards soil conservation practices in the study area

Items	Mean
1. Soil conservation practices should be used for farmers in hilly region.	2.77
2. It is an accepted fact that it reduces soil degradation.	2.80
3. It helps to conserve soil erosion.	2.82
4.It may improve soil fertility	2.75
5. It increases yield and production over shifting cultivation	2.61
6. It is not effective technology for soil conservation.	2.39
7. It may improve economic benefits for farmers.	2.72
8. It is cost effective for farmers.	4.45
9. They are eco-friendly.	2.66
10. It can be economically unviable and socially unacceptable.	2.31
11. It is not workable in a relatively short time	2.70

Figure 4. Attitude towards soil conservation practices by farmers in the study area

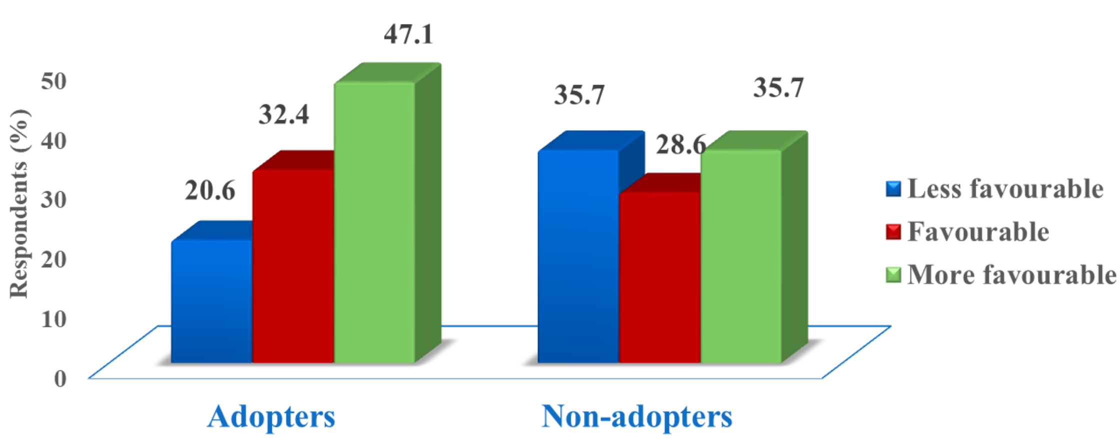
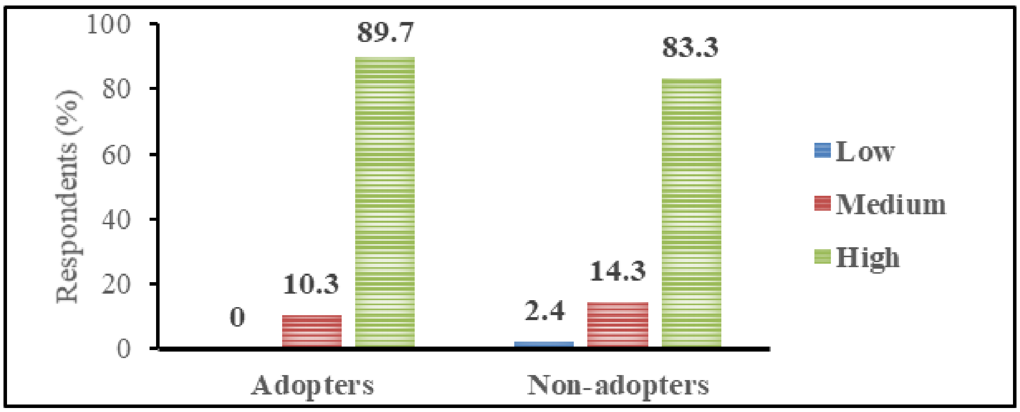


Table 7. Perceive of usefulness in soil conservation practices by farmers

Items	Mean
1. Soil conservation practices protect the soil erosion.	2.77
2. It will enhance effectiveness in farming.	2.82
3. In steep land, terrace farming will useful in soil conservation,	2.74
4. It will reduce soil degradation.	2.80
5. Overall, it will be useful for improving soil fertility.	2.79
6. It will increase the productivity.	2.72
7. Intercropping nitrogen fixing leguminous crops will increase soil fertility.	2.57
8. Using soil conservation practices is advantageous for farming in long term.	2.80

Figure 5. Perception of usefulness in soil conservation practices by farmers



soil conservation practices in their farming, respectively. The results revealed that the majority of the adopter and non-adopter farmers knew the usefulness of soil conservation practices in their farming.

3.10 Perceived ease of use of soil conservation practices by farmers

The data presented in Table 8 describes the perceived ease of use of the soil conservation practices by farmers that was measured by the 3-point Likert scale in 7 statements. The index for perceived ease of use of soil conservation practices from these 7 statements has been presented in Figure 6, which were 52.9 percent of adopters as high affirmation, followed by medium (17.6 percent) and low (29.4 percent) affirmation on perception of ease of using the soil conservation practices while non-adopters had high (28.6 percent), medium (26.2 percent) and low (45.2 percent) affirmation on ease of use of soil conservation practices in their farming respectively. The result found that the most of the non-adopters perceived that the soil conservation practices are not easy to adopt.

3.11 Risk orientation by farmers in the study area

Table 9 described that the risk orientation of farmers was measured by 6 statements using the 3-point Likert scale. The result in Figure 7 revealed that risk orientation index from these 6 statements, which were 79.4 percent of adopters as high-risk takers, medium (19.1 percent) and low (1.5 percent) risk orientation while 38.1 percent of non-adopters had high risk-taking, medium (42.9 percent) and low (19 percent) risk-taking attitude, respectively. Risk orientation favored decision making to adopt soil conservation technologies. Thus, the results found that adopter farmers had high- risk orientation than non-adopters who had risk aversion.

Table 8. Perceived ease of use of soil conservation practices by farmers in the study area

Items	Mean
1.It can be easy to learn soil conservation practices	2.26
2. Intervention soil conservation practices are clear and understandable.	2.26
3. It is easy to soil conservation operating procedures	2.04
4. I would find, soil conservation practices are easy to use in farming.	1.97
5. It is easy to do what I want soil conservation practices to do.	2.01
6. It is easy to plow along contour line.	1.95
7. In the contour hedgerow, it is easy to grow leguminous crop.	2.30

Figure 6. Perception for ease of using the soil conservation practices by farmers

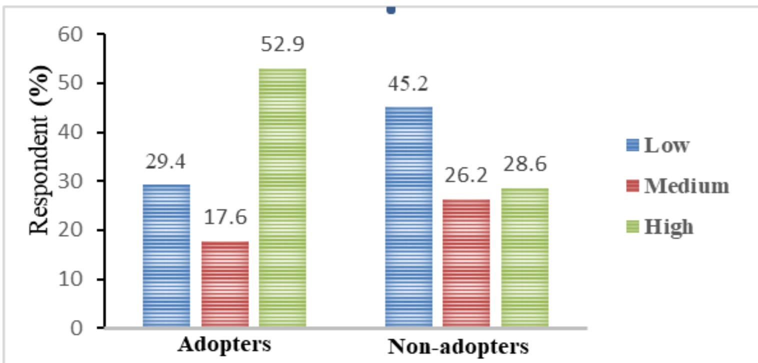


Table 9. Risk orientation of farmers in the study area

Items	Mean
1. I am trying an entirely new practice in farming involve worthy risk.	2.67
2. Soil conservation practices reduce risk due to cost effectiveness.	2.42
3. I am willing to make big profit by taking risk.	2.81
4. I want to take risk by using soil conservation practices.	2.58
5. Taking less risk is saving but less profit.	2.57
6. It should not to try new farming methods without success most of other farmers	1.69

Figure 7. Risk orientations of farmers in the study area

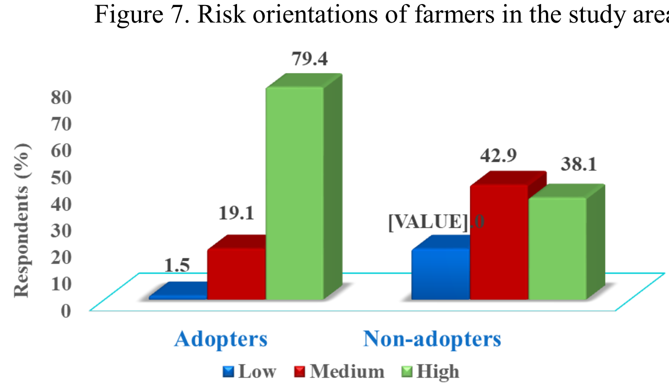
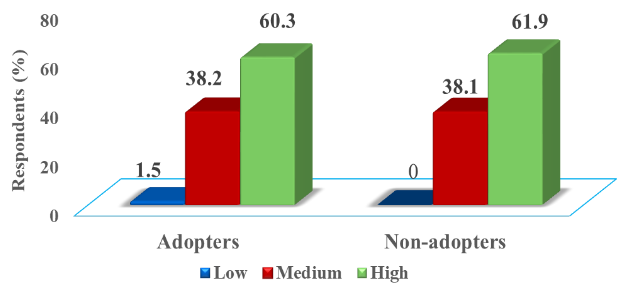


Table 10. Economic motivation of farmers in the study area

Items	Mean
1. I would like to work for larger yield and economic profit.	2.88
2. I need a reasonable amount of profit.	2.92
3. I try new methods to increase profit than old cultivation methods.	2.63
4.I would try new methods to increase monitory profit than old cultivation methods.	1.36
5.I don't hesitate to borrow money for purchasing new farm implement.	2.46
6. I hate to borrow money even when it is necessary for purchasing new farm implement.	2.46
7. I avoid excessive borrowing of money for investment in developing soil and water conservation structure.	1.73
8. The main aim is maximizing profit using soil conservation practices than old practices.	2.66

Figure 8. Economic motivations of farmers in study area



3.12 Economic motivation of farmers in the study area

Farmers' economic motivation was measured by 8 statements using the 3-point Likert scale (Table 10). Figure 8 described the economic motivation index from these 8 statements, in which 60.3 percent of adopters had high, followed by medium (38.2 percent) and low (1.5 percent) economic motivation while non-adopters had high (61.9 percent) and medium (38.1 percent) economic motivation, respectively. According to the results, both adopters and non-adopters had an economic motivation. Thus, economic motivation could not provide sufficient conditions for the adoption of soil and water conservation technologies at the farm-level.

3.13 Institutional services in the study area

Adopters obtained more institutional services such as received credit, being a beneficiary participant of any organization, having exposure to any extension services than the non-adopters. But both adopters and non-adopters obtained the least subsidy for soil conservation from any organization, and soil conservation training (Table 11).

3.14 Constraints for soil conservation practices faced by farmers

The most common constraints faced by farmers for adopting soil conservation practices were a high cost of the technology, not having enough investment, requirement of a huge amount of labor, receiving less of soil conservation training, having less exposure to extension agents, and no motivation for learning soil conservation practices.

3.15 Factors influencing adoption of soil conservation practices in the study area

The results of empirical probit models described the tendency to adopt soil conservation practices by households (Table 12). The results showed that age, education, number of family labor, farm income, degree of slope land, perceived ease of using soil

Table 11. Institutional services in the study area

Items	Adopters (n = 68)	Non-adopters (n = 42)	Pearson χ^2
1. Received Credit	34 (50)	11 (26.2)	6.089^{**}
2. Being a participant of any organization	37 (54.4)	16 (38.1)	2.769^{*}
3. Having exposure to any extension services	41 (60.3)	25 (59.5)	0.006^{ns}
4. Received subsidy for soil conservation from any organization	10 (14.7)	9 (21.4)	0.821^{ns}
5. Attended soil conservation trainings	17 (25)	11 (26.2)	0.019^{ns}

Note: **, * are significant at 5 percent and 10 percent level and ns is not significant. Value in parentheses indicates

Table 12. Factors influencing farmers' adoption of soil conservation practices

Items	Coef.	Std. Err	P-value	Marginal effect
Age	0.0096^{ns}	0.0127	0.447	0.0031
Education	0.0079^{ns}	0.0565	0.889	0.0076
Family labour	0.6597^{***}	0.2145	0.002	0.1322
Farm income	0.4562^{*}	0.2451	0.063	0.0977
Total cultivated land size	$- 0.0664^{ns}$	0.1974	0.736	- 0.0306
Farm distance	$- 0.0050^{ns}$	0.0057	0.376	- 0.0000
Degree of slope land	0.0306^{**}	0.0156	0.049	0.0054
Index for ease of using conservation practices	0.6393^{ns}	0.6712	0.341	0.1022
Index for perceived usefulness conservation practices	-1.8857^{ns}	1.1660	0.106	- 0.2712
Economic motivation index	-2.1455^{ns}	1.7606	0.223	- 0.4216
Risk orientation index	5.4139^{***}	1.4342	0.000	1.0457
Access to training of soil conservation	0.7936^{ns}	0.5222	0.129	0.0982
Access to credit	0.5009^{ns}	0.3828	0.191	0.1528

Log likelihood = -38.00, LR $chi^2 = 70.27^{***}$, Prob $>chi^2 = 0.0000$, Pseudo $R^2 = 0.4803$

Note: ***, **, * are significant at 1 percent, 5 percent, 10 percent level. ns is not significant.

conservation practices, risk orientation and access to soil conservation training and access to credit were positively correlated with the adoption of soil conservation practices, while total cultivated land size, farm distance, perceived usefulness of soil conservation practices and economic motivation were negatively correlated with the adoption of soil conservation practices.

Among the different variables, the adoption of soil conservation practices had positively and significantly influenced by the number of family labors at the 1 percent level. Some of the soil conservation practices were relatively labor intensive. The result was plausible that the family members in households who had the appropriate number of labor available for farming would have more probability to adopt soil conservation practices.

Farm income of households was found to have a positive and statistically significant influence on the adoption of soil conservation practices at the 10 percent level. This might be because of the fact that the farmers who had got more farm income would use their extra income in soil conservation practices in farming.

The degree of slope of land had a positive and significant influence on the adoption of soil conservation practices at the 5 percent level of significance. This result was consistent with the topography of the hilly region in the study area.

Attitude towards risk orientation by the farmers was found to have a positive relationship with the adoption of soil conservation, which was statistically significant at the 1 percent level. The result revealed that farmers who had a high attitude towards risk orientation might adopt soil conservation practices compared to others.

Total cultivated land holding had negatively correlated with the adoption of soil conservation practices. Thus, the farmers who properly owned large areas needed to be encouraged for adoption of soil conservation practices. Institutional services such as access to credit and training of soil conservation were important factors for the adoption of soil conservation techniques, although these factors did not significantly affect the adoption of soil conservation practices in the study area.

4. Conclusion

Among the farmers, the majority of the respondents relied on upland farming and had a small farm size. The study revealed that 61.8 percent of adopters and 38.2 percent of non-adopters observed to be involved in the adoption of soil conservation practices. The majority of adopters used terracing and crop residues management but the adoption of other practices such as composting, leaving long fallow periods, intercropping with leguminous crops, minimum tillage, constructing contour bands, windbreaks planting, mulching and growing the hedgerows was still weak. But both adopters and non-adopters had some limitations for the adoption of soil conservation practices. To overcome the limitations for adopting soil conservation practices, the appropriate intervention should be implemented. For the major constraints using soil conservation practices in this area, the study findings indicated that extension and other related services from government and non-government institutions such as training of soil conservation and education program, credits availability, and participation of farmer organizations at farm level are the limiting factors and need to be improved in order to increase the adoption rate of soil conservation technologies. Learning of farmers from each other are also very important to improve the adoption of new technologies.

Throughout the region, an attitude towards the shifting cultivation was pointed out to be the negative perception or impacts on the forest and low crop productivity. However, as their traditional practices could not be ceased, some most ecologically effective approaches such as slash and mulch instead of slash and burn, and other conservation practices should be promoted. Therefore, education and training, and extension services programs for soil conservation should be initiated by the government in collaboration with private sectors.

Although the intensity of technology adoption is generally reasonably high, there were farmers who used the technologies on a small scale. From the foregoing, it can be concluded that more effort is needed to ensure that all farmers begin to use soil erosion control technologies on a full scale. Farmers must be convinced and given a strong incentive to adopt conservation practices for the long-term productivity and sustainability of their farms. Income earned from crop production would be the main incentive for technology adoption and it should be noticed by extension institutions for the technology dissemination. Moreover, crop insurance should be initiated for farmers and the risk management system should be promoted among the farmers.

Adopter farmers knew about the shifting cultivation that harms the enviornment, but some non-adopters had poor knowledge about it. Therefore, a close understanding of land management practices is crucial to reduce soil erosion problems and to create sustainable soil conservation practices. Moreover, understanding of personal, socioeconomic, institutional, and biophysical factors should be considered to the design of appropriate strategies to achieve technical changes in the process of soil and water conservation in the study area and other similar areas of the region.

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Changes of rice production system in Central Dry Zone of Myanmar: A case study in Meiktila township

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Abstract

The Central Dry Zone comprises of about 22 percent of the total rice production of Myanmar. Drought is the most severe hazard amplified by climate change, since it causes scarcity of food and drinking water for human and cattle, changing cropping patterns, declining crop yield and losses in their livelihoods. The objective of this study was to investigate the changes in rice production system between 2000 and 2018 in Meiktila Township. This study was conducted in four village tracts of Meiktila Township during June-September, 2018. A total of 160 respondents were selected by using purposive random sampling method. The primary data were demographic characteristics and changes of cultural practices in rice production and secondary data were climate data, rice sown area and rice production. Due to the water uncertainty, total farm size and rice growing areas of respondents were decreased between 2000 and 2018 and number of small holders was increased in study area. But some respondents changed to practice double crop (rice-rice) from mono crop due to availability of irrigation water in some areas starting from 2015. In 2000, the respondents used animal drawn implements for land preparation, manual harvesting and threshing in wet season. In 2018, it changed to mechanization because they want to finish in time. As a results of the extension activitieschanging of traditional varieties to improved varieties (certified seed), more use of N, P, K fertilizers were found in 2018. Rice yield was increased to 3.3 ton per ha in 2018 from 2.3 ton per ha in 2000 in the study area. Similar trend was observed in dry season rice. In the study area, water was the most limiting factor for improvement in rice productivity.

Keywords: rice, changes of rice production system, water uncertainty, Central Dry Zone

1. Introduction

Myanmar has one of the highest rankings in the 2017 global climate risk index (Eckstein, Künzel & Schäfer, 2017). While total precipitation has changed little from 1990, the rainy season has shortened due to late onset and early withdrawal of the southwest monsoon, causing intense rainfall and flooding. Increasing temperatures, shallow soils, a long dry season, the increasing frequency of severe droughts, and poor crop husbandry are adding substantial risk to agriculture. Climate change projections to 2050 suggests Myanmar will experience longer dry spells and periods of heavy rains. Policy reforms undertaken since 2011 have enhanced the potential for growth in the agricultural sector (Raitzer, Wong & Samson, 2015). Global climate change is well evident not only in the delta, affected by Cyclone Nargis, but also in the central dry zone. In some areas, the onset of monsoon was later than usual and precipitation pattern has also changed causing extreme weather phenomenon.

The Central Dry Zone (CDZ) has 15.4 million inhabitants, most of whom (76 percent) live in rural areas; 58 percent of CDZ households depend on crops for their livelihoods (The European Chamber of Commerce in Myanmar, 2017). Crop production accounts for 72 percent of farm outputs. As a percentage of national production, the CDZ produces 25 percent of rice, 48 percent of pulses, and 89 percent of sesame. Low usage and quality of certified seed and agro-chemicals, limited irrigation, and poor quality and safety of farm products also contribute to low sector performance. Less than 5 percent of rice farmers in the CDZ use certified seed,

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while pulse and oilseed farmers use almost none. Private seed providers have been unable to produce enough to meet demand because of the poor business environment. Only 15 percent of crop area is irrigated, and more than 50 percent of the rural population lacks access to all-season roads, hindering farm-to-market connectivity. Credit (which is often unavailable) is of short tenure, and given only to land owners. Increased migration to urban areas and neighboring countries is worsening labor shortages. Farm mechanization is limited. Inefficient post-harvest operations such as drying are leading to reduced quality, and poor returns to farmers and processors.

Most exported crops of Myanmar are unprocessed and sold to lower-value markets. Private sector investment in agribusiness is limited because of the poor enabling policy environment related to land use and administration (Global Agriculture and Food Security Program, 2016). In Central Dry Zone, Meiktila Plain, of which agricultural production totally relies on water supply from small dams and tank irrigation for successful harvest and the impact of climate change is relatively severe. Although small dams and tanks could provide enough irrigation water for crop establishment, irrigation for the whole cropping season is not assured (Kyi, 2016). The dominant features of the Dry Zone regions include erratic rainfall, sandy soils with low fertility and low water-holding capacity, and high temperatures. Since the region chronically receives a low rainfall compared to the other parts of Myanmar, local people meet unstable livelihoods with little prospect of increasing agricultural production. It is said that most of the small holders have employed practices designed to optimize productivity in the long term rather than to maximize it in the short term (Glissman, Gracia & Amador, 1981). In order to achieve the optimized sustainable agricultural production, it is indispensable to evaluate the local agricultural resources and past and present farming systems. Therefore, survey and exploration had been made to investigate the changes of rice production system between 2000 and 2018 in Meiktila Township.

2. Research methodology

2.1. General description of the study area

Meiktila Township is situated in the Central Basin of Myanmar. It lies between North latitudes 20° 40' and 21° 00' and East longitudes 95° 30' and 96° 01'. It is one of the thirty townships of Mandalay Region. It is composed of 58 village tracts. Total population of the township was 309,663 including 111,522 and 198,141 are urban and rural population, respectively (Myanmar Environment Institute, 2017).

2.1.1. Climate condition

The rainfall pattern in Myanmar's Central Dry Zone is diurnal, with drought occurring in July. Based on 10-year data on annual rainfall between 2009 and 2018, a fluctuation trend was found in Meiktila Township while lower rainfall was observed in 2012 and 2014 (Figure 1). Weather data were recorded from 2009 to 2018.The average maximum temperature and average minimum temperature were about 33˚C and 22˚C, respectively (Figure 2).

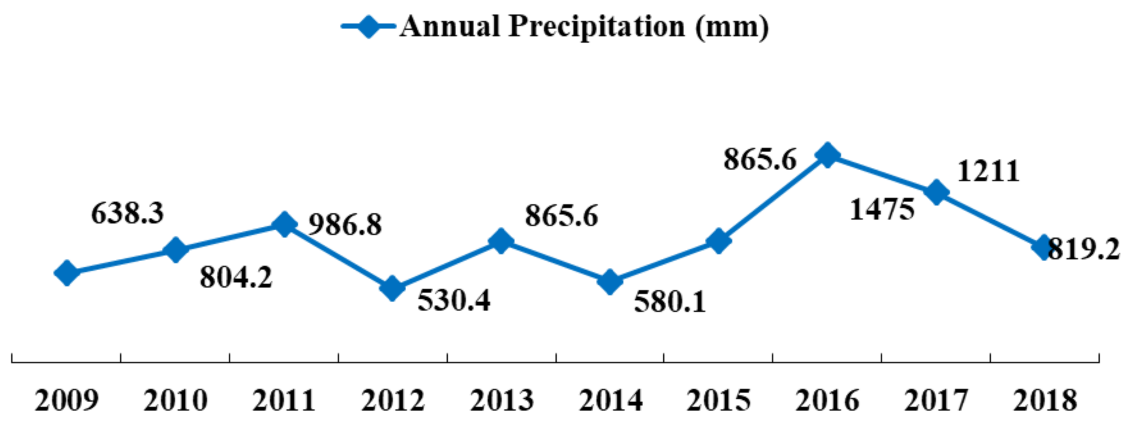
2.1.2. Rice sown area and production in Meiktila Township

The largest rice sown area and production of wet season rice were found in 2010-2011 and the lowest was found in 2014-2015 (Figure. 3).In dry season, the largest rice sown area and production were found in 2010 and dry season rice could not cultivate in 2012, 2014-2015. However, they cultivated dry season rice due to improvement of irrigation facilities in some areas starting from 2015 (Figure. 4).

2.2. Data collection and analysis

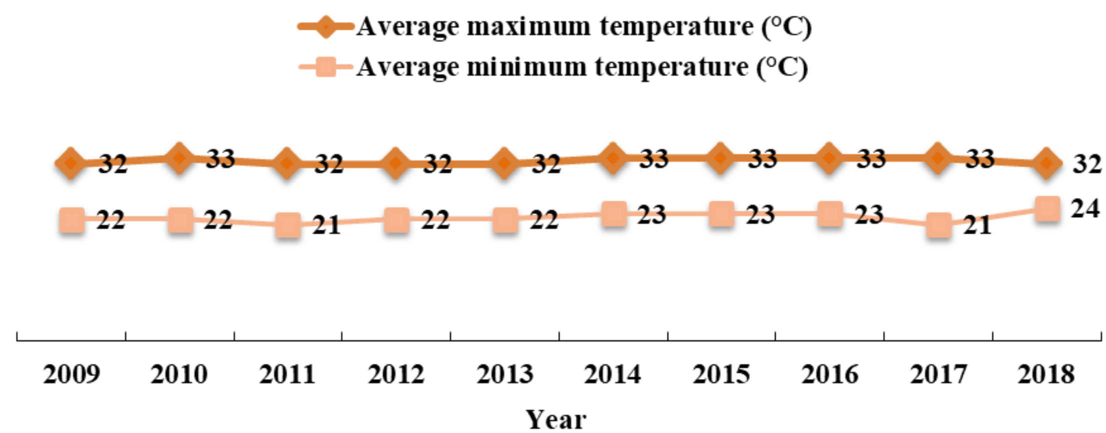
Both primary and secondary data were collected. The primary data were collected from 160 respondents of the four sample villages selected by using the purposive random sampling method through questionnaire survey. The primary data were demographic factors and changes of cultural practices in rice production and secondary data were climate data, rice sown area and rice production. The data were analyzed by the Statistical Package for Social Science Program (SPSS) version 23 software. Descriptive analysis was used to explore the changes of rice production by comparing between past and

Figure 1. Annual precipitation (mm) during 2009 and 2018 in Meiktila Township



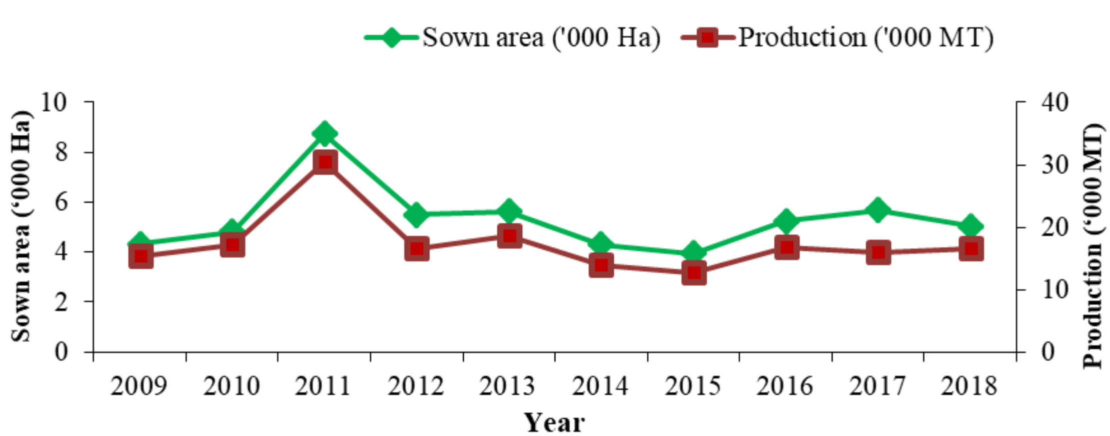
Source - Department of Agriculture [DoA], 2018

Figure 2. Average maximum and minimum temperature (°C) during 2009 and 2018 in Meiktila Township



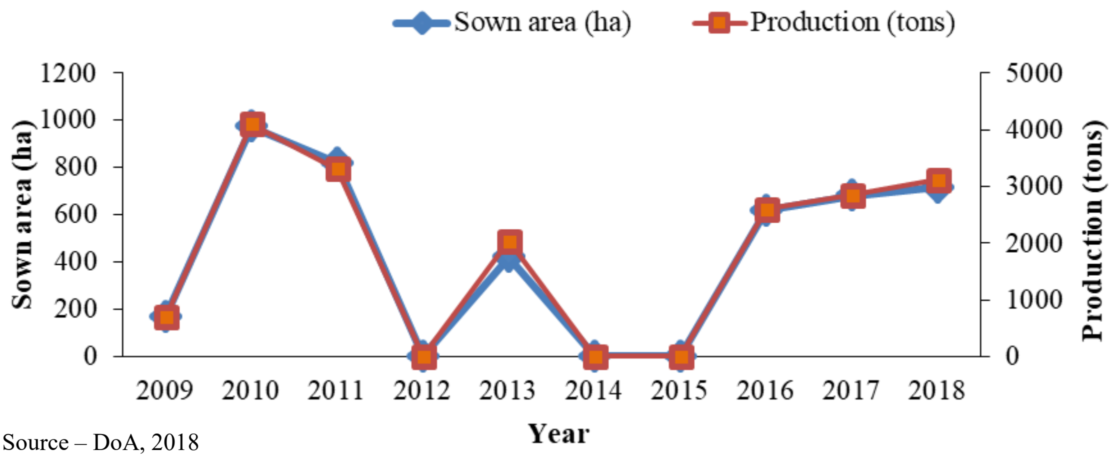
Source - DoA, 2018

Figure 3. Wet season rice sown area and production during 2009 and 2018 in Meiktila Township



Source - DoA, 2018

Figure 4. Dry season rice sown area and production during 2009 and 2018 in Meiktila Township



Source – DoA, 2018

present. The paired-sample t-test was used to analyze the statistically differences of rice farming systems between past and present. The chi-square test was used to analyze the group of differences for the comparison of rice production systems between past and present.

3. Results and discussion

3.1. Demographic characteristics of respondents

The total farm size of the respondents in Meiktila Township can be viewed in Table 1. Average farm holding sizes of respondents in 2000 and 2018 were 2.6 ha and 2.4 ha, respectively. During 20 years, total farm size of the respondents were significantly changes ($t = 3.3$, $p < 0.05$). Average rice cultivated areas were 1.5 ha and 1.3 ha in the past and present, respectively. Rice cultivated areas of respondents found to be significantly decreasing because of uncertainty of water availability and lessdevelopment of irrigation facilities ($t = 2.8$, $p < 0.05$).

According to their farm size, the respondents who possessed 2.1 to over 6 ha were decreased and hence the number of smallholder famers were increased in study area (Figure.5).

3.2. Changes of cultural practices in wet season between 2000 and 2018

3.2.1. Cropping pattern

Most of the respondents (87.5 percent) cultivated rice-based double cropping with upland crops (sesame, beans etc.) and decreased to 25 percent in 2018. In 2000, 12.5 percent of the respondents practiced rice-fallow and these percentages of respondents decreased to 6.9 percent in 2018. Based on the availability of water, most of the respondents (65.6 percent) practiced rice-rice in present but only 2.5 percent of respondents practiced irregularly cropping patterns (Figure.6).

3.2.2. Land preparation

Although the changes of land preparation methods of respondents in wet season were not significantly varied according to group of land preparation methods they used ($\chi2=0.3$), some groups were varied. In 2000, the majority of respondents (92.9 percent) used draught power for land preparation because machines were not available in this area which is now changed to the use of machine in 2018. In past, 100 percent of respondents prepared their cultivated land by manual which is now changed to the use of machine in the present condition (Table.2).

Changes of frequency of tillage operation for wet season practiced by respondents were significantly varied according to group of tillage they done ($\chi2=126.4$, $p < 0.01$). 2.8 percent of respondents operated two strokes of tillage in the past which is changed to three strokes of tillage in present and the rest (90.6 percent) continued with two strokes of tillage operation. Also 2.8 percent respondents changed to use one stroke of tillage operation in present. 39 percent of the respondents who practiced three strokes of tillage operation in 2000 continued this practice, however, 61 percent of them changed to two strokes of tillage operation in 2018 (Table.3).

Table 1. Changes of total farm size and rice sown area of the respondents between 2000 and 2018 in Mektila Township

	2000	2018	't' test
Total farm size (ha)			
Mean	2.6	2.4	3.3*
Minimum	0.2	0.4	
Maximum	12.0	10.0	
Rice sown area (ha)			
Mean	1.5	1.3	2.8*
Minimum	0.2	0.2	
Maximum	8.0	7.2	

* = significant at 5 percent level

Figure 5. Changes of rice growing area (ha) of the respondents between 2000 and 2018 in Meiktila Township

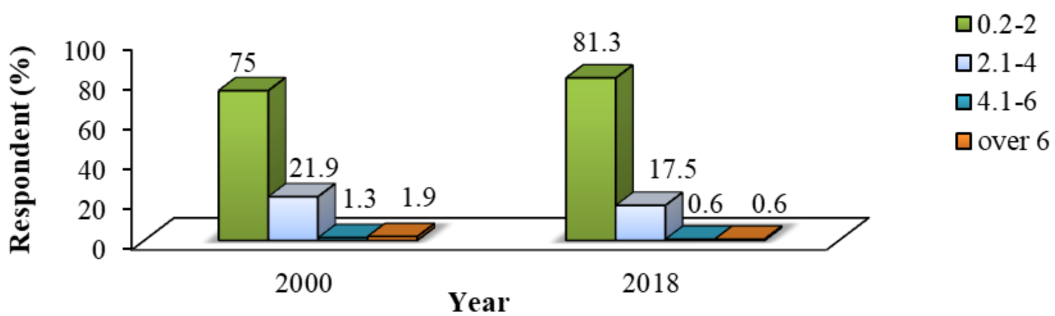


Figure 6. Changes of rice-based cropping patterns of the respondents between 2000 and 2018 in Meiktila Township

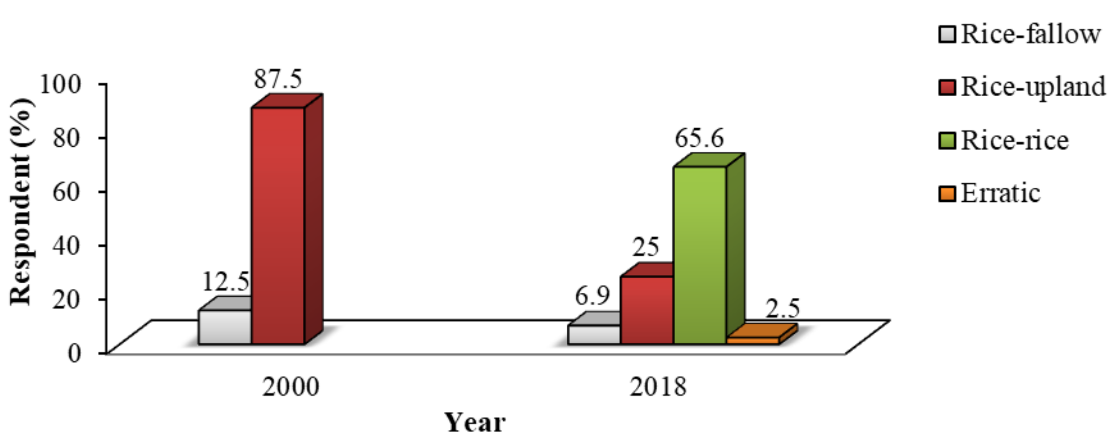


Table 2. Changes of land preparation for wet season practiced by respondents between 2000 and 2018 in Meiktila Township

Land preparation (2000)	Land preparation (2018)	
	Draught power	Machine
Draught power	11 (7.1)	145 (92.9)
Manual	0 (0.0)	2 (100.0)
Machine	0 (0.0)	2 (100.0)
χ^2	0.3^{ns}	

Figures in the parentheses are percentage. ns = non-significant, (n = 160)

Table 3. Changes of frequency of tillage operation in wet season practiced by respondents between 2000 and 2018 in Meiktila Township

Frequency of tillage operation (2000)	Frequency of tillage operation (2018)		
	One stroke	Two strokes	Three strokes
One stroke	4 (100.0)	0 (0.0)	0 (0.0)
Two strokes	3 (2.8)	101 (94.4)	3 (2.8)
Three strokes	0 (0.0)	30 (61.2)	19 (38.8)
χ^2	126.4**		

Figures in the parentheses are percentage. ** = significant at 1 percent level, (n = 160)

3.2.3. Rice varieties and establishment method

Although the changes of rice varieties of wet season used by respondents were not significantly varied according to group of rice varieties they grown ($\chi2$=0.5), only a small group varied. Most of the respondents (92.8 percent) used traditional rice varieties in 2000 and changed to use improved rice varieties in 2018 and also 5.2 percent of these respondents changed to hybrid varieties. Such changes were induced by water uncertainty. They used medium and short duration varieties because of short duration of water availability. (Table.4).

Changes of establishment methods in wet season rice practiced by respondents were significantly varied according to the group of establishment methods they practiced ($\chi2$=7.4, $p < 0.05$). In 2000, 66.7 percent of respondents practiced seed broadcasting method and which was changed to transplanting method in 2018. Transplanting method was used by (3.2 percent) of respondents in past whereas in present it changed to seed broadcasting method due to labor shortage (Table.5).

For wet season rice cultivation, average family labour used were 0.4 and 0.3 persons per hectare in 2000 and 2018 respectively. Changing family labour for wet season rice cultivation employed by respondents during 20 years were not significantly different (t = 0.4). In 2000 and 2018, respondents had hired 19.5 and 23.3 persons per hectare, respectively. During the last 20 year, changes of hired labour employed by respondents were significantly different (t= -5.9) (Table.6).

3.2.4. Water management system

Changes of sources of water for irrigation in wet season rice used by respondents were significantly varied according to the group of water management they practiced ($\chi2$=160, $p < 0.01$). In 2000, 120 respondents used communal system for rice field irrigation and they changed to use national irrigation system in 2018. Altogether 40 respondents used rain-fed rice cultivation in both past and present conditions (Table 7).

Changes of source of water for irrigation in wet season rice practiced by respondents were significantly varied according to group of water management they practiced ($\chi2$ =5.4, $p < 0.05$). Because of undeveloped irrigation channel and water uncertainty, permanent flooding was practiced by 61.6 percent of respondents in 2000. However, in 2018 these respondents changed to use intermittent irriga-

Table 4. Changes of rice varieties in wet season used by respondents between 2000 and 2018 in Meiktila Township

Rice variety (2000)	Rice variety (2018)		
	Hybrid	Improved	Traditional
Improved	0 (0.0)	7 (100.0)	0 (0.0)
Traditional	8 (5.2)	142 (92.8)	3 (2.0)
χ^2		0.5^{ns}	

Figures in the parentheses are percentage. ns = non-significant, (n = 160)

Table 5. Changes of establishment methods in wet season rice practiced by respondents between 2000 and 2018 in Meiktila Township

Establishment methods (2000)	Establishment methods (2018)	
	Broadcasting	Transplanting
Broadcasting	1 (33.3)	2 (66.7)
Transplanting	5 (3.2)	152 (96.8)
χ^2	7.4*	

Figures in the parentheses are percentage. * = significant at 5 percent level, (n = 160)

Table 6. Changes of family labour and hired labour employed for rice establishment of wet season by respondents between 2000 and 2018 in Meiktila Township

	2000	2018	‘t’ test
Family labour (persons/ha)			
Mean	0.4	0.3	0.4^{ns}
Minimum	0.0	0.0	
Maximum	17.5	6.7	
Hired labour (persons/ha)			
Mean	19.5	23.3	-5.9*
Minimum	0.0	0.0	
Maximum	38.5	38.5	

ns = non-significant, * = significant at 5 percent level, (n = 160)

Table 7. Changes of sources of irrigation in wet season rice used by respondents between 2000 and 2018 in Meiktila Township

Sources of irrigation (2000)	Respondent (n=160)	
	Sources of irrigation (2018)	
	Irrigation national system	Rainfall
Irrigation communal system	120 (100.0)	0 (0.0)
Rainfall	0 (0.0)	40 (100.0)
χ^2	160.0**	

Table 8. Changes of water management in wet season rice practiced by respondents between 2000 and 2018 in Meiktila Township

Water management (2000)	Water management (2018)	
	Permanent flooding	Intermittent irrigation
Permanent flooding	58 (38.4)	93 (61.6)
Intermittent irrigation	0 (0.0)	9 (100.0)
χ^2	5.4*	

Figures in the parentheses are percentage. * = significant at 5 percent level, (n = 160)

tion practice. Only 9 respondents used intermittent irrigation practice in 2000 and still continued using this practice in 2018 (Table 8).

3.2.5. Fertilizer, weed management and pest, disease control

In 2018, they changed to use increased amount of fertilizers than in the past. Mean value of fertilizer application were 71.7 N kg/ha, 5.6 P kg/ha and 8.3 K kg/ha. Some respondents did not apply P and K fertilizers at all at present (Table 9).

Changes of weed management for wet season rice practiced by respondents were significantly varied according to group of weed management they practiced ($\chi2=16.2$, $p < 0.01$). In 2000, 11.8 percent of respondents practiced weeding and in 2018 these respondents did not practice weeding. 37 percent of respondents who had no weeding in past changed to practice manual weeding in present.1.4 percent of them used chemical for weeding (Table 10).

In 2000, only 1.9 percent of respondents used chemical (pesticide) to control pests and diseases and these respondents significantly increased to 66.3 percent in 2018. 98 percent of respondents did not control pests and diseases in past which was decreased to 33.8 percent in present (Figure.8).

3.2.6. Harvesting and Threshing

For wet season rice, all respondents (100 percent) harvested rice by manual in 2000 which was decreased to 68.8 percent in 2018. 31 percent of the respondents changed to use combined harvester for rice harvesting in 2018. This change resulted in reduced harvest losses and moreover they can finish harvesting and threshing together (Figure.9).

For wet season rice harvesting, average family labour used were 1.1 and 0.7 persons per hectare in 2000 and 2018 respectively. Changing in family labour employed for wet season rice harvesting by respondents during 20 years was significantly decreased ($t = 1.6$, $p < 0.05$). In 2000 and 2018, the use of average hired labour were 20.2 and 15.6 persons per hectare respectively. During the last 20 years, the hired labour employed for harvesting of rice by respondents was significantly decreased ($t= 4.4$, $p < 0.01$) (Table.11).

For wet season rice, half of the respondents threshed the rice using animal in the past which has now decreased to 1.3 percent in present conditions. In 2000, 41.9 percent of respondents threshed rice by manual and in 2018 it decreased to 8.8 percent. Eight percent of respondents used thresher in past and which has increased to 58.1 percent in present. Combined harvester was used by 31.9 percent of respondents in present (Figure.10) situation (2018).

3.3. Rice yield in wet season

For wet season, average rice yield were 2.3 and 3.3 ton/ha in 2000 and 2018 respectively. Changing rice yield for wet season during 20 years was significantly different ($t = -9.6$, $p < 0.01$). They changed to use improved varieties and apply increased amount of fertilizer, resulted in increased rice yield in 2018 (Table 12).

3.4. Changes of rice cultivation in dry season between 2000 and 2018

In 2000, all respondents did not cultivate dry season rice because of water uncertainty. In 2018, irrigation

Table 9. Fertilizer application for wet season rice at 2018 in Meiktila Township

	Fertilizer application (kg/ha)		
	Nitrogen	Phosphorus	Potassium
Mean	71.7	5.6	8.3
Minimum	3.8	0.0	0.0
Maximum	201.3	57.5	32.1

Figure 7. Fertilizer application for wet season rice at 2000 in Meiktila Township

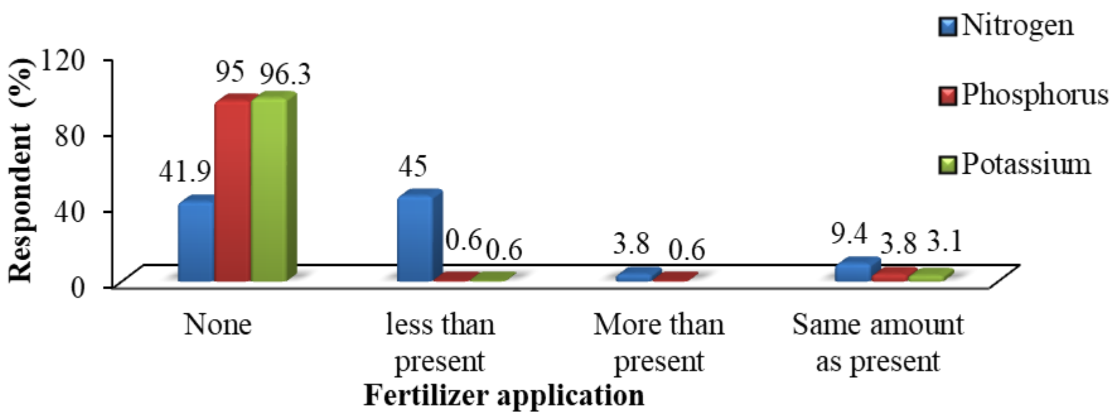


Table 10. Changes of weed management for wet season rice practiced by respondents between 2000 and 2018 in Meiktila Township

Weed management (2000)	No. of respondent (n=160)		
	Weed management (2018)		
	Chemical	Manual	None
Manual	0 (0.0)	15 (88.2)	2 (11.8)
None	2 (1.4)	53 (37.1)	88 (61.5)
χ^2	16.2**		

Figure 8. Changes of pest and disease management of respondents for wet season between 2000 and 2018 in Meiktila Township

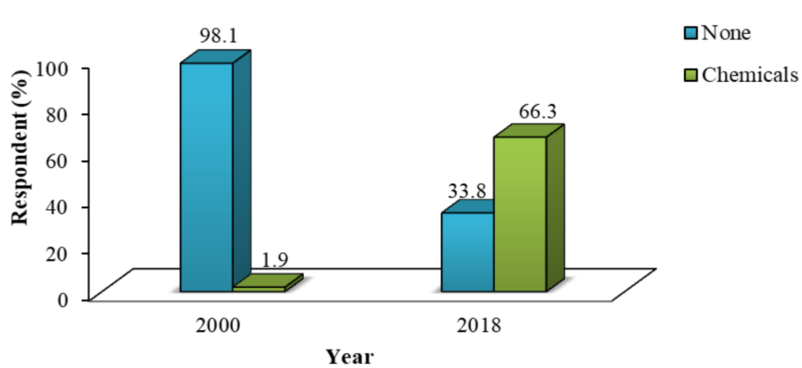


Figure 9. Changes of harvesting method for wet season rice practiced by respondents between 2000 and 2018 in Meiktila Township

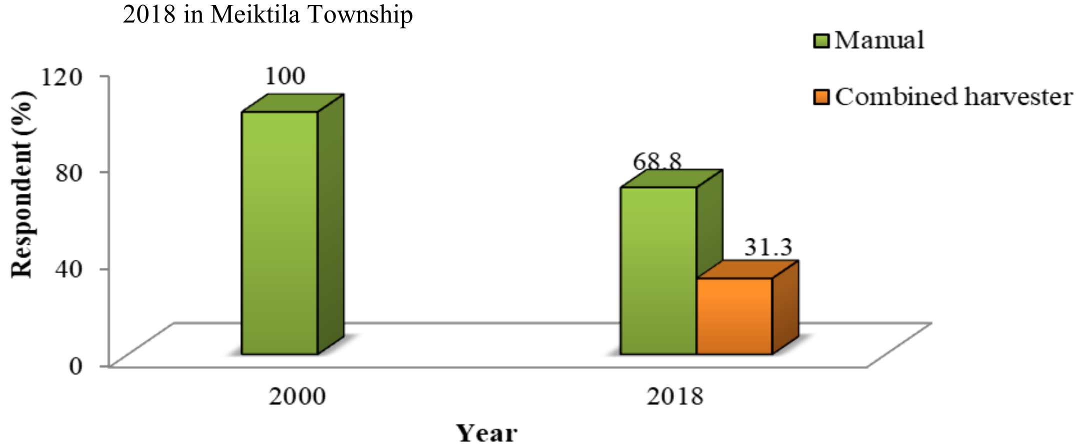


Table 11. Changes of family labour and hired labour used for harvesting of wet season rice by respondents between 2000 and 2018 in Meiktila Township

	2000	2018	't' test
Family labour (persons/ha)			
Mean	1.1	0.7	1.6*
Minimum	0.0	0.0	
Maximum	20.0	20.0	
Hired labour (persons/ha)			
Mean	20.2	15.6	4.4**
Minimum	0.0	0.0	
Maximum	40.0	40.0	

Figure 10. Changes of threshing method for wet season rice practiced by respondents between 2000 and 2018 in Meiktila Township

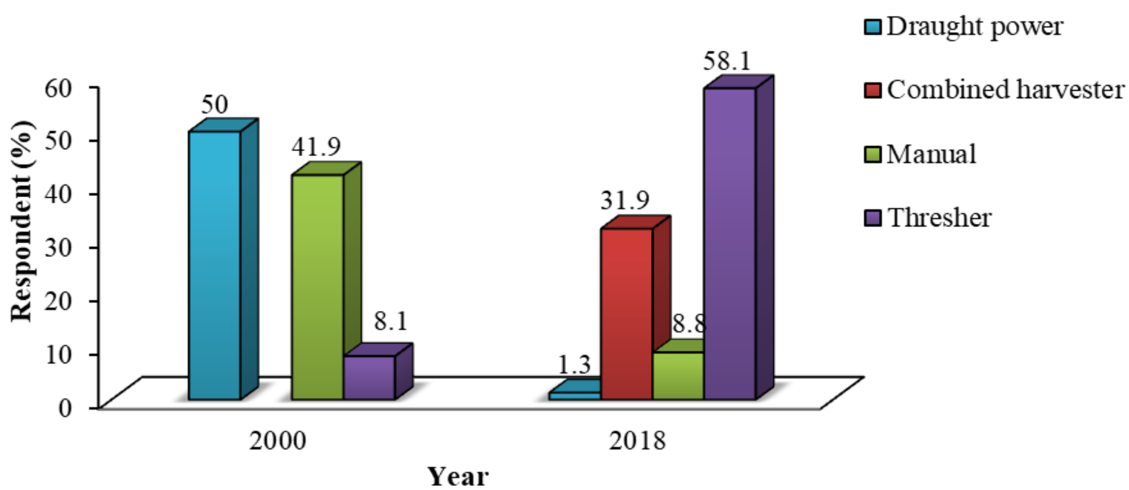
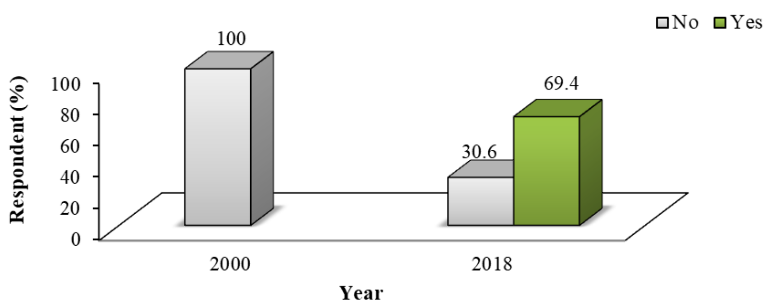


Table 12. Rice yield of respondents for wet season between 2000 and 2018 in Meiktila Township

Rice yield (ton/ha)	2000	2018	't' test
Mean	2.3	3.3	-9.6**
Minimum	0.5	0.6	
Maximum	4.1	6.1	

** = significant at 1 percent level

Figure 11. Changes of rice cultivation for dry season practiced by respondents between 2000 and 2018 in Meiktila Township



channel became developed in some areas with the supports from government therefore, more than half of the respondents cultivated dry season rice. however 30.6 percent of respondent had not grown dry season rice yet (Figure. 11).

3.5. Cultural practices in dry season at 2018

In the case of cultural practices for dry season rice, most of the respondents used machine for land preparation. They used improved varieties and practiced transplanting method. For water management, they practiced intermittent irrigation due to easy to control drainage with the improvement in irrigation channel. They used manual weeding and some respondents did not control weed because weed problem was not seriously occurred in their areas. Pest and disease problems were controlled by using chemical. And then they used combined harvester for harvesting and threshing operations (Table.13). Average rice yield for dry season was 4.5 tons/ha in 2018 (Table.14).

4. Conclusion

The study attempted to investigate changes of rice production system between 2000 and 2018 in the study area. Evidence was found that there is water insufficiency in all areas which has caused reduction in rice productivity in the last 20 years. But some of the respondents/farmers have started cultivating rice two times per year (rice-rice) due to irrigation facility available in some areas. Most of the respondents could cultivate dry season rice for 3 year (2015-2018) but some respondents still had not grown dry season rice in the study area.

Due to the uncertainty of water, they changed to use machine to catch moisture and lead to reduced labour and thereby making the work faster and easier. The farmers have also started changing the varieties from long duration varieties (Ngasein) to medium duration varieties (Manawthuka). As compared to 20 years back, the farmers are getting higher yield of rice in present by using improved varieties and increase amounts of chemical fertilizer application due to awareness creation by extension workers. Farmers have also changed to practice intermittent irrigation because of improve irrigation channel with governmental support. Nowadays, cultural practices used by the farmers have changed to new

Table 13. Cultural practices in dry season rice practiced by respondents at 2018

Cultural practices	Respondent (percent) (n=111)
	2018
Land preparation	
Draught power	4.5
Machine	95.5
Varieties	
Hybrid	23.4
Improved	76.6
Establishment method	
Seeding	1.8
Transplanting	98.2
Water management	
Permanent flooding	10.8
Intermittent irrigation	89.2
Weeding	
Chemicals	2.7
Manual	53.2
None	44.1
Pest and disease control	
No control	35.1
Chemicals	64.9
Harvesting method	
Combined harvester	95.5
Manual	4.5
Threshing method	
Combined harvester	95.5
Thresher	4.5

Table 14. Rice yield in dry season at 2018

Rice yield (ton/ha)	2018
Mean	4.5
Minimum	2.2
Maximum	8.0

improved practices in some cases however, nearly half of the respondents did not change in the study area.

Based on the result finding, it can be concluded that water was the most limiting factors for development in agriculture. Developing new irrigation schedules using early season rainfall could make it possible to keep water in reservoirs, allowing more opportunity for increasing the irrigated area during the dry season. And the other factor is fertilizer application; they were considering how to further increase their harvest, though they did not know the advantages and disadvantages of the different fertilizers. Farmers' fertilizer use was often at inefficient application rates and inappropriate nutrient composition.

In study area, some changes were found between 2000 and 2018, however, prominent changes in rice production system were not observed in this study. Therefore, based on this study, policy makers and all stakeholders involved in rice value chain should take into consideration of some recommendations for improving rice production systems in central dry zone.

5. Recommendation

One cannot modify the climatic regime, but can certainly improve the crop management practices through technical support to rice farmers to improve rice productivity.

The introduction of genotypes/varieties with tolerance to drought can increase further productivity.

The seed production sector should be strengthened to supply quality seeds with affordable price to farmers. Furthermore, farmers should be trained to carefully manage their own seed production fields.

A diversified agriculture should be practiced for sustainable production in the long run. Present rice cultivation systems require more water than most other food crops in terms of food and calories produced.

The new knowledge and technologies are not reaching all of the farmers. There are considerable knowledge gaps between researchers, extension agents, and farmers. The combined efforts of public, private, cooperative and Non-Governmental Organization (NGO) extension agencies should be needed to spread new knowledge and technologies to farmers.

Irrigation infrastructure should be expanded and systematically managed by government and local farmers.

6. Acknowledgements

I thank the township managers, the staffs from the Department of Agriculture (DoA) for their continuous support during my research and the farmers in the study areas. This study is a part of the project "Rich-3P." I thank Bonn University for partial financial support for this research.

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Session 2

Water saving techniques and irrigation

Effect of different water regimes on growth, yield and water use efficiency of groundnut (Arachis hypogaea L.) varieties

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Abstract

Two plot experiments were conducted during 2017 and 2018 post monsoon season (November-February) at the Water Utilization Research Section, Department of Agricultural Research, Yezin. 3 x 5 factorial arrangements in RCB design with three replications were used. Factor A consisted of three water application based on evapotranspiration (ET) ET100 percent, ET60 percent, ET30 percent and factor B comprised of 5 groundnut varieties: Sin-6, Sin-7, Sin-11, Sin-12, Sin-13 (Sin=Sinpadaetha). The objectives of this experiment were: (i) to investigate the effect of different water regimes on growth, yield and yield components of different groundnut varieties and (ii) to select groundnut varieties with high yield and water use efficiency under water stress conditions. The results showed that, ET100 percent produced significantly higher growth, yield and yield components in all tested groundnut varieties. ET60 percent, ET30 percent showed higher SCMR and lower SLA than ET100 percent. Under all water regimes, the maximum value of LAI, CGR and TDM were observed from Sin-13. The highest filled pod number, 100 seed weight, pod and seed yield were observed in Sin-13 followed by Sin-11 whereas Sin-7 produced the lowest value except 100 seed weight. In 2018, ET60 percent and ET30 percent gave higher WUE than ET100 percent. At ET60 percent and ET30 percent, Sin-13 produced the highest WUE followed by Sin-11 and the lowest WUE from Sin-7. Based on the findings, for maximum yield production of all tested groundnut varieties should be grown with ET100 percent. If irrigation water is limited, ET60 percent could be used to produce reasonable crop yield. Sin-13 and Sin-11 are suitable for all water regimes including stress irrigation.

1. Introduction

Climate change has already significantly affected agricultural production (Lobell, Schlenker & Costa-Roberts, 2011) and is expected to further affect directly and indirectly on food production. According to the water resources and economic condition of the region, water-saving agriculture is the most effective way to solve the problem in water shortage in agriculture and to make sustainable use in water resources and increase the water use efficiency of crops. Irrigation is essential for agricultural production and food security due to rapid population growth and as improper irrigation practices limits the water availability for farming. Therefore, under limited water availability, scheduling of irrigation at the critical stages or eliminating the least productive irrigations could increase crop productivity and water use efficiencies.

Oilseed crops play a vital role in Myanmar due to high consumption of cooking oil. Groundnut is the second most important oilseed crop next to sesame (Kumar, Sekhar, Reddy & Ismail, 2012). The yield of groundnut in Myanmar was still low when comparing with other countries (Food and Agriculture Organization of the United Nations, [FAOSTAT], 2016). In Myanmar, groundnut is grown under rainfed conditions in monsoon season. In post-monsoon seasons, it is cultivated with residual soil moisture and in places where water supply is available. In some case, it is cultivated with irrigation for higher

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yield. The crop can tolerate water stress but produces low yield with poor seed quality under drought condition (Sulc & Franzluebbers, 2014). The major groundnut growing areas in Myanmar are Central dry zone (Magway, Mandalay, Sagaing, Bago and Ayayarwady Regions). In central dry zone (CDZ) of Myanmar, scarcity of water, relatively low and erratic rainfalls have led to low agricultural productivity.

Climate change has a huge impact on rainfall, temperature and air humidity which are related to plant evapotranspiration and crop water requirement. Water requirement of crops depends on variation in crop canopy and climatic conditions. Total water requirements of groundnut may range from 500 to 700 mm throughout the growing season (Doorenbos & Kassam, 1979). Macro management of actual evapotranspiration, crop coefficient (Kc), crop water requirements, and critical crop growth stages are very important for optimizing crop water use and maximizing crop yield (Suleiman, Soler & Hoogenboom, 2007). Deficit irrigation (DI) is a valuable strategy for dry regions where water supply is the limiting factor in crop cultivation (Fereres & Soriano, 2006). Yield and yield components and suitable morpho-physiological traits are needed to overcome the yield barriers for selection of drought tolerance variety (Nigam et al., 2005). Using deficit irrigation with drought tolerance variety is an effective way for managing water shortages in crop cultivation for dry regions. Use of varieties with high water use efficiency (WUE) is one of the factors for the solution in areas with limiting water availability.

To increase groundnut production of Myanmar in winter, residual soil moisture is not enough for groundnut cultivation, therefore high WUE with high yield of groundnut varieties are needed. The experiments were conducted with objectives: (i) to investigate the effect of different water regimes on growth, yield and yield components of different groundnut varieties and (ii) to select the groundnut varieties with high yield and high-water use efficiency under water stress conditions.

2. Materials and methods

Experiment I and II were conducted from November 2017 to February 2018 at Water Utilization Research Section, Department of Agricultural Research (DAR), Yezin, Nay Pyi Taw. The experimental design was 3 x 5 factorial arrangements in randomized complete block design with 3 replications. Factor A consisted of three levels of water application based on evapotranspiration (ET): ET100 percent, ET60 percent, ET30 percent which were measured using Class A Pan evaporation and factor B comprised of five groundnut genotypes: Sin-6, Sin-7, Sin-11, Sin-12, Sin-13. Groundnut seeds were sown in soil placed in concrete tanks which were filled with 330 kg of soil. The size of each plot was 1.8 m long, 0.9 m wide and 0.2 m deep. The total plant population were 54 plants/plot with a spacing of 30 cm × 10 cm.

2.1 Cultural practices

Prior to planting, soil moisture for all the plots was placed at field capacity until 20 day after sowing (DAS) for uniform germination. After 15 DAS, thinning was done to maintain 10 cm distance from plant to plant. The seeds were sown in furrows at a depth of 4 cm approximately. The fertilizers were used according to recommended dosage for groundnut production by DAR. 14.26 kg N/ha from Urea fertilizer, 18.88 kg P/ha from triple super phosphate and 15.37 kg K/ha from muriate of potash fertilizer were applied at basal. One packet of 150 g rhizobium was used by applying a water-diluted treated with seed at the time of sowing. Gypsum 225 kg/ha was applied (40-45 DAS) at the pegging stage. After 20 DAS, the irrigation treatments were initiated until 15 days before the plants were harvested.

2.3 Calculation of irrigation water

Amount of irrigation water required for evapotranspiration ET100 percent, ET60 percent and ET30 percent were estimated and applied at 7 days interval. Crop water requirement was calculated using the methods described by (Doorenbos & Pruitt 1992).

$$ETcrop = ETo \times Kc \qquad \text{Equation (1)}$$

Where, ETcrop = Crop evapotranspiration (mm/day), ETo = Potential Evapotranspiration (mm/day), Kc = Crop coefficient

Daily pan evaporation results were collected with a pan of Class A. Kc = the crop water requirement coefficient for groundnut, which varied depending on growth stage [initial stage (1-15 DAS) Kc = 0.3-0.40, development stage (15-45 DAS) Kc = 0.7-0.8, mid-season (45-75 DAS) Kc = 0.95-1.1 and late season (75 DAS-harvest) Kc = 0.7-0.8 (Doorenbos & Pruitt 1992).

2.4 Variables measurements

Growth parameters such as plant height and SPAD chlorophyll meter (SCMR) value were recorded from randomly selected 5 plants from each plot at 14 days interval starting from 14 to 90 DAS. Leaf area and total dry matter value (TDM) were collected from 1 plant from each plot at 20 days interval starting from 20 to 80 DAS. Leaf area index (LAI) and specific leaf area (SLA) were calculated from these collected data. Yield and yield components characters were determined from a 10 sample plants of internal row from each plot. Water use efficiency (WUE), shelling percentage (percent) and harvest index (HI) were calculated with following formula.

LAI was determined by the ratio of the total leaf area and the area of ground space covered by each plant following the method of (Watson, 1952):

Leaf area index= (Sum of the leaf area of all leaves (cm^2)) / (Ground area of field where the leaves have been collected (cm^2))

Equation (2)

The leaf samples of whole plant that were measured for leaf area and then the leaf samples were oven-dried at 80 ºC for at least 48 hours until reaching constant weight and leaf dry weight was determined. SLA was calculated using the following formula suggested by (Nageswara, Talwar & Wright, 2001)

Specific leaf area (SLA) = (Leaf area (cm^2)) / leaf dry weight (g)

Equation (3)

Water use efficiency was calculated as crop yield divided by the actual evapotranspiration (ET) consumed by the crop during the growing season for a specific treatment. WUE was calculated using the formula described by (Boutraa, Akhkha, Alshuaibi & Atta, 2011):

Water use efficiency (WUE) = (Crop yield (usually economic yield)(g)) / (Water used to produce yield (L))

Equation (4)

The shelling percent of full seeds was calculated as the ratio of the weight of shelled seeds to the weight of pods and then was multiplied by 100. Shelling percentage was calculated as (Vorasoot, Akkasaeng, Songsri, Jogloy & Patanothai, 2004):

Shelled (percent) = (weight of shelled seed) / (pod weight) ×100

Equation (5)

Harvest index was calculated by dividing the economic yield (pod yield) by biological yield. HI was calculated using the following formula suggested by (Donald & Hamblin, 1976):

Harvest index (HI)= (Economic yield) / (Biological yield) Equation (6)

Table 1. Physicochemical properties of the experimental soil before doing experiment

Properties (Items)	Results (2017)	Results (2018)
Textural class	Sandy Loam	Sandy Loam
Soil pH	7.41 (Moderately alkaline)	6.35 (neutral)
EC (dSm^{-1})	0.14 (Non-Saline)	0.25 (Non-Saline)
Bulk density ($g\ cm^{-3}$)	1.23	1.23
Field capacity (FC) (percent)	21.61	20.79
Permanent Wilting Point (PWP) (percent)	4.17	4.26
Plant Available Water (PAW) (percent)	17.44	16.53

2.5 Statistical analysis

Experimental data were analyzed by ANOVA using statistix software (version 8). Mean value was compared using least significant differences (LSD) test at 5 percent probability level.

3. Results and discussion

3.1 Climatic conditions

Average daily rainfall, relative humidity, sunshine hours, minimum and maximum temperature and pan evaporation value for both experiments were collected at meteorological station of DAR, Yezin from November to February. The averaged relative humidity value in 2017 was 72.1 percent and in 2018 it was 73.4 percent. The averaged sunshine hour in 2017 was 6.4 hr and in 2018 it was 7.3 hr which was higher than sunshine hour in 2017. The average maximum and minimum temperatures were 32.3 and 18.4 in 2017 and 32.8 and 18.4 ºC in 2018, respectively. The total amount of rainfall was 70 mm between 24 to 68 DAS in 2017. Due to the presence of rainfall, water treatments were initiated lately at 37 DAS. In 2018, the total amount of rainfall was 30 mm between 42 to 69 DAS which was lower than in 2017. Mean daily pan evaporation value was 1.0 to 5.0 mm/day in 2017 and 2018, respectively.

3.2 Plant height (cm)

Plant height in all water regimes continuously increased from 14 DAS to 90 DAS. In both experiments, plant heights were significantly different between water regimes and groundnut varieties at all stages except 20, 34 DAS in 2017 and 20 DAS in 2018 (Figure 1). The maximum plant height was observed from ET100 percent followed by ET60 percent and the minimum plant height was observed from ET30 percent. These results were in agreement with the findings of Mitchell et al., 1998 where they stated that decreasing soil water availability reduced plant height because of reducing plant water use. Sin-6 showed significantly highest plant height among the other tested varieties and Sin-12 showed the lowest plant height at different water regimes. Although, there was no interaction effect between water regimes and varieties on plant height, the tallest plant height was observed from Sin-6 with ET100 percent.

3.3 SPAD chlorophyll meter reading (SCMR)

SCMR values were significantly different for different water regimes at 48 and 76 DAS in 2017 and 34, 48, 62 and 76 DAS in 2018 (Figure 2). The highest SCMR value was observed from ET30 percent followed by ET60 percent and the lowest value was observed from ET100 percent. The results showed that water stress conditions produced darker green color in groundnut leaves. This finding was similar to the results of Boontang et al., 2010 where they reported that SCMR increased under severe drought. SCMR values were significantly different among groundnut varieties at 76 DAS in both experiments. The highest SCMR value was obtained from Sin-6, Sin-12 in both experiments. There was no interaction effect between water regimes and varieties on SCMR value, but Sin-6 and Sin-12 with ET30 percent produced the best SCMR value.

3.4 Leaf area index (LAI)

The values of LAI were highly significant difference between water regimes and varieties at all stages in 2017 and 40, 60, 80 DAS in 2018 (Figure 3, Figure 4). In both experiments, maximum LAI was resulted from ET100 percent and minimum value was resulted from ET30 percent. These results were in line with the findings of Mitchell et al., 1998 where they stated that decreasing soil water availability reduced leaf number and LAI was the result of reducing plant water use. At all water regimes, Sin-13 showed higher LAI value than the other varieties. This could be due to the fact that Sin -13 had high leaf area at all stages in all treatments. Sin-7 showed the lowest LAI value. There was interaction between water regimes and varieties on LAI at 80 DAS in 2017 and 60 DAS in 2018. The highest LAI value was observed from ET100 percent + Sin-13. In the case of water regimes and varieties, the highest LAI value was obtained from Sin-13 with ET100 percent.

3.5 Specific leaf area (SLA) (cm2 g-1)

There were no significant differences between water regimes and varieties on SLA in 2017, however there were significant difference for the results of different water regimes at 60, 80 DAS in 2018 (Figure 5). At 80 DAS, the highest SLA value was observed from ET100 percent and the lowest value

Figure 1. Mean values of plant height as affected by three water regimes and five groundnut varieties in 2017 post monsoon season (A) water, (B) varieties and in 2018 post monsoon season (C) water, (D) varieties.

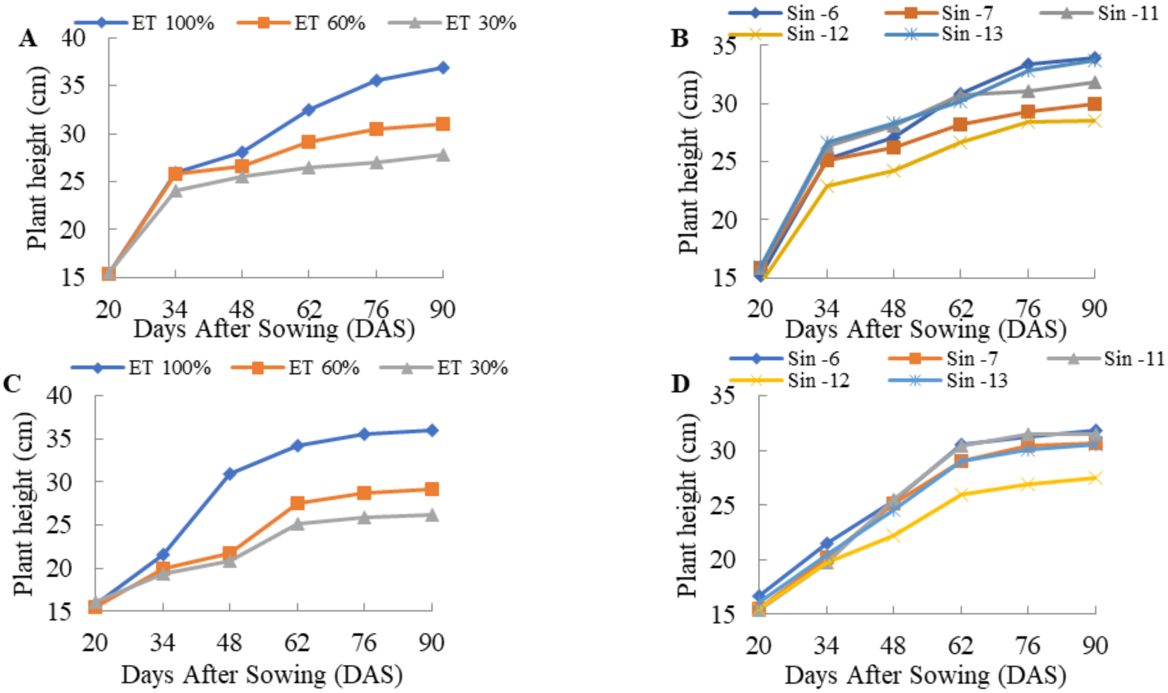


Figure 2. Mean values of SPAD meter reading (SCMR) as affected by three water regimes and five groundnut varieties in 2017 post monsoon season (A) water, (B) varieties and in 2018 post monsoon season (C) water, (D) varieties.

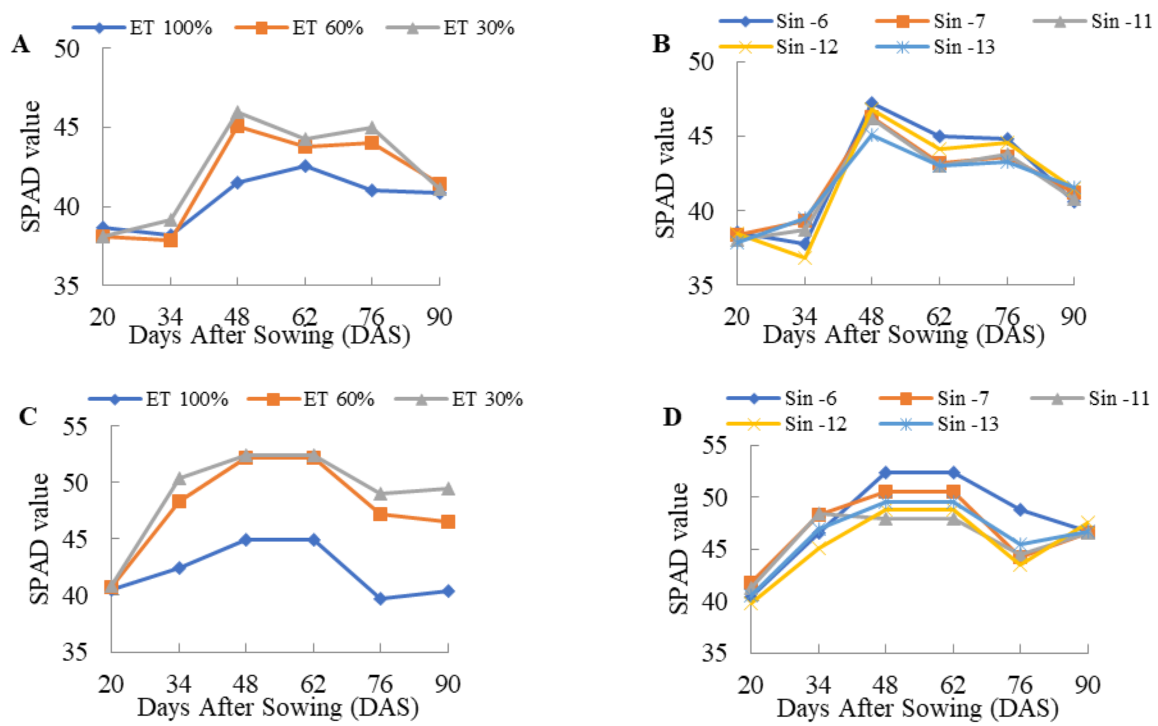


Figure 3. Mean values of leaf area index (LAI) as affected by three water regimes (A), five groundnut varieties (B) and their combination (C) in 2017 post monsoon season.

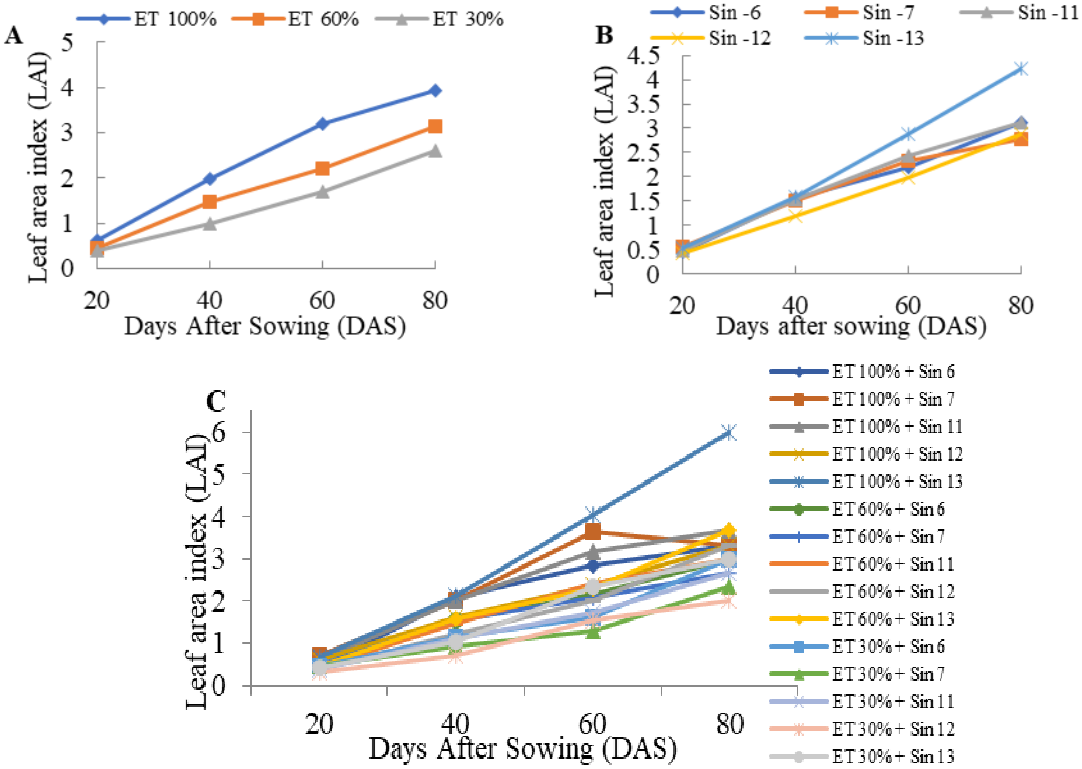


Figure 4. Mean values of leaf area index (LAI) as affected by three water regimes (A), five groundnut varieties (B) and their combination (C) in 2018 post monsoon season

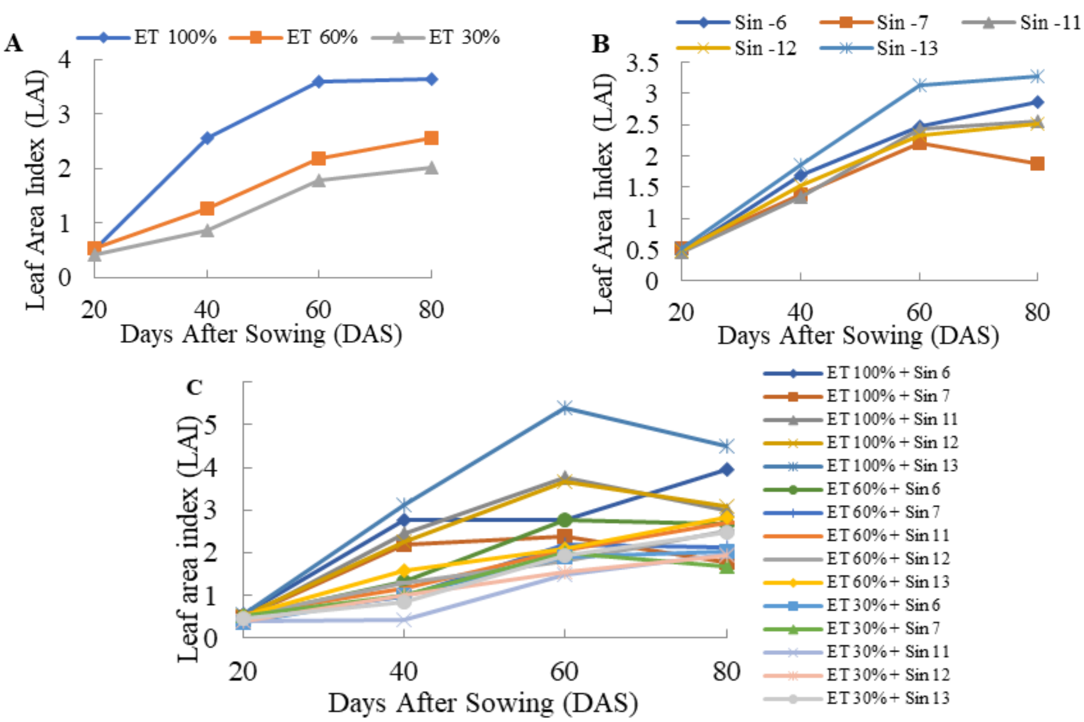
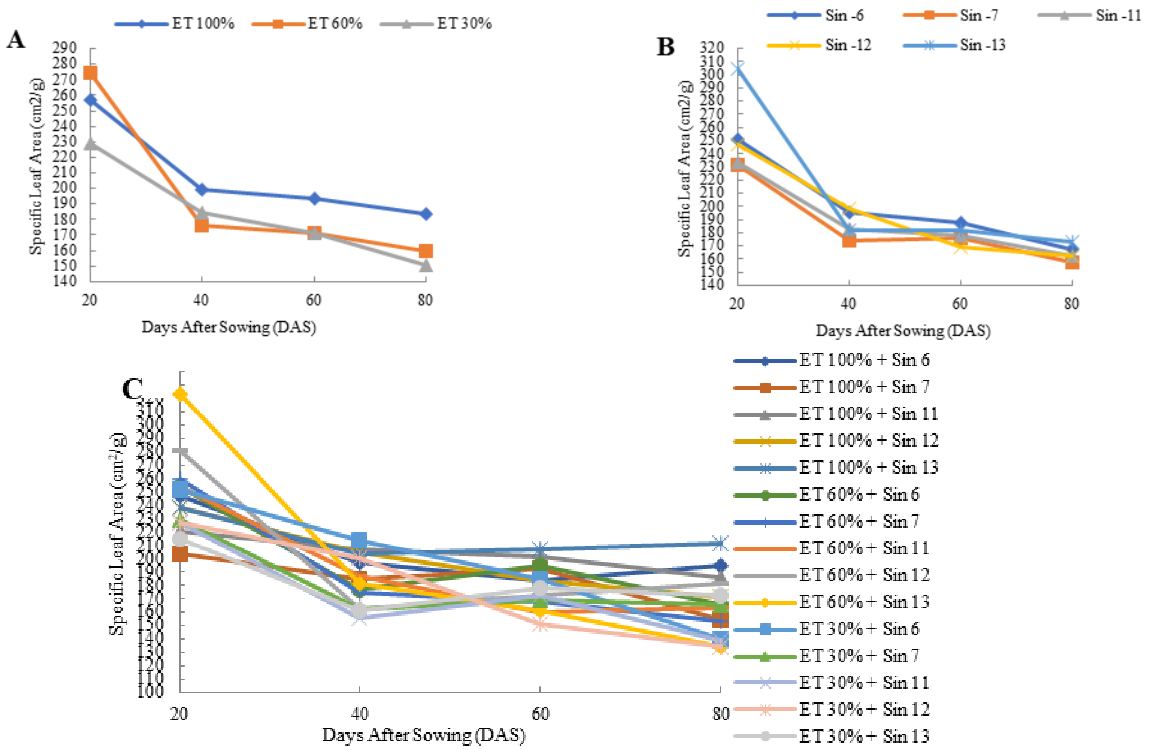


Figure 5. Mean values of specific leaf area (SLA) as affected by three water regimes (A), five groundnut varieties (B) and their combination (C) in 2018 post monsoon season



was observed from ET30 percent which was statistically similar to ET60 percent. This result was consistent with the finding of Songsri et al., 2009 where they found that decreased SLA and increased SCMR were observed due to the effect of water stress. There was an interaction effect between water regimes and varieties on SLA at 80 DAS in 2018. The highest SLA was observed from ET100 percent with Sin-13 and Sin-12 with ET30 percent resulted the lowest value.

3.6 Total dry matter plant-1 (TDM) (g)

The total dry matter continuously increased from 20 DAS to maturity stage. In both experiments, TDM values of all groundnut varieties were highly significant difference for different water regimes and varieties at the harvest stage (Table 2, Table 3). In all water regimes, ET100 percent gave significantly greatest value of TDM and lowest value from ET30 percent. The results were also in agreement with the findings of Ravindra, Nautiyal & Joshi, 1990 where they indicated that under water stress conditions, TDM of groundnut was highly reduced compared with no moisture stress at flowering and pod development stage. Among the varieties, Sin-13 showed significantly higher TDM than other varieties and which was similar to Sin-11 in 2018. Sin-7 showed the lowest TDM values in all water regimes. There was interaction effect between water regimes and varieties on TDM at 1 percent level in 2018 (Table 4). The highest TDM value was observed from ET100 percent with Sin-13 and lowest value was observed from Sin-6 and Sin-12 with ET30 percent.

4. Yield and yield components character

4.1 Harvest index (HI)

Harvest index (HI) values of all groundnut varieties were highly significant different between water regimes and varieties in 2018, however only significant difference was observed among groundnut varieties in 2017 (Table 2, Table 3). The highest value of HI was observed in both years form ET100 percent and the lowest value from ET30 percent. The same results were found by Samsukumar, 1991 who showed that HI of all groundnut genotypes significantly were reduced due to water stress at pod filling and pod maturity stages. Among the varieties, the highest HI values were observed from Sin-11,

Table 2. Effect of different water regimes on yield and yield components of groundnut varieties at harvest stage in 2017 post monsoon season

Treatments	Total dry matter (g)	Harvest index (HI)	No. filled pods plant^{-1}	Shelling (percent)	100 seed wt. (g)	Pod yield (kg ha^{-1})	Seed yield (kg ha^{-1})	WUE (g L^{-1})
Water regimes								
ET100 percent	31.1 a	0.59 a	19.07 a	78.9 a	49.8 a	6112 a	4775 a	1.75
ET60 percent	24.0 b	0.53 b	13.88 b	77.3 b	44.8 b	4247 b	3173 b	1.71
ET30 percent	18 .2c	0.40 c	9.53 c	76.6 b	40.5 c	2427 c	1838 c	1.52
Pr>F	**	**	**	*	**	**	**	ns
LSD $_{0.05}$	3.78	0.04	2.06	1.55	3.17	842	642	0.26
Varieties								
Sin-6	22.7 b	0.51 ab	13.25 ab	79 a	45.0 b	4036 bc	3261 ab	1.55
Sin-7	20.8 b	0.48 b	11.47 b	77 bc	43.5 bc	3457 c	2743 b	1.63
Sin-11	24.6 b	0.54 a	14.86 a	78 b	45.4 b	4644 ab	3239 b	1.86
Sin-12	21.2 b	0.54 a	15.72 a	76 c	40.1 c	3894 bc	2982 b	1.56
Sin-13	32.7 a	0.46 b	15.50 a	77 bc	51.0 a	5278 a	4085 a	1.69
Pr>F	**	*	*	*	**	*	*	ns
LSD $_{0.05}$	4.89	0.05	2.67	1.99	4.09	1087	829	0.33
CV percent	20.72	10.61	19.49	2.67	9.42	26.41	26.31	20.84

Table 3. Effect of different water regimes on yield and yield components of groundnut varieties at harvest stage in 2018 post monsoon season

Treatments	Total dry matter (g)	Harvest index (HI)	No. filled pods $plant^{-1}$	Shelling (percent)	100 seed wt. (g)	Pod yield (kg ha^{-1})	Seed yield (kg ha^{-1})	WUE (g L^{-1})
Water regimes								
ET100 percent	26.5 a	0.55 a	16.3 a	79.0 a	44.3 a	4817 a	3732 a	1.31 b
ET60 percent	21.2 b	0.47 b	12.8 b	77.7 b	41.0 b	3336 b	2547 b	1.55 a
ET30 percent	17.3 c	0.34 c	8.8 c	76.2 b	38.5 c	1962 c	1469 c	1.47 ab
Pr>F	**	**	**	**	**	**	**	*
$LSD_{0.05}$	1.53	0.04	1.29	1.48	1.76	335	287	0.18
Varieties								
Sin-6	20.3 b	0.40 b	11.3 b	79.0 a	43.3 a	2849 c	2253 cd	1.14 c
Sin-7	19.8 b	0.39 b	9,4 c	76.3 c	42.8 a	2687 c	2082 d	1.05 c
Sin-11	23.0 a	0.48 a	12.8 b	76.4 bc	41.1 a	3730 b	2836 ab	1.56 b
Sin-12	20.9 b	0.48 a	12.8 b	78.3 b	36.2 b	3419 b	2561 bc	1.47 b
Sin-13	24.2 a	0.51 a	16.8 a	76.4 bc	42.8 a	4173 a	3182 a	1.99 a
Pr>F	**	**	**	*	**	**	**	**
$LSD_{0.05}$	1.98	0.05	1.66	1.92	2.27	432.80	370.63	0.24
CV percent	9.46	11.92	13.64	2.57	5.69	13.29	14.86	16.97

Means followed by the same letter in each column are not significantly different by LSD at 5 percent level.

ns = no significant, * = significant at 5 percent level, ** = significant at 1 percent level.

Table 4. Combined effect of different water regimes and varieties on total dry matter (TDM), harvest index (HI) and water use efficiency (WUE) in 2018 post monsoon season.

Treatments	TDM (g)	HI	WUE (g L^{-1})
ET100 percent + Sin-6	26.1 ab	0.46 bcd	1.03 fgh
ET100 percent + Sin-7	23.6 bc	0.54 ab	1.10 efgh
ET100 percent + Sin-11	26.6 ab	0.57 a	1.26 defg
ET100 percent + Sin-12	27.0 ab	0.57 a	1.46 cde
ET100 percent + Sin-13	28.9 a	0.59 a	1.67 bc
ET60 percent + Sin-6	21.3 cd	0.46 bcd	1.38 cdefg
ET60 percent + Sin-7	19.5 de	0.41 de	1.23 defgh
ET60 percent + Sin-11	21.7 cd	0.51 abc	1.67 bc
ET60 percent + Sin-12	21.6 cd	0.42 de	1.51 cd
ET60 percent + Sin-13	22.2 cd	0.54 ab	1.96 ab
ET30 percent + Sin-6	13.8 f	0.28 fg	0.99 gh
ET30 percent + Sin-7	16.3 ef	0.22 g	0.83 h
ET30 percent + Sin-11	20.7 cd	0.36 ef	1.75 bc
ET30 percent + Sin-12	14.1 f	0.44 cde	1.42 cdef
ET30 percent + Sin-13	21.7 cd	0.40 de	2.35 a
Pr>F	**	*	*
$LSD_{0.05}$	3.43	0.09	0.41
CV percent	9.46	11.92	16.97

Sin-12 in 2017 and Sin-11, Sin- 12, Sin-13 in 2018 at different water regimes. HI values of groundnut varieties decreased with decreasing water regimes. In 2018, there was an interaction effect between water regimes and varieties on HI at 5 percent level (Table 4). The highest HI was observed from ET100 percent with Sin-13 and the lowest HI was observed from Sin-7 with ET30 percent.

4.2 Number of filled pods plant^{-1}

Number of filled pods plant^{-1} was highly significantly different for all water regimes and varieties in both experiments however only significant difference for groundnut varieties was observed in 2017 (Table 2, Table 3). The highest filled pods plant^{-1} was observed from ET100 percent and the lowest value from ET30 percent. These results are in agreement with the investigations of Távora & Melo, 2001 who explained that water deficit during the growth and development phases of the gynophores and pods decreased the number of pods. Among the varieties, the highest filled pod plant^{-1} was observed from Sin-11, Sin-12, Sin-13 in 2017 and Sin-13 also highest in 2018.

4.3 Shelling percentage (percent)

In both experiments, shelling percent was significantly different between water regimes and varieties however, highly significant difference between water regimes was observed in 2018 (Table 2, Table 3). The highest shelling percent was observed from ET100 percent and lowest value was observed from ET30 percent which was statistically similar to ET60 percent. These results are supported by Patel & Golakiya, 1988 where they stated that shelling percentage was decreased due to water stress at pegging to pod development stages. Shelling percent for all the groundnut tested varieties showed similar trend in both years. Sin-6 resulted the greatest shelling percent and Sin-12 resulted the lowest.

4.4 100 seeds weight (g)

In both years, results of 100 seed weight were highly significant difference between water regimes and varieties (Table 2, Table 3). The highest value of 100 seed weight was observed from ET100 percent while the lowest value was from ET30 percent. These findings were similar to that of Arunachalam & Kannan, 2013 who reported that 100 pods weight and kernel weight were decreased under moisture stress conditions compared to irrigated conditions. In 2017, the highest value of 100 seed weight was observed from Sin-13 and lowest value was observed from Sin-12. Sin-6, Sin-7, Sin-11 and Sin-13 were not significantly different but significantly greater than that of Sin-12 in 2018.

4.5 Pod yield and seed yield (kg ha^{-1})

The results of the effect of different water regimes and varieties on pod and seed yield in both experiments are presented in Table 2 and Table 3. The results were highly significant in both years. The maximum yield was observed from full supplement of water ET100 percent and minimum yield was observed from lowest supplement of water treatment ET30 percent. The results were in agreement with Vorasoot et al., 2003, where they showed that the groundnut agronomic characteristics and grain yield of all cultivars decreased under drought conditions. The highest yield was observed from Sin-13 and the lowest yield was observed from Sin-7. Sin-13 produced the highest yield under all water regimes which could be due to the production of higher leaf area and higher total dry matter at all growth stages over other varieties. Although, there was no interaction effect between water regimes and varieties on pod and seed yield, the highest yield was resulted from the variety Sin 13 with 100 percent water requirement of crop evapotranspiration ET100 percent.

4.6 Water use efficiency (WUE) (g L^{-1})

In 2018 post monsoon season, the values of WUE for different water regimes were significantly difference at 5 percent level and varieties at 1 percent level, however the results were not significantly difference in 2017 (Table 2, Table 3) because there was rainfall during the experimental period. The values of WUE for ET60 percent and ET30 percent were higher than that of ET100 percent in 2018. It could be due to the supplement of proper amount of water for ET60 percent and ET30 percent which is required for normal development of groundnut at all stages to produce yield. The results were in agreement with Dagdelen, Başal, Yılmaz, Gürbüz, & Akcay, 2009 where they reported that WUE increased with deficit in irrigation, and the more severe the deficit, the more efficiently the crop converted water to yield. At ET100 percent, Sin-13 resulted the highest WUE and Sin-7 resulted the lowest WUE. At ET60 percent and ET30 percent, the highest WUE values were observed from Sin-13 followed by Sin-11 and Sin-7 showed the lowest WUE. In 2018, the result showed that there was interaction between water regimes and varieties at 5 percent level on WUE (Table 4). The highest WUE was observed from Sin-13 and followed by Sin-11 with ET30 percent.

5. Conclusion

In both experiments, ET100 percent treatment produced significantly higher results in growth, growth rate, yield and yield components in all tested groundnut varieties. ET60 percent, ET30 percent showed higher SCMR and lower SLA than ET100 percent. Highest SCMR value was obtained from Sin-6 and Sin-12 with ET30 percent. Under three water regimes, SLA values were not different among varieties because of 7 days irrigation interval. In the case of all water regimes, the maximum value of LAI, CGR and TDM were observed from Sin-13. The results showed that, the highest number of filled pods, 100 seed weight, pod yield and seed yield were observed in Sin-13 followed by Sin -11 while Sin-7 produced the lowest value except 100 seed weight at all water regimes. In 2018 post monsoon season, ET60 percent and ET30 percent resulted higher WUE than ET100 percent. At ET60 percent and ET30 percent, Sin-13 produced the highest WUE followed by Sin-11 and the lowest WUE was observed from Sin-7. Judging from the results of present investigation, it can be concluded that for maximum yield production, all tested groundnut varieties should be grown with ET100 percent, if irrigation water is available. If availability of irrigation water is limited, water supplement with ET60 percent could be used to produce reasonable crop yield. Groundnut varieties, Sin-13 and -11 are suitable for all water regimes including stress irrigation.

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Effect of straw and nitrogenous fertilizer application on methane and nitrous oxide emissions from rice production under different water regimes

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Abstract

To study the effect of different nitrogenous fertilizer application with and without straw incorporation on methane (CH_4) and nitrous oxide (N_2O) emissions and yield of rice under different water regimes, the experiment was conducted in Water Utilization Research Section, Department of Agricultural Research at Yezin, Naypyitaw, Myanmar during summer season 2019. Two levels of water regimes : Continuous Flooding (CF) and Alternate Wetting and Drying (AWD) in the main plot and five levels of nitrogenous fertilizer applications with or without straw incorporation: Control (0 kg N ha^{-1}), Urea (85 kg N ha^{-1}), Ammonium Sulfate (85 kg N ha^{-1}), Straw incorporation (5 ton ha^{-1})+ Urea, Straw incorporation + Ammonium Sulfate in the subplot was laid out in split-plot design with three replications. AWD treatments not only reduced CH_4 emission by 63.6 percent and global warming potential (GWP) by 59.8 percent but also saved irrigation water by 13 percent when compared to CF. Rice yield was not significantly different between the water regimes but significantly higher in nitrogen applied plots than control. Application of only nitrogenous fertilizer without straw gave the higher yield and yield components than straw incorporated treatments. Although the lower N_2O emission was observed by the application of straw with nitrogenous fertilizer treatments, straw incorporation emitted greater CH_4 gas and leads to increased GWP than without straw. If the straw is to be incorporated, it would be better to use AWD than CF management. Therefore, to maintain rice yield, AWD with nitrogenous fertilizer application without straw are effective in saving irrigation water, reducing CH_4 emission and leading to reduce GWP.

Keywords: global warming, methane, nitrous oxide, rice production, water management

1. Introduction

Global warming, the most prominent environmental issue all over the world, is caused by the increasing concentration of greenhouse gases (GHGs) in the atmosphere. The global average temperature was forecasted to rise from 1.4°C to 5.8°C from 1990 to 2100 (Intergovernmental Panel on Climate Change [IPCC], 2001). Such changes are expected to have a great impact on the ecosystem of the earth. Carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) are dominant greenhouse gases which contribute to about 60 percent, 20 percent, and 6 percent of the global warming potential, respectively (Solomon et al., 2007). CH_4 and N_2O are second and third most important anthropogenic greenhouse gas after CO_2 in the atmosphere, and 25 and 298 times higher in global warming potential than CO_2 at 100-year time horizon (IPCC, 2007). There is an urgent need to reduce GHG emissions to the atmosphere to mitigate the adverse impacts of climate change.

Rice (Oryza sativa) is the most important staple food for more than half of the world's population and is grown in 114 countries over a total area of around 153 million ha, which is 11 percent of the world's arable land (FAOSTAT, 2011). Rice production should be increased by 40 percent by the end of 2030 to meet rising demand from a growing

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world population (Food and Agricultural Organization of the United Nations [FAO], 2009). Barker et al. (1999) reported that in Asia, irrigated agriculture accounted for 90 percent of total diverted fresh water and more than 50 percent of this is used to irrigated rice. Water saving rice cultivation system is essential to maintain food security due to increasing fresh water scarcity. Moreover, flooded rice and irrigated lowland rice production systems are known to be significant sources of anthropogenic CH_4 and N_2O. Estimates of global CH_4 emissions from paddy soils range from 31 to 112 Tgy−1; accounting for up to 19 percent of total emissions, while 11 percent of global agricultural N_2O emissions come from rice fields (United States Environmental Protection Agency [US-EPA], 2006 and IPCC, 2007). Under conventional flooded rice fields, high CH_4 emission may be expected by anaerobic decomposition of organic matter. Htay et al. (2017) observed that alternate wetting and drying (AWD) technology not only reduced methane emission rate of about 60-70 percent but also reduced the amount of water used and increased water use efficiency. However, AWD can result increased N_2O emissions due to repetition of alternate nitrification and denitrification (Xu et al., 2015). Therefore, it is needed to compare the AWD with traditional continuous flooding for its effect on CH_4 and N_2O emissions.

Nitrogenous fertilizer application is essential for rice production and is the most important practice associated with direct or indirect CH_4 and N_2O emission (Venterea et al., 2011).Urea, a commonly used nitrogenous fertilizer in Asian countries can reduce CH_4 emission by stimulating CH_4 oxidizing bacteria in the rhizosphere. However, Watanabe (1999) observed that application of urea indirectly increased CH_4 emission through improving the growth of rice plant. Studies have shown that urea applied to puddled lowland rice fields is prone to high gaseous losses, particularly by ammonia volatilization and denitrification to the volatile forms, N_2O and N_2 (Mikkelsen et al. 1978) . Sandeep et al. (2016) reported that the application of ammonium sulfate significantly reduces CH_4 emission from rice fields. However, other studies found the higher N_2O emission from Ammonium sulfate than from the urea (Zucong et al., 1997). Therefore, there is a need to know and compare the effects on CH_4 and N_2O emission from rice cultivation by the application of urea and ammonium sulfate.

Application of rice straw to paddy fields significantly increases the CH_4 emission rate (Aulakh et al., 2001). However, in recent decades, plant residues have commonly been scattered on the soil surface during harvesting with a combine harvester. Thus, after monsoon rice harvesting, the residues often experience aerobic decomposition at or inside the near-surface layer during the post monsoon fallow season. It is needed to study on CH_4 and N_2O emissions from rice field as affected by straw incorporation at the previous season under aerobic condition. Therefore this experiment was conducted with objectives: (1) to study the CH4 and N_2O emissions as affected by different water regimes in rice production, (2) to investigate the effect of different nitrogenous fertilizer application with and without previous straw incorporation on CH_4 and N_2O emissions under different water regimes in rice production and (3) to evaluate the effect of straw and nitrogenous fertilizer application and their combination on yield and yield components of rice.

2. Materials and methods

The experiment was conducted at the Water Utilization Research Section of the Department of Agricultural Research (DAR) in Yezin, Naypyitaw, Myanmar (19° 38′ N, 96° 50′ E) during summer season from November 2018 to June 2019. The experiment was laid out in a split-plot design with three replications. Two levels of water regimes: Continuous Flooding (CF) and Alternate Wetting and Drying (AWD) were arranged in the main plot and five levels of nitrogenous fertilizer applications with or without straw incorporation: Control (0 kg N ha^{-1}), Urea (85 kg N ha^{-1}), Ammonium Sulfate (85 kg N ha^{-1}), Straw incorporation (5 ton ha^{-1}) + Urea, Straw incorporation (5 ton ha^{-1}) + Ammonium Sulfate assigned in subplot. There were 30 experimental units using concrete tank with the size of (1.8m×0.9m ×0.5m) as individual unit. In the experiment, the rice straw (5 ton ha^{-1}) was incorporated after the monsoon rice harvesting about 95 days before summer rice sowing in mid-November 2018.

Soil preparation was done during March 2019 and twenty one-day-old seedlings of Thee Htat Yin variety (110-115 days) were transplanted into the experimental plot at 20 cm × 20 cm spacing during the middle of March. Triple superphosphate (18.5 kg P ha^{-1}) was applied at basal and nitrogenous fertilizers and muriate of potash (31 kg K ha^{-1}) were applied four equal splits at recovery, tillering, panicle initiation and flowering stages. The properties of initial soil samples before straw incorporation collected from at 0-15 cm depth is mentioned in Table 1. In this experiment, rice straw before incorporation contained 1.1 percent N and 43.4 percent organic carbon with C: N ratio of 39.5.

In CF treatment, the plots were maintained 5 cm water depth above the soil surface throughout the growing season. Two weeks after transplanting, AWD treatment was started and it continued until 14 days before harvest. The timing of irrigation in the AWD plots was based on the water depth in the field water tube installed in all plots. When the water level reached 15 cm below the soil surface, the plot was irrigated up to 5 cm above the soil surface. During one week before and after flowering, all experimental units were maintained 5cm water depth.

The CH_4 and N_2O fluxes from the paddy fields were measured using the closed chamber method (Minamikawa et al. 2015). The glass rectangular chamber with a basal area of (0.5 m × 0.5 m) and 1m height was used. Plant density inside the chamber was four hills. A small fan and a digital thermometer were installed inside the chamber. The measuring frequency was weekly from five days after transplanting to harvesting for the estimation of seasonal emissions of CH_4 and N_2O. Measuring time of the sampling day was mid-morning (08:00 to 11:00) to obtain the daily mean CH_4 and N_2O flux from all treatments at the same timing. On each sampling day, three gas samples per chamber deployment were collected at 0, 20, and 40 minutes with sampling bags. The air temperature inside the chamber was measured at the time of gas sampling. The concentrations of collected gas samples were determined using gas chromatography (GC 2010, Shimadzu Corporation, Kyoto, Japan) equipped with a flame ionization detector (FID) for detection of CH_4 and electron capture detector (ECD) for N_2O. The hourly gas flux of CH4 (mg CH_4 m^2 h^{-1}) and N_2O (ug N m^2 h^{-1}) were calculated by using the following equation (Minamikawa et al., 2015).

$$\text{Flux } CH_4 = \Delta C/\Delta t \times V/A \times p \times [273/ (273 + T)]$$

$$\text{Flux } N_2O = \Delta C/\Delta t \times V/A \times p \times [273/ (273 + T)] \times 28/44$$

$\Delta C/\Delta t$ = concentration change over time (ppm CH_4 h^{-1}) or (ppb-N_2O h^{-1})

V= chamber volume (m^3)

A=chamber area (footprint; m^2)

p =gas density (0.717 kg m^{-3} for CH_4 and 1.9777 kg m^{-3} for N_2O at 0°C)

T =the mean air temperature inside the chamber (°C)

Daily fluxes equal hourly fluxes multiplied by 24.The seasonal total (cumulative flux) CH_4 and N_2O emissions were calculated by successive linear interpolation of average gas emissions on the sampling days.

Table 1. Physicochemical properties of experimental soil before doing the experiment

Soil properties	Result
Texture	Loamy Sand
Bulk density (gcm^{-3})	1.51
pH	7.12 (Neutral)
Total N (percent)	0.07
Organic Carbon (percent)	0.5 (Very Low)
C: N	7.1
Available N (mg kg^{-1})	12.6 (Very Low)
Available P (mg kg^{-1})	14.9 (Medium)
Available K(mg kg^{-1})	510.7(High)

Global warming potential is an index defined as the cumulative radiative forcing between the present and some chosen later time "horizon" caused by a unit mass of gas emitted now. In GWP estimation, CO_2 is typically taken as the reference gas and an increase or reduction in emission of CH_4 and N_2O is converted to "CO_2 equivalents" through their GWPs (Hou et al., 2012). The GWP was calculated using the following equation.

GWP (kg CO_2-eq ha^{-1}) = ($TCH_4 \times 34 + TN_2O \times 298$) where TCH_4 and TN_2O are the total amounts of each gas emission (kg ha-1), and 34 and 298 are the IPCC's GWPs for CH_4 and N_2O, respectively, to CO_2 over a 100-year time horizon (IPCC, 2013).

Irrigation water use for all treatments was measured using digital flow meter. The yield components such as number of panicles $hill^{-1}$, number of spikelets $panicle^{-1}$, filled grain (percent) and 1000 grain weight (g) were measured from 4 sample plants per plot. The grain yield was also measured from the harvested area. The data were subjected to analysis of variance by using Statistix (Version 8.0) and mean comparison was done by the least significant difference (LSD) at 5 percent level.

3. Results and discussion

3.1 Weather condition

The total rainfall during the experimental period was 102.5 mm (Figure 1). The average air temperature in straw incorporation period and rice-growing period ranged from 22.6°C to 31.2 °C. The higher air temperature occurred during flowering and ripening growth stages.

3.2 Methane fluxes

The trend of CH_4 fluxes over the whole rice growing period was affected by the different water regimes as seen in Figure 2A). The first small peak was observed at maximum tillering stage.CH_4 flux showed an increasing trend until the full flowering period and then at 66 days after transplanting (DAT), decreased suddenly until harvesting. The CH_4 flux from CF was much greater than those from the AWD. CH_4 emission was significantly affected by different nitrogenous fertilizer applications with or without straw incorporation (Figure 2B).

The highest CH_4 emission was observed from straw incorporation with urea and from straw incorporation with ammonium sulfate at the maximum tillering stage. When considering under CF, the CH_4 fluxes from the rice straw incorporated plots were significantly higher than those from the without straw plots throughout the flooding period (Figure 2C). These results were in agreement with the findings of Naue (1993), who observed that the flooding in irrigated rice fields produces anaerobic soil conditions that are conducive to the production of CH_4 from the decomposition of soil organic matter and added organic materials such as rice straw residues. It also showed that straw incorporation with ammonium sulfate emitted more CH_4 than Straw incorporation with urea under CF. Under AWD condition, the highest emission rate was observed in straw with ammonium sulfate while the lowest trend observed in only ammonium sulfate application.

Figure 1. Monthly rainfall and average temperature during the experimental period

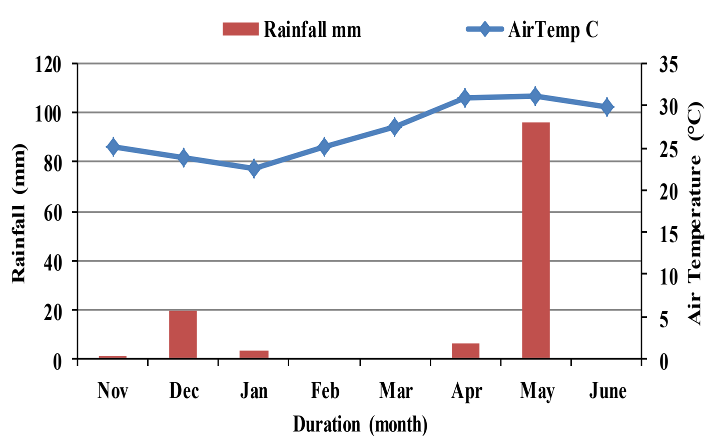
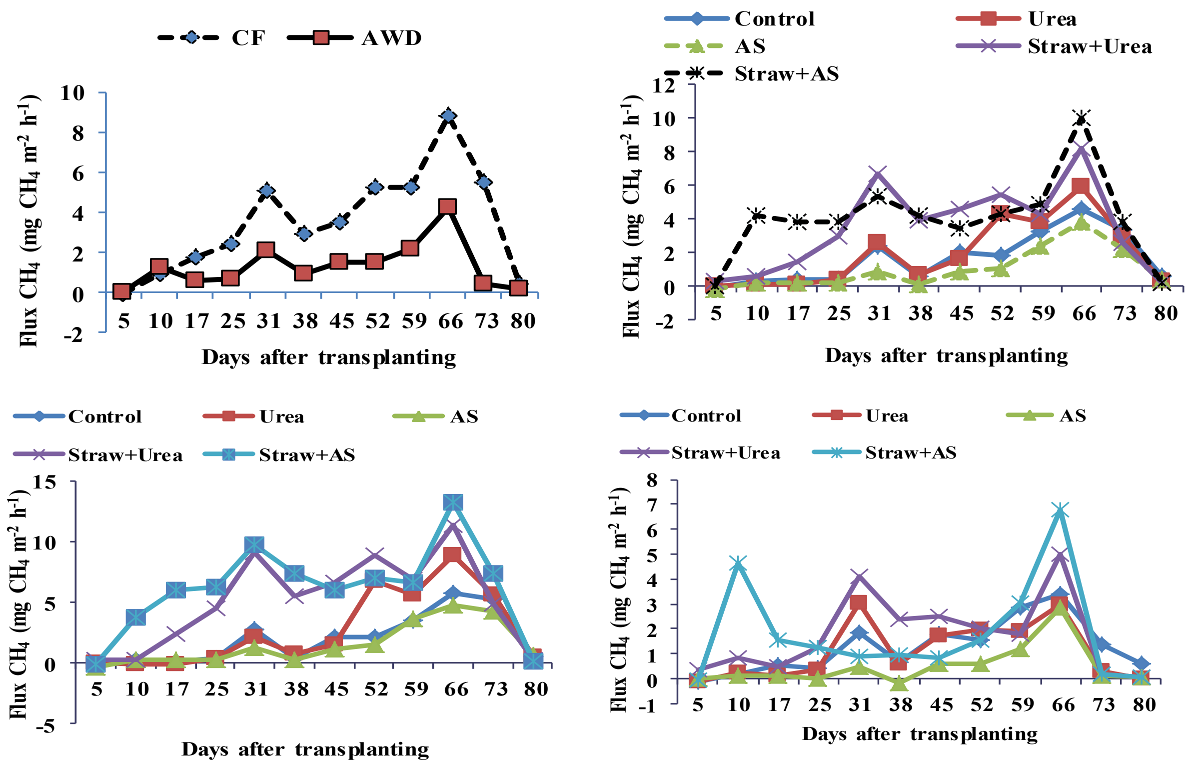


Figure 2. Trend of CH_4 flux under different water regimes (A), under different nitrogenous fertilizer with and without straw incorporation (B), under continuous flooding (C) and under alternate wetting and drying conditions (D)



Aulakh et al. 2001 stated that the application of sulfate (SO_4) containing fertilizers to rice soil reduced CH_4 fluxes because SO_4 reducers in the presence of SO_4, could outcompete methanogens for substrates such as acetate and H_2, resulting in an inhibition of CH_4 formation.

3.3 Cumulative CH_4

The cumulative CH_4 was significantly different ($pr<0.05$) between the water regimes however highly significant difference ($pr<0.01$) was observed among the nitrogenous fertilizers and straw incorporation treatments (Figure 3). The higher cumulative CH_4 emission was observed in CF than AWD (Figure 3A). AWD reduced the cumulative CH_4 emissions by 63.6 percent as compared to CF. Cumulative CH_4 emission was significantly higher in straw incorporation treatments than without straw treatments (Figure 3B). Straw incorporated with urea produced 14 percent less of CH_4 as compared to straw incorporated with ammonium sulfate. Application of ammonium sulfate incorporated with straw produced the greater cumulative CH_4 emission than application of only ammonium sulfate, urea, and control treatment by 74 percent, 52 percent and 58 percent respectively. The amount of CH_4 from rice straw incorporated with nitrogen fertilizers under CF was much greater than that from the other plots (Figure 3C).

3.4 Nitrous oxide fluxes

The highest N_2O emission peak was detected after first fertilization and when the soil was drying under AWD treatments, and then suddenly decreased (Figure 4). The small peaks were detected towards crop maturity. There was no significant effect of water regimes and also different nitrogen fertilizer application with or without straw incorporation on N_2O emission rate.

3.5 Cumulative N_2O

There was no significant difference in cumulative N_2O emission between different irrigation

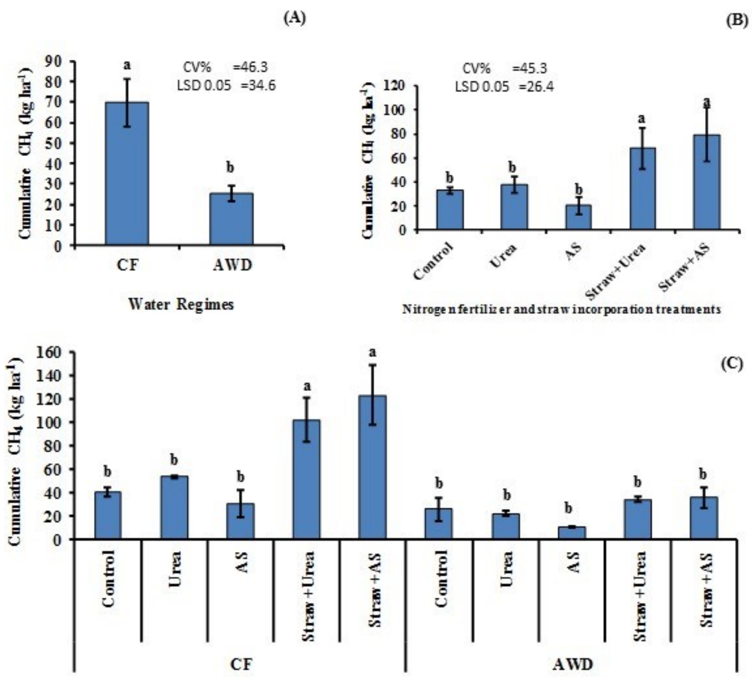


Figure 3: Cumulative CH_4 emissions from rice cultivation as affected by different water regimes (A) nitrogenous fertilizer and with and without straw incorporation (B) interaction of water regimes and nitrogen fertilizer application with and without straw incorporation(C). Vertical bars represent standard error of the mean. The same letters above each column indicate no significant difference among treatments using LSD at 5 percent level

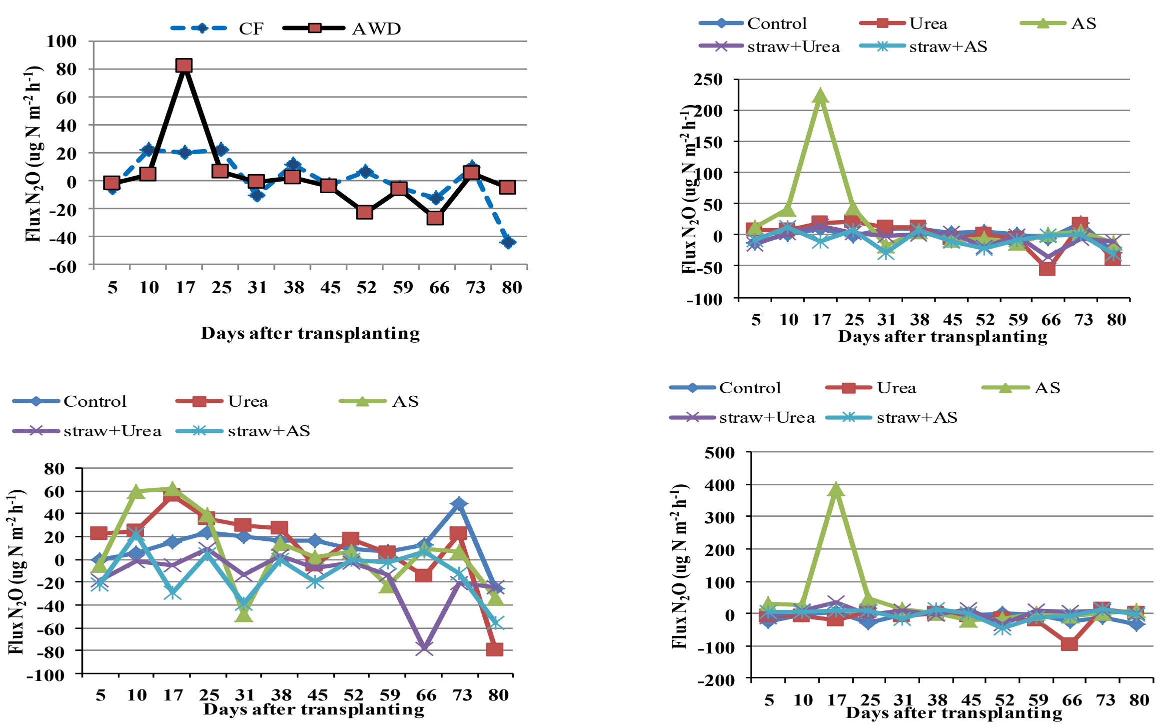


Figure 4: Trend of N_2O flux under different water regimes (A), under different nitrogenous fertilizer with and without straw incorporation (B), under continuous flooding (C) and under alternate wetting and drying conditions (D)

Figure 6. Global warming potential from rice production as affected by different nitrogenous fertilizer and with and without straw incorporation under different water regimes. Vertical bars represent standard error of the mean. The same letters above each column indicate no significant difference among treatments using LSD at 5 percent level

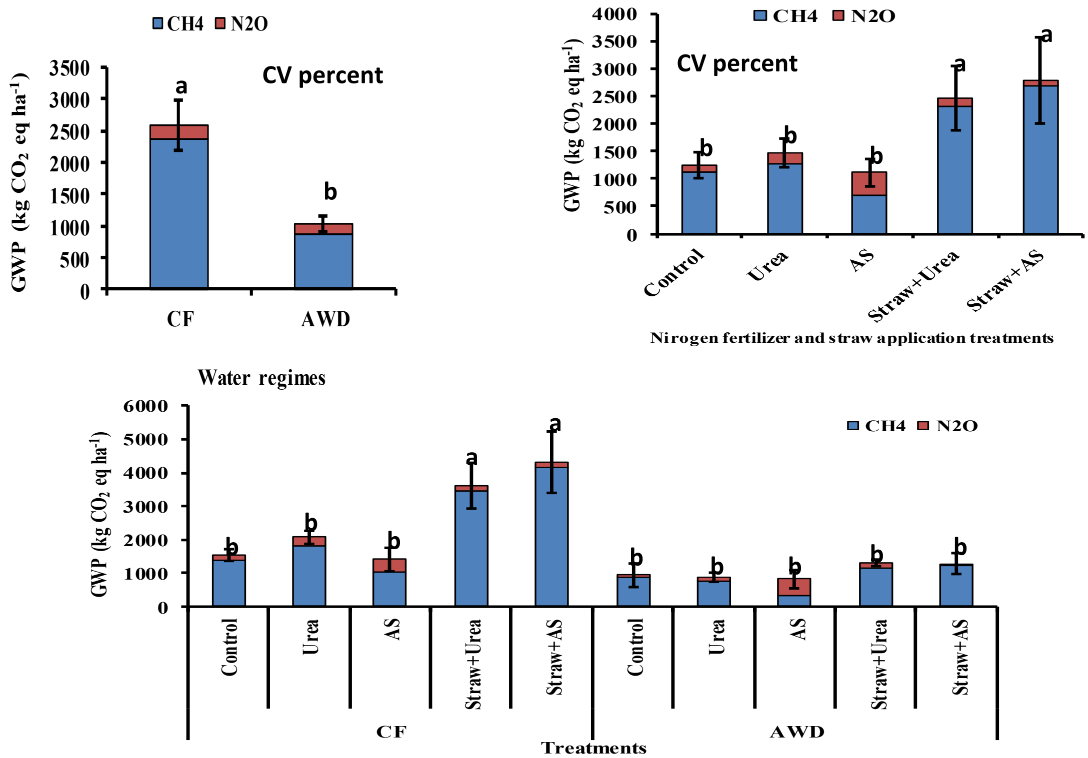
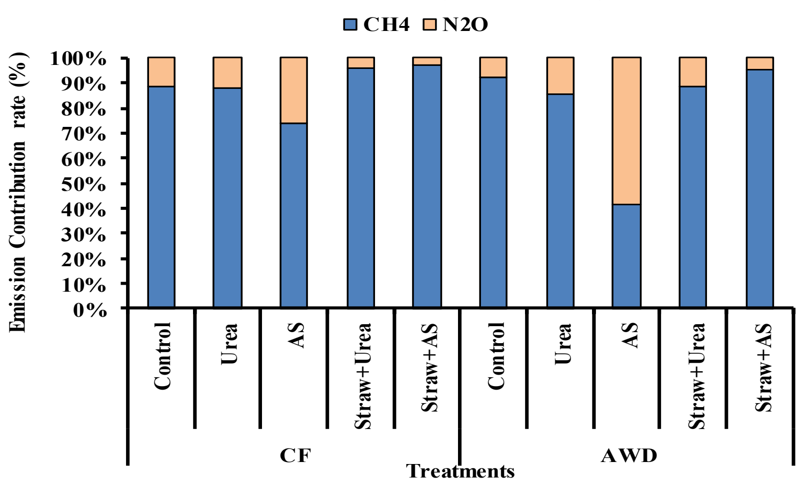
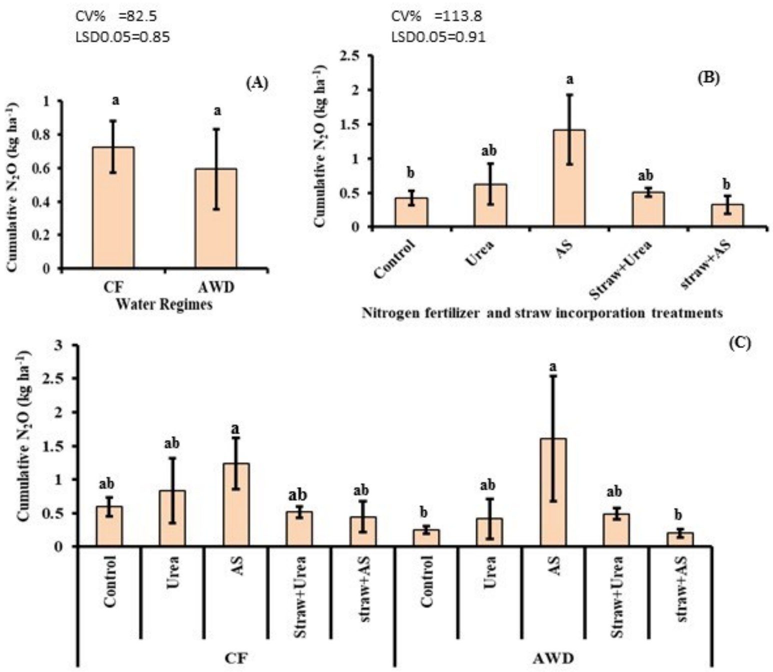


Figure 7. Emission contribution of CH_4 and N_2O to global warming potential from rice production



practices and among the application of nitrogenous fertilizer with and without straw incorporation (Figure 5). Also no interaction was observed between water regimes and straw and nitrogenous fertilizer application on cumulative N_2O emission. The higher amount of N_2O emission was observed in CF than the AWD treatment. Application of only ammonium sulfate emitted a higher cumulative N_2O than that from the application of only urea treatment.

Figure 5. Cumulative N_2O emissions from rice cultivation as affected by different water regimes (A) nitrogenous fertilizer and with and without straw incorporation (B) interaction of water regimes and nitrogen fertilizer application with and without straw incorporation(C). Vertical bars represent standard error of the mean. The same letters above each column indicate no significant difference among treatments using LSD at 5 percent level.



These findings were similar to Wang et al. (2017) where; they observed that SO_4 concentration was significantly and positively correlated with soil N_2O emissions. Rikmann et al. (2012) also reported that sulfate, as an oxidant, could facilitate the oxidation of NH_4^+, which could then enhance the production of N_2O. However, the opposite result was observed in this experiment when ammonium sulfate was applied in the straw incorporated plot, cumulative N_2O emission was decreased even lower than the control. Under both water regimes, the lowest cumulative emission of N_2O was observed in the ammonium sulfate incorporated with straw.

3.6 Global warming potential

CF practice induced significantly higher global warming potential (GWP) than AWD practice (Figure 6). GWP from AWD was 59.8 percent lower as compared to CF. Under the CF condition, nitrogenous fertilizer incorporated with straw treatments significantly increased GWP as compared to without straw incorporated treatments. Under AWD water management, the application of nitrogenous fertilizers with or without straw incorporation was not significantly different in GWP.

Average over the nitrogenous fertilizer and straw incorporation treatments, the contribution of CH_4 emissions to GWP was higher under CF (92 percent) than under AWD (83 percent).The percentage of the GWP resulting from N_2O emissions ranged from 3 to 26 percent under CF and 5 to 58 percent under AWD (Figure 7).

3.7 Yield and yield components of rice

There was no significant difference in the number of panicles hill^{-1}, the number of spikelets panicle^{-1}, filled grain (percent) and 1000 grain weight (g) and also harvest index in different water regimes (Table 2). However, all yield components except the number of spikelets panicle-1 were highly significantly different (pr<0.01) within the nitrogen fertilizer application with or without straw incorporation. Grain yield was not significantly different in water regimes, but nitrogenous fertilizer application with or without straw incorporation significantly affected the rice yield.

Table 2. Yield, Yield components and Harvest Index of rice as affected by different nitrogenous fertilizer and straw incorporation under different water regimes

Treatments	No. of panicles hill^{-1}	No. of spike-lets panicle^{-1}	Filled grain (percent)	1000 grain weight (g)	Yield (g plot^{-1})	Harvest Index
Water						
CF	13.80	155.52	47.30	21.12	90.19	0.33
AWD	14.00	151.30	41.27	21.67	77.08	0.30
LSD $_{0.05}$	2.63	15.1	18.77	1.66	40.9	0.16
Nutrient						
Control	12.08 b	146.47	21.89 b	20.75 b	32.55 c	0.18 b
Urea	14.71 a	158.55	52.30 a	21.68 a	106.07 a	0.35 a
AS	14.63 a	158.61	52.96 a	21.78 a	106.87 a	0.37 a
Straw+Urea	13.54 ab	151.35	44.90 a	21.35 a	79.17 b	0.32 a
Straw+AS	14.54 a	152.07	49.36 a	21.42 a	93.55 ab	0.35 a
LSD $_{0.05}$	1.7	12.7	8.77	0.43	23.43	0.07
Pr>F						
Water(W)	ns	ns	ns	ns	ns	ns
Nutrient(N)	*	ns	**	**	**	**
W*N	ns	ns	ns	ns	ns	ns
CV a (per-cent)	12.0	6.3	26.9	2.5	31.1	32.4
CV b (per-cent)	9.9	6.8	16.2	1.7	22.9	19.1

Means followed by the same letter in each column are not significantly different by LSD at 5 percent level.
ns=no significant, *=significant at 5 percent level, **= significant at 1 percent level

The maximum yield and yield components were observed form the application of only ammonium sulfate or only urea plots followed by the application of ammonium sulfate incorporated with straw treatments. The minimum yield was obtained from control plots. There was no interaction between different water regimes and nitrogen fertilizer application with or without straw incorporation in grain yield.

3.8 Total water use

In CF, total water use and the number of irrigation were significantly higher than AWD (Table 3). The irrigation frequency was 50 percent lower in AWD while saving irrigation water by 13 percent as compared to farmer practices. Application of nitrogenous fertilizer with or without straw incorporation resulted in the higher water use efficiency (WUE) than control treatment.

4. Conclusion

AWD practices produced no significant difference in yield and yield components as compared to CF. AWD treatments not only reduced CH_4 emission by 63.6 percent, N_2O emission by 18.2 percent and GWP by 59.8 percent but also saved irrigation water by 13 percent when compared to CF. Rice yield was significantly increased by the application of nitrogenous fertilizers with and without straw incorporation when compared to control. According to this result, application of nitrogen fertilizer is needed to improve yield of rice. Application of only nitrogenous fertilizer without straw gave the higher yield and yield components than the straw incorporated treatments. Although the lower N_2O emission was observed in the application of straw with nitrogenous fertilizer treatments, it emitted greater CH_4 gas and leads to increased GWP. Based on the results of present investigation, it can be concluded that to maintain rice yield, AWD with nitrogenous fertilizer application without straw are effective in saving irrigation water, reducing CH_4 emission and leading to reduce GWP. If the straw is to be incorporated, it would be better to use AWD than CF management.

Table 3. Total water use and water use efficiency of rice as affected by different nitrogenous fertilizers with or without straw incorporation under different water regimes

Treatments	Number of irrigation	Total water use (mm)	Water use efficiency (g L^{-1})
Water			
CF	33.20 a	1307.1 a	0.28
AWD	16.73 b	1149.8 b	0.29
LSD $_{0.05}$	3.6	84.7	0.09
Nutrient			
Control	24.33	1147.8 c	0.10 b
Urea	25.66	1293.6 a	0.36 a
AS	25.66	1254.4 ab	0.34 a
Straw+Urea	24.00	1194.9 bc	0.29 a
Straw+AS	25.16	1251.3 ab	0.35 a
LSD $_{0.05}$	1.62	66.2	0.08
Pr>F			
Water(W)	**	*	ns
Nutrient(N)	ns	**	**
W × N	ns	ns	ns
CV a (percent)	9.2	4.4	17.7
CV b (percent)	5.3	4.4	25.0

Means followed by the same letter in each column are not significantly different by LSD at 5 percent level. ns = no significant, *=significant at 5 percent level, **= significant at 1 percent level

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Effects of Water Saving Technique and Rice Varieties on Methane Emissions from a Paddy Field, Myanmar

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Abstract

Myanmar is an agricultural country, mainly cultivating paddy rice. Agriculture is vulnerable to changing climate threating on food security. Climate change is caused by natural and anthropogenic activities. Greenhouse gases (GHG) emission, especially methane (CH_4), from paddy production is one of the anthropogenic activities to climate change. The methane is emitted to the atmosphere mainly through the plant, ebullition and diffusion. Therefore, the methane emission will be different depending on the different rice varieties. The methane emissions from conventional rice production are largely associated with its water use creating the anaerobic soil environments that drive microbial methane production. The present study was conducted at the Department of Plant Breeding, Physiology and Ecology, Yezin Agricultural University during the summer season (January to May) in 2019. Split plot design was used with three replications. Water managements i.e. alternate wetting and drying (AWD) and continuous flooding (CF) were used as main plot factor and three rice varieties (Thai Hnan Khauk, Thee Htet Yin and HHZ-3-SAL 4-Y1-Y1) were assigned to subplot. Among the different rice varieties, methane emission of Thee Htat Yin was higher than Thai Hnan Khauk and HHZ-3-SAL 4-Y1-Y1 in both AWD and CF. In water regimes, there was significant difference on methane emission. CF (14.7 $mgCH_4m^{-2}h^{-1}$) emitted five times more methane than AWD (2.9 $mgCH_4m^{-2}h^{-1}$). The methane emissions were high at 35 DAT (during effective tillering stage) and 77 DAT (during flowering stage). AWD is a water management technique that can reduce water use in rice cultivation with mitigating climate change.

Keywords: *Alternative wetting and drying (AWD), rice varieties, methane emission*

1. Introduction

Rice is mostly cultivated under flooded soil condition. Water, either from rainfall or supplied to rice farms through a man-made irrigation, is an essential input in rice production. The rice ecosystems of Myanmar include irrigated lowland, rainfed lowland, deep water, and upland. More than 75 percent of the world's rice is produced in irrigated rice lands, which are predominantly found in Asia (Hoek et al., 2001).

The abundant water environment in which rice grows best differentiates it from all other important crops. There is a great need to increase the productivity of water in rice irrigation systems in a sustainable way.

To allow farmers to actively reduce their water use and associated costs, or save water for other purposes or times (Bouman 2007), various water saving irrigation techniques have been developed. One such technology, developed in the 1990s by the International Rice Research Institute (IRRI), is alternate wetting and drying (AWD) irrigation (Price et al., 2013). AWD is a water-saving technology that farmers can apply to reduce their irrigation water consumption in rice fields without decreasing its yield. This method has become a recommended practice in water-scarce irrigated rice areas in South and Southeast Asia. In the Philippines, the adoption

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of safe AWD started in Tarlac Province in 2002 with farmers using deep-well pump systems (Lampayan et al., 2009). IRRI has been promoting AWD as a smart water-saving technology for rice cultivation through national agricultural research and extension in Bangladesh, the Philippines and Vietnam.

AWD reduced global warming potential by 45-90 percent compared to continuously flooded systems (Linquist et al., 2014.) There have been worldwide efforts to promote AWD in rice in an attempt to reduce GHG emission. The intermittent drainage reduced the GHG (CH_4 and nitrous oxide, N_2O) emissions by 37 percent compared to continuous flooding in South Kalimantan, Indonesia (Hadi et al., 2010). However, there is limited information on the feasibility of AWD as a way to achieve less GHG emissions, including CH_4 and N_2O, and maintain rice yields in local situation, especially for tropical region. Rice fields using this technology are alternately flooded and dried. The number of days of drying the soil in AWD can vary according to the type of soil and the cultivar from 1 day to more than 10 days. Rice cultivation is responsible for 10 percent of GHG emissions from agriculture (CTCN 2009).

Rice cultivation is a major source of a potent GHG, methane (CH_4), contributing to about 11 percent of the global anthropogenic CH_4 emissions (Ciais et al., 2013). Wassmann et al. (2000) reported that, among rice ecotypes, irrigated rice emits approximately 70–80 percent of CH_4 from the global rice area, followed by rainfed rice (15 percent) and deep-water rice (10 percent). One practice that has been shown to reduce water use in rice systems is an irrigation management practice referred to as Alternate Wetting and Drying (AWD) (Linquist et al., 2014; Lampayan et al., 2015). AWD has been reported to reduce water inputs by 23 percent (Bauman and Tuong, 2001) compared to continuously flooded rice systems. And also, one of the ways of rice cultivation coping with the drought or water scarcity is reduction of water use, particularly irrigation water, because rice does not need to be submerged in water all time to grow. AWD involves technology that tackles water scarcity in irrigated rice cultivation and has the potential to contribute to a more sustainable and effective water and energy use. In AWD system, the AWD tool is needed to check water level in rice field for deciding the time of irrigation. AWD tool made with PVC pipe of 30 cm long, and have a diameter of 10−15 cm so that the water table is easily visible, and it is easy to remove soil inside. The tube was perforated with many holes on all sides so that water can flow readily in and out of the tube. It was controlled at 5 cm and was allowed to dry out naturally to 15 cm below the soil surface (IRRI's “safe AWD” recommendations) (Siopongco et al., 2013). AWD was continuously flooded during flowering and grain formation stages to prevent yield reductions (Bouman 2007). AWD also has the potential of reducing greenhouse gas (GHG) emissions, especially methane (Wassmann et al., 2010).

In this study, field experiment was conducted to compare the methane emission from different rice varieties (Thee Htet Yin, Thai Hnan Khauk and super green rice (HHZ-3-SAL 4-Y1-Y1) with two water management techniques including continuous flooding (CF) and alternate wetting and drying (AWD).

2. Materials and methods

2.1 Experimental design and treatments

The experiment was conducted at the field of Department of Plant Breeding, Physiology and Ecology, Yezin Agricultural University during the summer season (January to May) 2019. This experiment was laid out in split-plot design with three replications. Two water management techniques (AWD and CF) were used as main plot factor, and three rice varieties - high yielding variety (Thee Htet Yin), hybrid rice (Thai Hnan Khauk) and Super Green Rice (HHZ-3-SAL 4-Y1-Y1)) were used as subplot factor.

Triple super phosphate (62.7 kg ha^{-1}) was applied as basal fertilizer, and Urea (188.2 kg ha^{-1}) and Potash (62.7 kg ha^{-1}) were applied at vegetative stage, reproductive stage and flowering stage for equal splits. Each plot was $5m^2$ and the fully five-leaf aged seedlings (21 day old seedlings) were transplanted at single seedling per hill with the spacing of 25 cm × 25 cm.

The average temperature was higher in April (40.2 °C) and lower in January (31.8 °C). The higher average temperature occurred in flowering stage. In this experiment period, the total rainfall was 6.4 inches (Figure. 1).

2.2 Data collection

SPAD-502 chlorophyll meter (Konica Minolta, Tokyo, Japan) was used to determine chlorophyll content at flowering stage because chlorophyll content will be higher at this condition. Plant height (cm), panicle length (cm), above- ground biomass weight (grain and straw), number of panicle per hill, filled grain percent, 1 000 grain weight (g) and yield per hectare (ton ha^{-1}) were collected at harvest time.

2.3 Methane calculation

Methane gas was collected at 14 days after transplanting until harvest at weekly interval by using closed chamber method. The transparent glass chambers (45 cm length, 45 cm width and 90 cm height) was placed in the field each covering four rice hills. The chamber was equipped with a battery -operated small fan to ensure the inside gas mixing during chamber setup. The temperature inside the chamber was recorded using a thermometer during gas collection. After 15 minutes deploying the chamber, the gas was collected into the gas sampling bags, which were evacuated, by using air pump from 8:30 am until 10:00 am and four times (0, 30, 60 and 90 minutes) in each treatment for gas flux calculation. CH_4 concentration was analyzed with a gas chromatograph (GC 2030, Shimadzu Corporation, Kyoto, Japan) equipped with a flame ionization detector (FID). The amount of CH4 fluxes was calculated by using the following equation;

$$\text{Flux } CH_4 = \Delta C/\Delta t \times V/A \times \rho \times (273/((273+T)))$$

Where, ΔC / Δt = the concentration change over time (ppm CH4),V = chamber volume (m^3),A = chamber area (m^2) , P = gas density (0.717 kg m^3 for CH_4), T = the mean of air temperature inside the chamber(˚C) (Minamikawa et al., 2015)

2.4 Data analysis

The data was statistically analyzed using Statistical Tool for Agricultural Research (STAR, Version 2.0.1) and mean comparison was computed with the use of Least Significant Difference (LSD) test at 5 percent level.

3. Results and discussion

3.1 Yield and yield components

The mean values of agronomic characters and yield components of rice varieties as affected by water regimes are presented in Table 1. The water regimes did not significantly affect on SPAD reading, biomass weight, plant height, panicle length, no. of spikelet $panicle^{-1}$, 1 000 grain weight and harvest

Figure 1. Daily rainfall distribution, maximum and minimum temperatures during the summer rice growing seasons, 2019

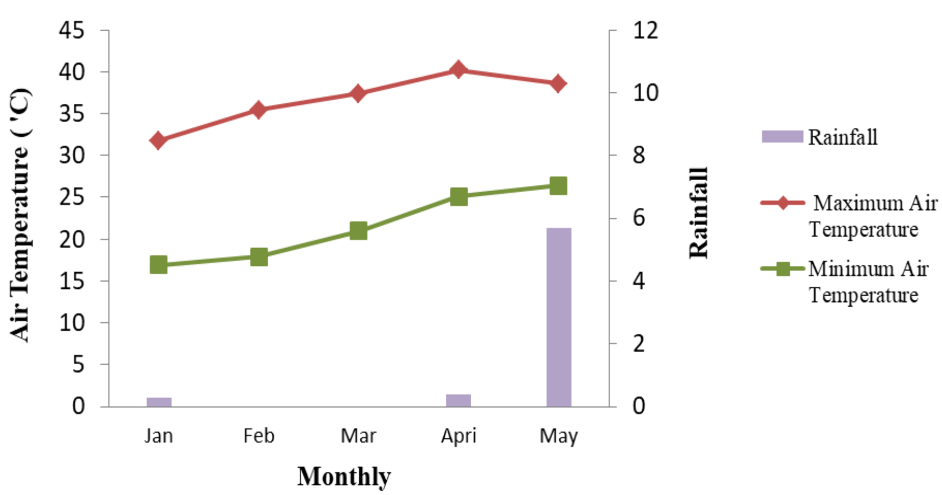


Table 1. Mean values of agronomic characters and yield components of rice varieties as affected by water regimes

Treatment	SPAD Reading	Biomass weight (g)	Plant height (cm)	Panicle length (cm)	No. panicle $hill^{-1}$	No. spikelets $panicle^{-1}$	Filled grain percent	1 000 grain.wt (g)	Harvest Index
Water Regimes									
CF	42.0	81.3	163.6	24.2	16.7 b	145.2	82.1 b	24.2	0.6
AWD	43.3	92.3	166.6	24.5	18.1 a	133.2	84.6 a	25.1	0.5
$LSD_{0.05}$	3.9320	27.646	5.5481	0.8638	0.4781	17.547	1.2208	1.2132	8.9628
Varieties									
Thai Hnan Khauk	41.3	68.6 b	163.2 b	24.0 b	15.3 b	109.0 c	88.6 a	29.8 a	0.7
Thee Htet Yin	45.0	85.8 b	150.6 c	24.1 b	19.2 a	142.7 b	78.5 b	21.6 c	0.6
HHZ-3-SAL 4-Y1-Y1	41.5	106.0 a	181.4 a	25.1 a	17.7 a	168.9 a	83.0 ab	22.5 b	0.5
$LSD_{0.05}$	3.4943	17.6701	2.9856	0.7933	1.7472	16.5498	2.5454	0.4640	12.293
Pr>F									
Water regimes	0.2849	0.2304	0.1421	0.1779	0.0059	0.0755	0.0120	0.0818	0.0639
Varieties	0.0701	0.0039	0.0000	0.0273	0.0031	0.0001	0.0001	0.0000	0.1170
Water regimes & Varieties	0.6940	0.7311	0.1020	0.1772	0.5654	0.8676	0.0104	0.5447	0.9738
CV_a percent	4.55	15.71	1.66	1.75	1.36	6.17	0.72	2.29	7.65
CV_b percent	6.16	15.29	1.36	2.44	7.55	8.87	2.29	1.41	15.98

*significance at 5 percent level, ** highly significance at 1 percent level and ^{ns} non-significance index. However, it significantly affected the no. of panicle hill^{-1} and filled grain percent. The higher no. of panicle hill^{-1} and filled grain percent were recorded from AWD compared to CF. The grain yield was not significantly different among the water regimes. However, numerically the higher yield (7.8 t ha^{-1}) was found in AWD (Table 2).

In tested varieties, there were no significant differences in SPAD reading and harvest index. Biomass weight, plant height, panicle length, no. of panicle hill^{-1}, no. of spiketlets panicle^{-1}, filled grain percent and 1 000 grain weight were significantly different among the tested varieties at 1 percent level. The higher values of these characters were observed in HHZ-3-SAL 4-Y1-Y1 (Table 1). Therefore, HHZ-3 -SAL 4-Y1-Y1 had superior characters than the other two varieties. There was highly significantly difference on grain yield among the varieties. The increased yield was recorded from HHZ-3-SAL 4-Y1-Y1 (8.9 t ha^{-1}) followed by Thee Htet Yin (7.4 t ha^{-1}) and Thai Hnan Khauk (7.1 t ha^{-1}). Rahman et al., (2014) reported that the water regimes had no significant effects on plant height, panicle length and no. of spikelet panicle^{-1}, 1 000 grain weight and grain yield.

3.2 Methane emissions

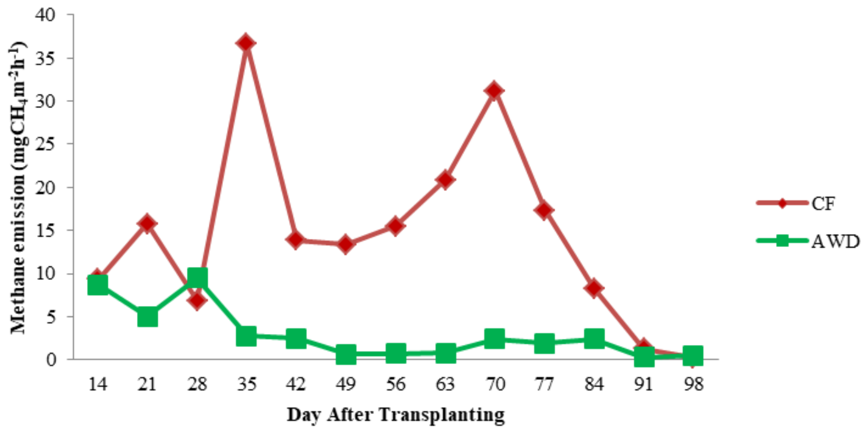
Methane emission varied with varieties depending on water regimes. The peak values under AWD were lower than in CF and methane emissions in CF were high in 35 DAT (during effective tillering stage) and 77 DAT (during flowering stage) (Kim et al., 2014). However, during the mature stage, the field drained and soil permeability was better, increasing methanotroph activities and inhibiting methanogens, and thus less CH4 emission flux was observed (Figure. 2). The highest methane emission was recorded in CF (14.7 mgCH_4m^{-2}h^{-1}) and the lowest emission in AWD (2.9 mgCH_4m^{-2}h^{-1}) (Table 2). Methane emission can be influenced by rainfall, water management, temperature and growth stages. The relatively high soil temperature increases the methanogenic activity, and the flooding layer creates a strict anaerobic condition for soil, promoting the production of CH_4 (Serrano-Silva et al., 2014).

Table 2. Mean effects of water regimes and rice varieties on grain yield and CH_4 emission

Treatment	Grain Yield (t ha^{-1})	Flux of CH_4 (mg CH_4m-^{2} h-^{1})
Water Regimes		
CF	7.7	14.7 a
AWD	7.8	2.9 b
$LSD_{0.05}$	0.8078	8.0244
Varieties		
Thai Hnan Khauk	7.1 b	7.8
Thee Htet Yin	7.4 b	9.4
HHZ-3-SAL 4-Y1-Y1	8.9 a	7.6
$LSD_{0.05}$	0.5988	13.450
Pr>F		
Water regimes	0.7008	0.0117
Varieties	0.0003	0.9196
Water regimes & Varieties	0.8446	0.9016
CV_a percent	5.15	95.51
CV_b percent	5.80	79.19

*significance at 5 percent level, ** highly significance at 1 percent level and ^{ns} non-significance

Figure 2. Methane emission of rice varieties as affected by water regimes



In this study, AWD was found to be an effective method to save water and reduce methane emission.

Among the different rice varieties, the maximum methane flux was observed at maximum tillering stage (35 DAT) in CF and active tillering stage (21) DAT in AWD in Thai Hnan Khauk (Figure.3). In Thee Htet Yin variety, the peak methane emission was found at maximum tillering stage (35 DAT) in CF and tillering stage (14DAT) in AWD (Figure 4). In HHZ-3-SAL 4-Y1-Y1 variety, the maximum methane emission was observed at the flowering stage (70 DAT) in CF and the tillering stage (14 DAT) in AWD (Figure. 5). Methane emission of Thee Htet Yin was higher than other two varieties i.e. Thai Hnan Khauk and HHZ-3-SAL 4-Y1-Y1 (Table 2). In this study, Super Green Rice (HHZ-3-SAL 4-Y1-Y1) had the lowest methane emission (Figure. 6).

4. Conclusion

In this study, HHZ-3-SAL 4-Y1-Y1 variety was found producing higher grain yield and biomass weight than the Thai Hnan Khauk and Thee Htet Yin varieties. This result showed that AWD is a good water management technique that can reduce water use in rice cultivation without compromising the yield. The overall average yields in AWD were higher than CF. Moreover, AWD is a technique to reduce methane emission due to its water input reduction. Therefore, AWD become suitable technology for water management in developing countries to save water and mitigate the methane emission. However, many experiments needed to apply AWD technique with GHG reduction, increasing rice yield, saving water, and enabling farmers to cope better with climate change. These techniques would work to the benefit of both developing and industrialized countries.

Figure 3. Methane emission of Thai Hnan Khauk rice variety as affected by water regimes

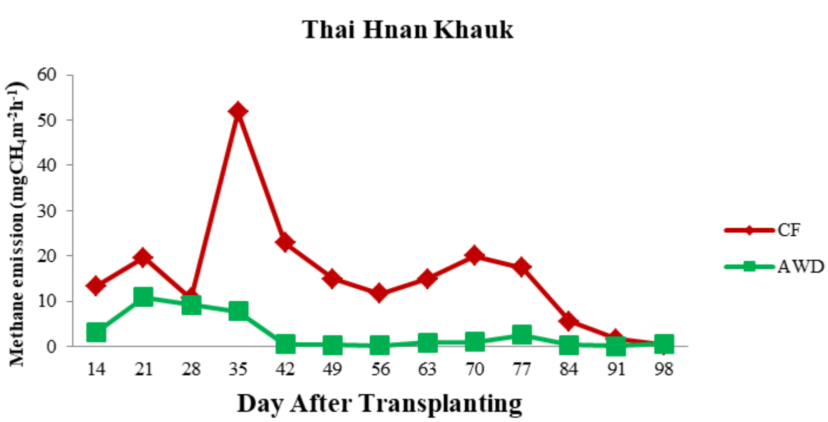


Figure 4. Methane emission of Thee Htet Yin rice variety as affected by water regimes

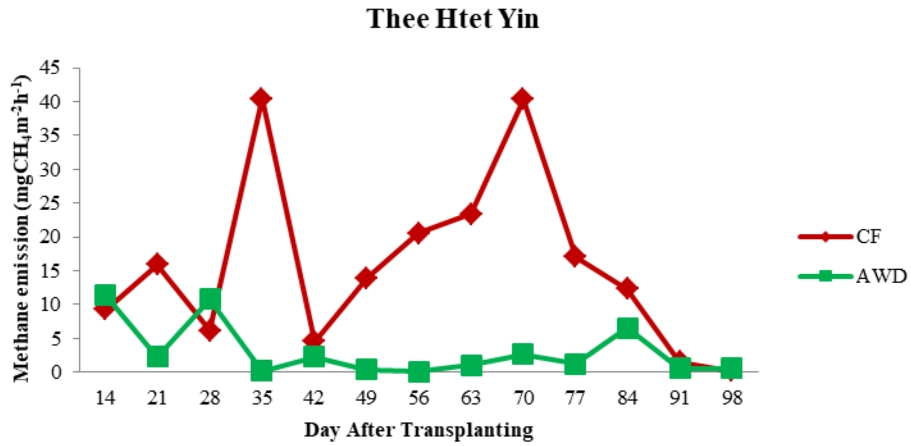


Figure 5. Methane emission of HHZ-3-SAL4-Y1-Y1 variety as affected by water regimes

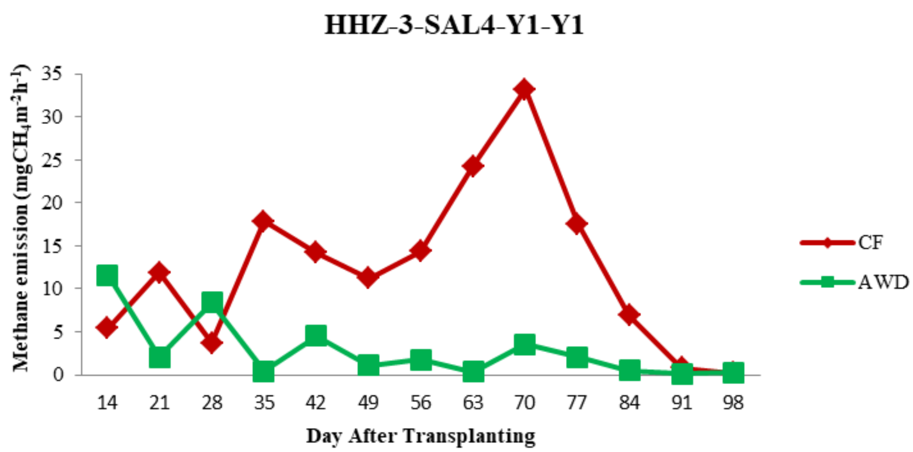
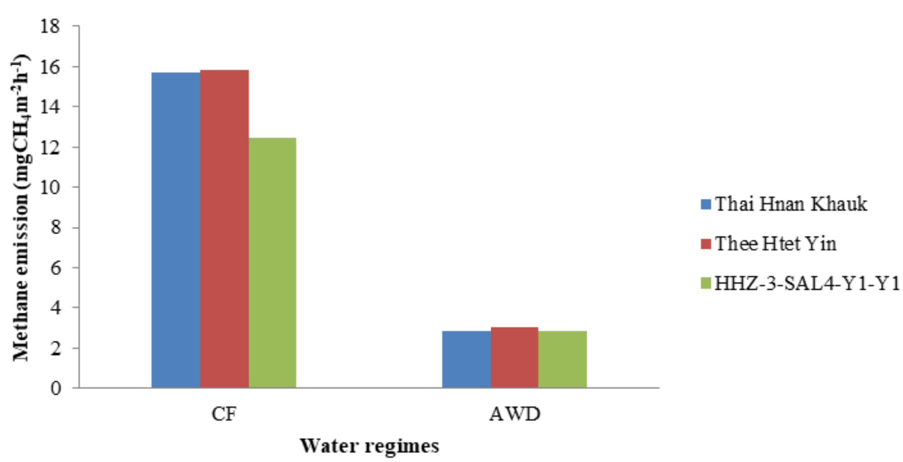


Figure 6. Methane emission of rice varieties under different water regimes



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Relationship between water absorption and carbohydrate metabolism in germination tolerant rice genotypes

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Abstract

The aim of this study was to investigate the water absorption rate and relationship between water absorption and dynamics of carbohydrate catabolism, and amylase activity in germinating seeds of newly identified anaerobic germination (AG) tolerant rice genotypes. Two growth chamber experiments were conducted in randomized complete block design (RCBD) with three replications in each experiment. Treatments consisted of saturated (control) condition and flooding with 10 cm water depth after dry seeding using four newly-identified tolerant genotypes and two checks, one used for the tolerant genotypes and another for the sensitive genotype. Tolerance to AG was observed in all of the genotypes and is associated with better seedling emergence, longer coleoptile, heavier coleoptile fresh weight, and faster water absorption rate during the first 48 h. Rapid starch depletion, higher soluble sugar concentration, higher total and α amylases activities in all tolerant genotypes were observed, explaining their improved survival rate and growth under flooding. This study highlights the involvement of several mechanisms associated with the tolerance of anaerobic condition during germination in rice.

Keywords: *anaerobic germination, starch, soluble sugar, total and α amylases activity*

1. Introduction

Most of the Asian farmers are shifting their rice establishment method from transplanting in puddle soil to direct seeding in either puddled or dry soil after tillage. Direct seeding of rice is mainly adopted in rice growing areas because of its low labor costs, time saving, less drudgery and easy cultivation. Maintaining a few centimeters of water above the soil after dry seeding is an effective, cheap and sustainable method of weed control, but this practice is stalled by the inaccessibility of suitable germplasm. Although direct seeding can potentially reduce cultivation cost, it makes the crop vulnerable to the fluctuations of monsoon rains which are quite frequent in South and South-East Asia (the rice bowl of the world) dominated by low land rain-fed ecosystem. However, farmers in flood prone areas who were practicing direct seeding may face the problems of poor germination and crop failure because of early season flooding. Rice shows the unique mechanism to germinate and elongate its coleoptile under water (nearly at the rate of 1 mm h^{-1}) even in complete absence of oxygen-a phenomenon termed as anaerobic germination (AG); (Ismail, Ella, Vergara, & Mackill, 2009, Magneschi & Perata, 2009; Narsai, Edwards, Roberts, Whelan, Joss & Atwell, 2015). However, anaerobic germination potential (AGP) varies greatly among the different rice cultivars which ultimately provide an edge to a few cultivars to perform better under oxygen deprived conditions over others.

Moreover, early flooding helps the suppression of weeds and reduction of the costs for weeding. The possible solution is to use breeding lines with tolerance to anaerobic conditions during germination and early seedling establishment will help overcome the problems of weed and poor rice establishment (Ismail, Johnson, Ella, Vergara, Baltazar, 2012). Estioko et al. (2014) reported that 100-mm of water depth can suppress the growth of two common

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weeds in rice fields such as *Echinochloa colona* and *Echinochloa crus-galli* (Estioko, Miro, Baltazar, Merca, Ismail & Johnson, 2014). However, the reduction of growth is more in *E. colona*. Flooding of 2 to 4 days after seeding with 100 mm water depth has less injury in terms of survival percentage and growth in both species. Although flooding after direct seeding of rice suppress weeds growth, it can also adversely affect germination and growth of rice itself.

Water is an essential component for germination as it has many functions such as triggering enzyme for starch conversion into sugar, turgor pressure for moving the radicle root down and the cotyledons up, and for transporting nutrients and enzymes within the seed. The imbibed rice seeds need to reboot the system activity and mobilize the reserves for germination. El-Hendawy, Sone, Ito, & Sakagami (2011) screened 58 rice genotypes (including nine AG + Sub1 lines) for tolerance of anaerobic germination. According to their result, the water uptake rate between 0 and 48 h of imbibition was more correlated with the anaerobic germination tolerance than those between 48 and 96 h and 96 and 120 h of imbibition. They concluded that AG + Sub1 lines were characterized their tolerance by rapid water absorption and rapid germination under both conditions.

In addition, tolerance to flooding during germination is associated with rapid coleoptile growth (Bailey-Serres, Fukao, Ronald, Ismail, Heuer, & Mackill, 2010) and lesser in reduction of root and shoots growth under flooding (Ismail et al., 2009). The breakdown of stored carbohydrate under anoxia by activating α-amylase (Ismail et al., 2009), and alcoholic fermentation to provide energy are important adaptive traits (Estioko et al., 2014). The study of AG in rice is gradually becoming an area of active research, in order to intensify as well as economize rice cultivation (Kumar and Ladha, 2011). However, previous research in this field has failed to consider the relationship of water absorption and tolerance together with carbohydrate breakdown. The present study was carried out to investigate the water absorption rate of newly identified AG tolerant rice genotypes under saturated and flooded conditions and relationship between water absorption and dynamics of carbohydrate catabolism, and amylase activity in germinating seeds.

2. Materials and methods

The experiments were carried out in the incubator (Thermo Scientific model- 3758) of Weed Science Laboratory and greenhouse, International Rice Research Institute (IRRI) by using randomized complete block design with factorial arrangement in three replications. Previously screened anaerobic germination tolerant rice genotypes were evaluated for their adaptive traits. Treatments consisted of saturated (control) condition and flooding with 10 cm water depth after dry seeding using four newly-identified tolerant genotypes and two check, one for tolerant and another for sensitive (Table 1). The temperature of the incubator was 30°C during the day and 20°C during night with 12 h of light and dark. Biochemical analysis was carried out at the Plant Physiology Laboratory, IRRI. One set of incubator experiment was carried out to study water absorption rate and water content of germinating seeds. For the anaerobic treatment, twenty viable seeds per genotype per replicate were put in 50 mL falcon tube containing Whatman filter paper no. 4 and sterilized water was added until 10 cm water depth above the seeds. In this experiment, autoclaved water was used to maintain low oxygen level in the water. For the control (saturated) treatment, 5 mL of water was added to the 50 mL falcon tube. The water absorption rate was recorded at 0, 12, 24, 36, 48, 60, 72, 84, 96, 108, and 120h after sowing. Water absorption rate was calculated as the difference of water content before and after oven drying, then expressed as percentage. The initial moisture content was the difference before sowing and moisture content of the seeds after drying at 70 °C for 3 days. The rate of water uptake was calculated by subtracting the moisture content of two effective consecutive measurements and divided by the time difference.

At the same time, another experiment was also set-up in the incubator and data were collected at 24, 48, 72, 96 and 120 h after sowing under control (saturated) and flooded condition for the determination of carbohydrate concentration and amylase activity. Total amylase activity was measured following the method of Bernfeld (1955).

Table 1. Name and origin of the genotypes used for the present study

No.	Genotypes	IRGC Acc.No.	Origin
1.	Bota Bara :: IRGC 62162-1	121292	Bhutan
2.	Vavilovi	117928	Kazakhstan
3.	Zi Gan Nan Gu :: IRGC 70468-1	121164	China
4.	Kon Suito	117788	Mongolia
5.	Ma-Zhan Red (Tolerance check)		China
6.	IR 42 (sensitive check)		IRRI

Seedlings were harvested and immediately frozen in liquid N. Two hundred milligram of liquid N grounded samples was weighted and protein extraction was carried out. Crude extract was used in the assay and 200 mL of crude protein was added in two different tubes containing 50 mL of 100 mM $CaCl_2$. One set of the tubes was used for total amylase and one was for a-amylase. The a-amylase tubes were heated at 70°C for 15 min to deactivate b amylase, while tubes for total amylase were kept on ice. To every tube, 1 mL of 1 percent starch solution was added and incubated at 0, 3 and 5 min to allow the conversion of starch to maltose as catalyzed by amylase. After incubation, 100 mL of 3,5- dinitrosalicyclic acid (DNS) color reagent was added to the solution. The samples were boiled for 3 min then cooled down. After that, 1.8 mL of ultra-pure water was added to all tubes and was read at 540 nm using a SPECTRO star- Nano (type 0601). The absorbance reading was compared with the standard with increasing amount of maltose. The activity was expressed in units per milligram protein; one unit of a amylase activity is defined as μ moles of maltose produced per minute. Five germinating seeds per genotype per replicate were used to measure coleoptile length by using Image J software. For coleoptile fresh weight, 20 germinating seeds per genotype per replicate were weighted at each sampling point.

3. Result

3.1 Coleoptile length

The length of the coleoptiles was measured at 5, 7 and 10 DAS under saturated and flooded conditions. Increased in coleoptile elongation was more significant under flooded condition compared to control condition. All of the tolerant genotypes had longer coleoptiles at 5, 7 and 10 DAS relative to sensitive check, IR42 under flooded condition (Figure 1). Among the tolerant genotypes, Vavilovi had the longest coleoptile under the flooded condition while the length of coleoptiles did not differ among Bota Bara, Zin Gan Nan Gu, Kon Suito and Ma-Zhan Red. All tolerant genotypes showed longer coleoptile than IR42 in every sampling point (Figure 2a).

3.2 Coleoptile fresh weight

Fresh weight of coleoptile (mg) was measured under both saturated and flooded conditions and was significantly higher in control condition compared to flooded condition at 5, 7 and 10 DAS. Under flooded condition, the coleoptile fresh weight of all tolerant genotypes were significantly higher than IR42 under flooded condition with the heaviest fresh weight in Vavilovi at different sampling points (Figure 2b).

3.3 Moisture percentage of genotypes

The moisture percentage of all genotypes increased from 0 to 120 h of seed imbibition under both conditions (Figure 3) meanwhile, moisture percentage of all genotypes under flooded condition decreased, with 27.45 percent reduction reference to saturated condition. Under flooded condition, Vavilovi had the highest mean moisture percentage from 0–120 h (30.71 percent), followed by Bota Bara (25.01 percent) and Kon Suito (23.67 percent) while IR42 was the lowest with the mean value of 13.82 percent moisture content.

3.4 Water absorption rate

Water uptake rate over different times of seed imbibition (0-48, 48-96 and 96-120 h) under saturated and flooded conditions are presented in Table 2.

Figure 1. Coleoptile length (cm) at 5, 7 and 10 days after sowing (DAS) under saturated (control) and flooded (AG, anaerobic germination) conditions. ns indicates non-significant, *** indicates that eans significant at 0.1 percent. Boxplot shows the distribution of data and the line in boxplot indicates the median value.

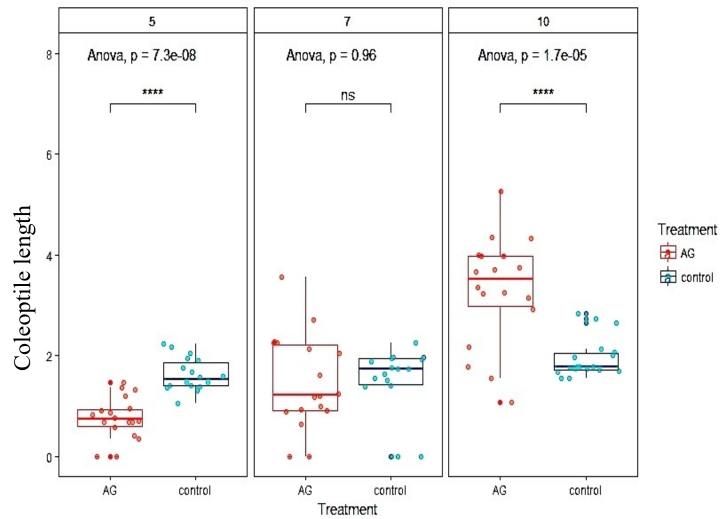


Figure 2. Coleoptile length (a) and coleoptile fresh weight (b) of six rice genotypes at 5, 7 and 10 DAS under flooded (AG, anaerobic germination) condition. Vertical bar indicates HSD value at $P< 0.05$.

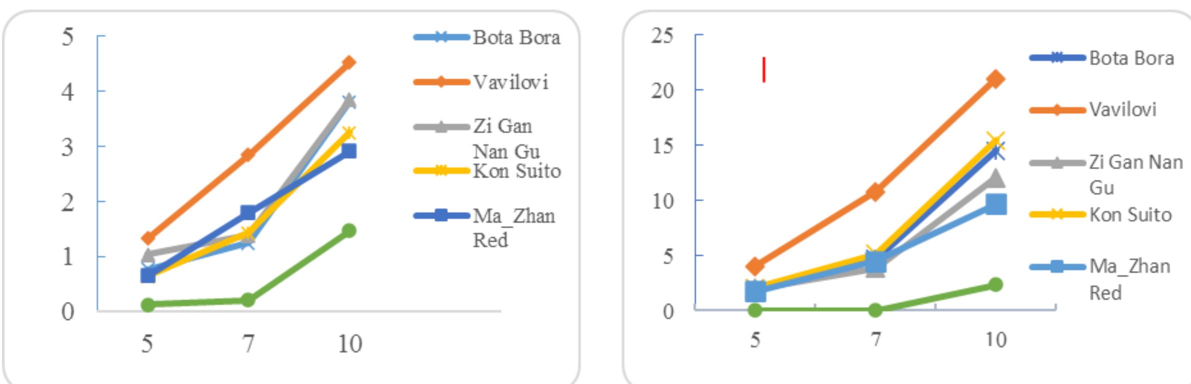
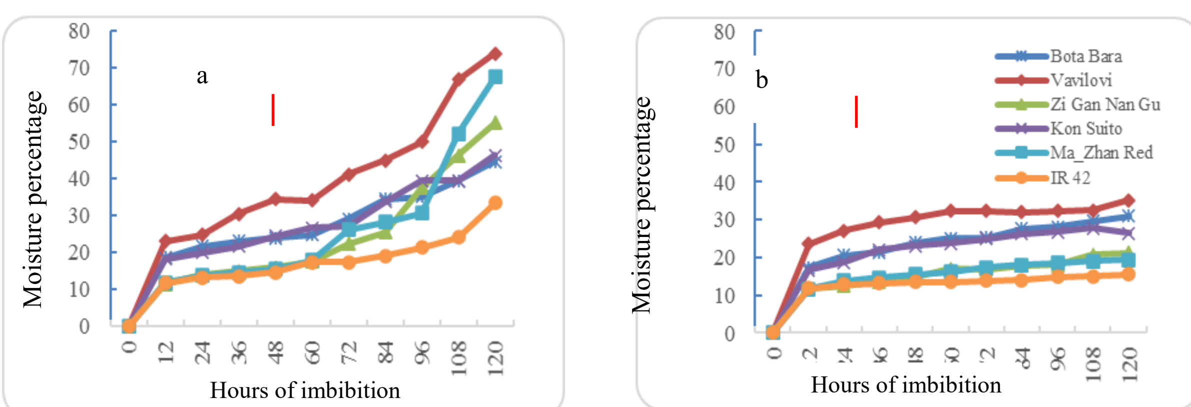


Figure 3. Moisture percentage of six rice genotypes from 0 to 120 hours under (a) saturated (control) and (b) flooded (AG, anaerobic germination) conditions.



Under saturated condition, all genotypes showed rapid water absorption rate during the first 0-48 h of imbibition though there was no significant difference among them. Under flooded condition, tolerant genotypes also had higher water absorption rate during the first 48 h of imbibition than IR42, while the highest rate was observed in Vavilovi. After 48 h of imbibition, water absorption rate of all genotypes, except Zi Gan Nan Gu and Ma_Zhan Red, decreased under control treatment and did not differ among genotypes during 48-96 h of imbibition. Under flooded condition, the water absorption rate also decreased with no significant difference among the genotypes at 48-96 h.

Under saturated condition, water absorption rate during 96-120 h increased again in all genotypes and were significantly different among them. Similarly, under flooded condition, the water absorption rate of all genotypes also increased again where the highest water absorption rate was in Zi Gan Nan Gu and the lowest water absorption rate was found in Kon Suito but did not differ among genotypes. The faster water absorption rate during 0-48 h of imbibition in all tolerant genotypes than IR42 explained the importance of rapid water absorption rate after imbibition.

3.5 Changes of starch concentration with water absorption

The rate of starch depletion was higher in the saturated condition than in the flooded condition. However, the depletion percent of the genotypes was not different under saturated condition, whereas the tolerant genotypes had higher starch depletion percent than that of the sensitive genotype (IR42) under flooded condition. The highest mean starch depletion across sampling points was observed in Vavilovi and the lowest starch depletion was in IR42 (Figure 4).

3.6 Changes in sugar concentration with water absorption

Concentration of soluble sugars was higher in saturated condition as compared to flooded condition from 0 to 5 DAS. Under control condition, soluble sugars increased from 0 to 5 DAS, with the highest mean across measurement intervals was observed in Bota Bara, followed by Vavilovi, Kon Suito, Ma-Zhan Red, Zi Gan Nan Gu and IR42. Flooding reduced the soluble sugar concentration in all genotypes relative to control condition with the highest reduction in IR42. The reduction percentages in tolerant genotypes were in the ranges of 23-40 percent with the lowest reduction in Vavilovi relative to control condition (Figure 5).

3.7 Total and α- amylase activities

Total and α-amylase activities of imbibed seeds under saturated and flooded conditions were not significantly different among genotypes. Total amylase activity increased from 0 to 5 DAS in all genotypes, whereas the mean total amylase activity across the day intervals in Bota Bara showed the highest activity, which was not significantly different from that of Ma-Zhan Red, Vavilovi, Kon Suito, and lowest was in Zin Gan Nan Gu which was similar to IR42. Under flooded condition, all of the tolerant genotypes maintained their total amylase activity, while IR42 showed 42.65 percent decreased in activity compared to saturated condition (Figure 6).

Similar to total amylase activity, a-amylase activities in all genotypes showed increasing trend from 0 to 5 DAS under control condition, with no significant difference among the genotypes. The lowest mean a-amylase activity across the intervals was noted in Zi Gan Nan Gu and the highest mean was found in Vavilovi. Upon flooding, IR42 showed significant decrease activity as compared to control condition; while Vavilovi, Zi Gan Nan Gu, Kon Suito, Ma_Zhan Red and Bota Bara exhibit increased activities compared to saturated condition (Figure7).

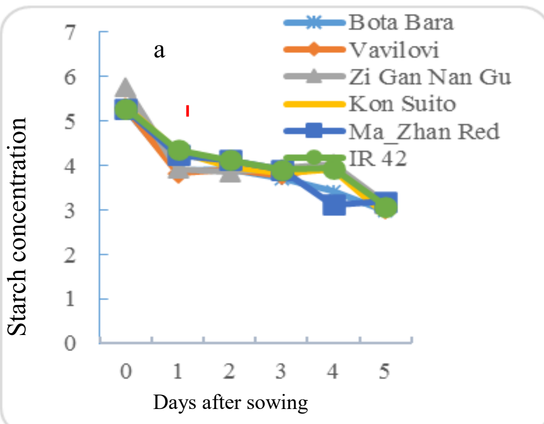
3.8 Relationship between water absorption, carbohydrate dynamics and amylase activity under AG condition

Moisture percentage of the rice seeds were significantly and positively correlated with total amylase activity (r = 0.62***), α - amylase activity (r = 0.61***), soluble sugar concentration (r = 0.59***); while negatively correlated with starch concentration (r = -0.76***) (Figures 8). Under both conditions, total amylase activity and α - amylase activities were significantly and positively correlated with

Table 2. Water uptake rate over different times of seed imbibition (0-48, 48-96 and 96-120 hours of seed imbibition) for five tolerant and one sensitive rice genotype under flooded (AG, anaerobic germination) and saturated (control) conditions.

GENOTYPES	WATER ABSORPTION RATE (UG MG^{-1} DW HR^{-1})					
	Flooded condition			Control condition		
	0-48h	48-96 h	96-120 h	0-48h	48-96 h	96-120 h
Bota Bara	7.07 ^{ab}	1.63 ^{a}	2.16 ^{b}	7.04 ^{a}	4.35 ^{a}	7.31 ^{c}
Vavilovi	8.55 ^{a}	0.56 ^{a}	1.99 ^{b}	9.84 ^{a}	5.42 ^{a}	16.55 ^{b}
Zi Gan Nan Gu	4.48 ^{ab}	1.56 ^{a}	10.12 ^{a}	4.42 ^{a}	10.34 ^{a}	16.78 ^{b}
Kon Suito	8.43 ^{a}	1.73 ^{a}	0.32 ^{b}	7.41 ^{a}	5.92 ^{a}	15.49 ^{b}
Ma_Zhan Red	5.16 ^{b}	1.44 ^{a}	0.78 ^{b}	5.14 ^{a}	7.15 ^{a}	34.68 ^{a}
IR 42	1.3 ^{b}	0.85 ^{a}	1.16 ^{b}	5.03 ^{a}	3.91 ^{a}	12.27 ^{bc}

Figure. 4 Starch concentration (percent dry wt.) of six rice genotypes from 0 to 5 DAS under (a) saturated (control) and (b) flooded (AG, anaerobic germination) conditions. Vertical bar indicates HSD value at $P< 0.05$.



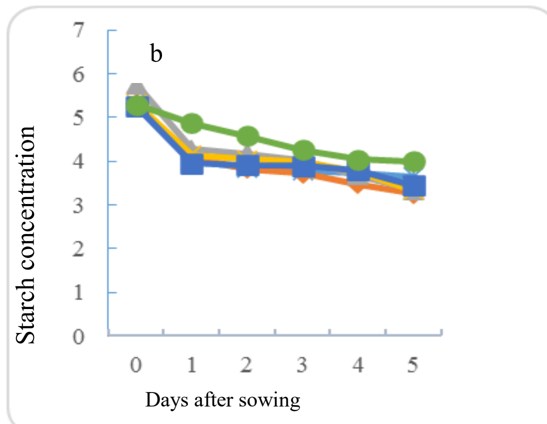
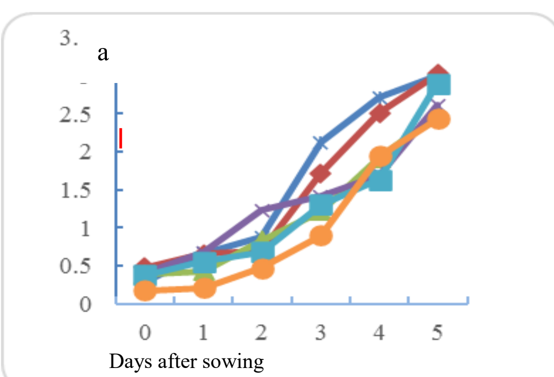


Figure 5. Sugar concentration (percent dry wt.) of six rice genotypes from 0 to 5 days after sowing (DAS) under (a) saturated (control) and (b) flooded (AG, anaerobic germination) conditions. Vertical bar indicates HSD value at $P< 0.05$.



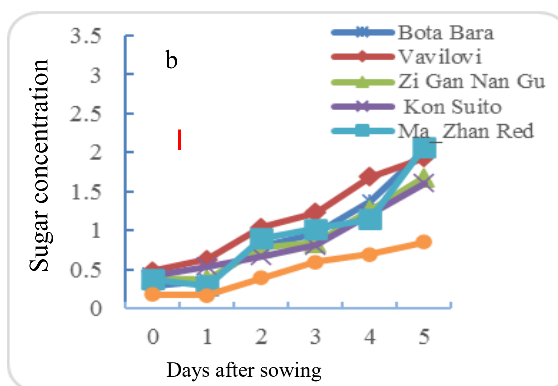


Figure 6. Total amylase activity of six genotypes under (a) saturated (control) and (b) flooded (AG, anaerobic germination) conditions. Vertical bar indicates HSD value at *P< 0.05*.

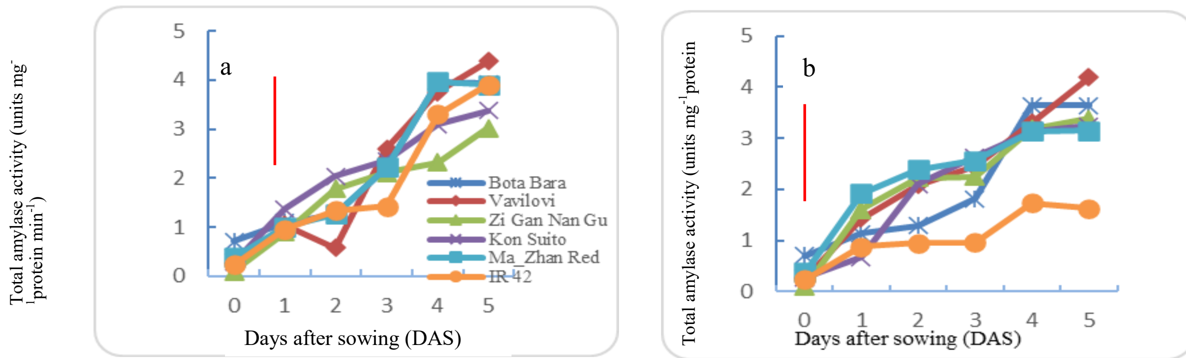


Figure 7. α - amylase activity (units/mg protein) of six genotypes under (a) saturated (control) and (b) flooded (AG, anaerobic germination) conditions. Vertical bar indicates HSD value at *P< 0.05*.

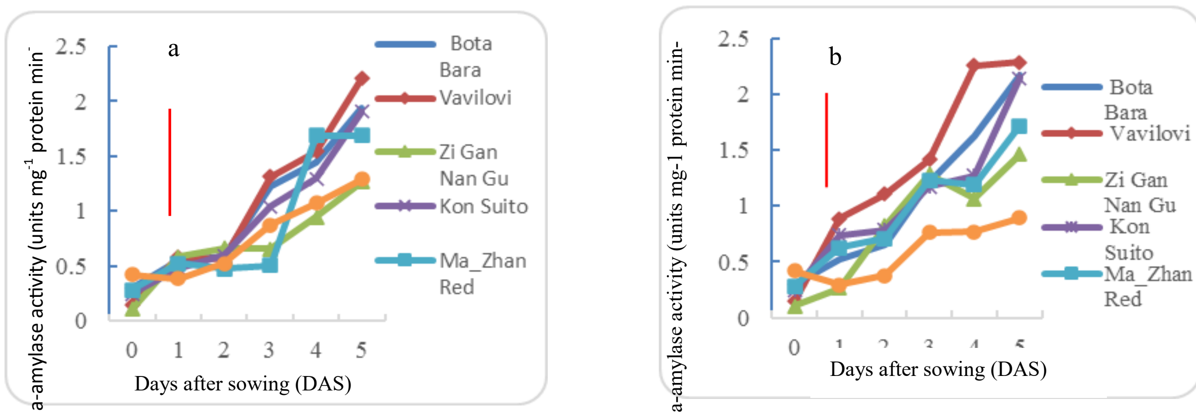
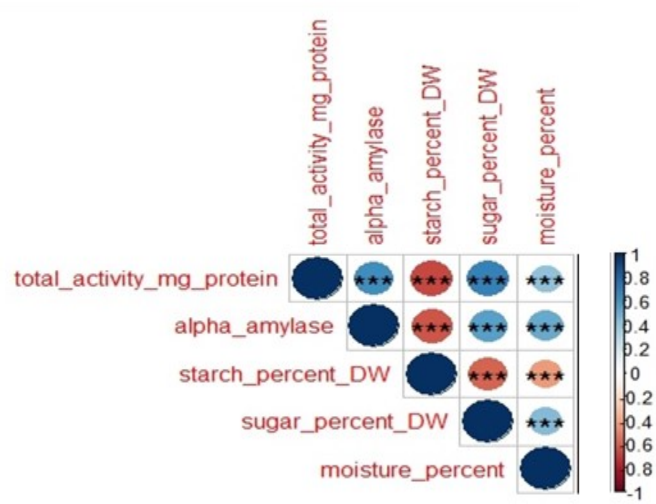


Figure 8. Correlation between water absorption rate, α- amylase and non-structural carbohydrate concentration during water absorption from 0 to 5 DAS under flooded (AG, anaerobic germination) condition. Positive correlations are displayed in blue, and negative correlation in red. The color intensity and circle size are proportional to the correlation coefficients. *** indicates that means are significant at 0.1 percent.



sugar concentration and negatively correlated with starch concentration.

4. Discussion

Coleoptile elongation of all tolerant genotypes was started at 5 DAS, while no growth was observed in IR42 under flooding (Figure 2a). Similar result was recorded by Meguro, Tsuji, Tsutsumi, Nakazono & Hirai (2006) in which coleoptile elongation was started at 4 DAS in Khon Hla On (AG tolerant genotype). In the present study, mean coleoptile length under anaerobic condition was higher than that under control condition. This could be associated with AG tolerance, with greater ability to reach water surface for oxygen. It was noticed that all tolerant genotypes had longer coleoptiles compared to control condition, and the length of all tolerant genotypes increased from 5 to 10 DAS, with Vavilovi having the longest coleoptiles. AG+Sub 1 lines also elongated more rapidly and developed longer coleoptiles under AG than control (EI-Hendawy et al., 2014). Moreover, flooding tolerance during germination was mainly due to major submergence avoidance or escape mechanisms with fast shoot elongation (El-Hendawy et al., 2014). Even though, flooding induced the coleoptile elongation, it reduced the coleoptile fresh weight in all genotypes. The coleoptile fresh weight under AG showed 65 percent reduction compared to the plants grown under control condition. This observation is consistent with the result of Huang et al. (2003), in which coleoptile fresh weight of two rice genotypes (Calrose and Amaroo) exposed to anoxia were reduced by about 70 percent relative to aerated condition. Under flooded condition, all tolerant genotypes had heavier coleoptile fresh weight than IR42.

Variation in water absorption rate might be present among rice genotypes and could relate to their tolerance to AG. Variations in activities of amylase and carbohydrate metabolism may also be associated with variations in responses to flooding during germination and early seedling growth. Significant variation in water uptake rate and duration of each phase among the genotypes under anaerobic and aerobic conditions were observed (Table 2). The tendency of water uptake rate of most genotypes under both conditions was increased during 0-48 h followed by reduced water uptake rate during 48-96 h and increased again during 96-120 h, suggesting that the higher water absorption rate at post germination stage was probably needed for transportation of soluble sugars and nutrition for seedling growth. All of the tolerant genotypes had faster water absorption rate at the first 0-48 h under flooded condition and the highest rate in Valivoli and Kon Suito, indicating that first hours of water absorption rate may be associated with anaerobic germination tolerance. EI-Hendawy et al. (2011) reported that genetic variation in water absorption rate among rice genotypes was observed and faster water uptake during the first 48 h of imbibition play a key role for rapid germination ability of AG+Sub1 genotypes under anaerobic condition and lower water absorption rate at 48-96 h, and higher rate at 96-120 h of imbibition under aerobic and anaerobic conditions. Moisture percentage of all genotypes increased from 0 to 120 h of imbibition in both conditions, however, moisture content under flooding reduced in all genotypes with the tolerant genotypes maintaining higher mean values (Figure 3), which agreed with the results of EI-Hendawy et al. (2011).

Starch concentration decreased upon imbibition and rapid degradation was observed from 0-1 DAS and 4-5 DAS (Figure 4), which may probably be due to rapid water absorption rate at 0-48 h and at 96-120 h. The degradation of starch concentration of either tolerant or sensitive genotypes was negatively correlated with sugar concentration and moisture percentage in both conditions. Unlike, the availability of soluble sugar was increased from 0 to 5 DAS in both control and flooded conditions and it was higher in control than that in flooded condition (Figure 5). Except for IR42, all tolerant genotypes maintained high value of soluble sugar under flooded condition, suggesting that tolerant genotypes were able to degrade the stored starch under flooded condition. Similar to this finding, increased of sugar concentration resulting from starch degradation by amylase or sucrose synthase has been found in AG tolerant *Cyperus rotundus* L. (Penã-Fronteras, Villalobos, Baltazar, Merca, Ismail & Johnson, 2009) and rice (Guglielminetti, Perata, & Alpi, 1995; Ismail et al., 2009).

The α-amylase activity during germination is important to breakdown the stored starch to soluble sugars which is needed for the growth and maintenance metabolism. From this study, the results revealed that the activities of total and α-amylase were important under control and flooded conditions to breakdown the starch. Noticeably, the activities did not differ under the two conditions (Figure 6 and 7). Loreti, Yamaguchi, Alpi & Perata. (2003) reported that under aerobic conditions gibberellin-induced *Amy1A* gene was enhanced and under anaerobic condition, the expression of *Amy3D* gene was higher which was triggered by a lower carbohydrate concentration of rice grains kept under anoxia. With increasing moisture percentage, total and α- amylase activity increased from 0 - 5 DAS in all genotypes but the increase was slower in IR42 than that in the tolerant genotypes under flooded condition (Figure 6 and 7). Similarly, Illangakoon et al. (2016) reported that α-amylase activity increased over the time and AG tolerant, IR 06F459 had higher α-amylase activity than IR42 at 1, 2 and 4 DAS under anaerobic condition.

Total and α-amylase activity correlated positively with moisture percentage, soluble sugars concentration, and negatively correlated with starch concentration (Figure 8), suggesting that absorbed moisture by seed may stimulate the activity of amylase to breakdown stored starch to soluble sugars, explaining the higher soluble sugar concentration in all tolerant genotypes under flooded condition. Similarly, Adachi, Sugiyamam, Sakagami, Fukuda, Ohe & Watanabe (2015) and Illangakoon et al. (2016) highlighted that soluble sugars had strong positive correlation with α-amylase activity while starch had negative correlations with both soluble sugars and α -amylase activity.

5. Conclusion

The aim of this study was to unravel the morphological and physiological mechanisms associated with tolerance of newly- discovered rice genotypes that are tolerant to flooding during germination. Genetic variation among the tolerant genotype was observed for most of the traits, with all of the tolerant genotypes had higher survival rate, longer coleoptiles, higher coleoptile fresh weight and greater moisture absorption rate during imbibition. However, all of the tolerant genotypes had better growth parameters than IR42. The faster water absorption rates during 0-48 h in tolerant genotypes indicated that faster imbibition is probably one of the adaptive traits of tolerant genotypes with the highest rate in Vavilovi. Higher mobilization of stored starch to soluble sugar with increased amylase activity in all tolerant genotypes under flooded condition is associated with better seedling survival rate and growth under flooded condition.

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Session 3

Agroecology

Diversity and abundance of insect pests in intensive monsoon rice growing areas of Nay Pyi Taw

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Abstract

The experiment was conducted to investigate the community structure and species diversity of rice insect pests in monsoon rice on 56 grid points (G) (300 m ´ 300 m) over 550 ha. Insect pests were collected by using D-Vac vacuum at Kyee Inn village, Pyinmana Township in monsoon season 2018. According to the Shannon-Wiener function, 44 families from 7 orders of insect pest species were recorded: Blattodea, Coleoptera, Dermaptera, Diptera, Hemiptera, Lepidoptera and Orthoptera . The diversity and equitability of species were high in all grid points throughout the monsoon season.. Among the grid points, the highest diversity index (3.69) was found in G28 while G2 grid point showed the highest equitability (0.84). Noticeably, the lowest diversity index (1.85) and the lowest equitability (0.43) of insect pest species were found in the grid point G18., The highest mean population number of *Sogatella furcifera* and *Nilaparvata lugens* belonging to the family Delphacidae from order Hemiptera was identified in the grid point G18. Data suggested that the insect pest species were diversed widely according to the location of grid points.

Keywords: *Kyee Inn village*, *species diversity*, *equitability*, *intensive monsoon rice growing areas*

1. Introduction

Rice (*Oryza sativa* L.) is one of the most important staple foods for more than half of the world's population and it is cultivated in almost all the tropical, subtropical and temperate countries of the world (International Rice Research Institute [IRRI] 2006). Thiha (as cited in May Thet Hlaing, 2018) stated that Myanmar is the seventh largest rice producing countries in the world.

Rice is an essential crop for growing populations of South and South East Asia. Rice provides more than 50 percent of the calories consumed in Bangladesh, Cambodia, Myanmar, Laos, and Vietnam and 20-44 percent in Thailand, Philippines, Malaysia, India, Nepal and Sri Lanka (Gianessi, 2014). Rice represents a primary source of nourishment. Due to its adaptability, rice can be grown almost anywhere, and can be easily distributed to any part of the world (Milano, 2015).

In Myanmar, rice is the main staple food, and people consume more rice compared to other Asian countries (Tin Maung Shwe and Thida Chaw Hlaing, 2011). Since rice is the major crop for both food security and economy of the country, low yield is the most important problem for rice crop production. In Myanmar, rice was grown in an area of 7.26 million hectare in 2017 (Ministry of agriculture, livestock and irrigation [MOALI] 2017).

One of the major constraints of rice production and low productivity is the occurrence of insect pests at various stages of the crop growth. Over 800 species of insects in rice ecosystems have been reported worldwide. The rice plant is subject to attack by more than 100 species of insects and 20 of them can cause economic damage (Pathak and Khan, 1994). Most of rice plant parts are exposed to pest attack from period of sowing till harvest. Insects damage plant parts by chewing plant tissues, boring into

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stems or sucking fluid saps from stem and grains. Damages caused by insects disturb physiology of plants and result into lower crop yield (Nasiruddin and Roy, 2012).

The biodiversity of the rice paddy ecosystem refers generally to all living organisms in cultivated rice fields, including genetic diversity, species diversity, ecosystem diversity and related to ecosystem processes, crops, weeds, pests and their natural enemies. They are important parts of paddy field ecosystems and together form biological communities, thus maintaining the stability of the paddy field ecosystem. The diversity is only one measure of ecosystem complexity (Tang *et al*, 2009).

As in many other agro-ecosystems, the rice agroecosystem has a few primary pests that may actually limit production under certain conditions. Numerous species of primary pests cause periodic losses and a few species that may occur in such low numbers that no damage occurs. The actual species complex differs in abundance and distribution from locality to locality and from year to year (Pathak and Khan, 1994).

Species diversity is a parameter of community structure involving species richness and their abundance for the taxa. Moreover, knowledge of the species present and their role in the ecosystem can be essential for deciding whether or not to use insecticides (Wang *et al*, 2000). In general, species diversity and complexity of association among species are essential to the stability of the community. Information about species diversity and abundance of rice insect pests as a part of taxonomic works is needed for rice protection in Myanmar. At present, there is limited information and knowledge on rice insect pest diversity available..

Accordingly, this study was carried out to investigate the species diversity of rice insect pests and the structure of its community for the information to provide theoretical basis for the sustainable control of rice insect pests.

2. Material and methods

2.1 Study area

The experiment was conducted in 56 farmers' fields from Kyee Inn village, Pyinmana Township, Nay Pyi Taw. Area measuring 2.4 km wide by 3.9 km long (550 ha) was selected for the intensive insect pests collection of monsoon rice season in 2018. Monsoon season rice crop was grown from July to November 2018. The rice cultivar Manawthukha was planted with farmers' usual practices at all experimental fields.

2.2 Insect pest sampling

Rice insect pests were collected on a 300 m by 300 m grid pattern, resulting in a total of 56 grid points. The rice insect pest community was sampled at fortnightly interval 20 days after sowing (DAS). Five samples were taken at random in each rice field. All samples were collected near the center of the field, at least 5m from the edge in order to reduce edge effects. Insect pests inhabiting the rice field and those on the water surface were sampled by using D -Vac vacuum (Insect Net-Hand Carry Model 122S, made by Rinconm-Vitova Insectaries). One sample usually covered 4-5 hills of rice plant after sowing but only 2-3 hills after the rice plant reach maximum tillering stage. Sampling duration was fixed at 1 to 2 min depending on the growth stage of the rice. All collected samples were transferred to sample jars containing 70 percent ethanol, which were returned to the laboratory for identification. Sampling at each sampling time was repeated 3 times on each of the rice plots (Zhang *et al*, 2013).

2.3 Identification of insect pests

All collected samples were carried to JICA-ELB1 Laboratory, Department of Entomology and Zoology, Yezin Agricultural University for further identification. All the samples were identified for the orders, families, genus and species level as far as possible by using keys outline from the textbooks of Insect of Australia (Commonwealth Scientific and Industrial Research Organization [CSIRO] 1970), Manual of Nearctic Diptera, Volume 1, 2, 3 (McAlpine *et al*, 1981), Pest of rice and their natural enemies in Peninsular Malaysia (Vreden and Ahmadzabidi, 1986), Friends of Rice Farmers (Shepard *et al*, 1987) and the internet websites.

2.4 Data analysis

Abundance and species diversity of insect species from different grid points were measured by the Shannon-Wiener function (Krebs, 1978).

Shannon-Wiener function was used to measure the index of species diversity by the following formula:

$$H = -\sum_{i=1}^{s} (P_i)(\log_2 P_i)$$

Where;

H = index of species diversity or information content of sample (bits/individual)

S = number of species

P_i = proportion of total sample belonging to i^{th} species (Krebs, 1978)

"H" is a measure of the amount of uncertainty, so that the larger the value of indexs of species of diversity, the greater the uncertainty. Two components of diversity (number of species and equitability or evenness of allotment of individuals) among species are combined in the Shannon-Wiener function (Lloyd and Ghelardi, 1964).

A more even or equitable distribution among species will also increase species diversity measured by Shannon-Wiener function (Krebs, 1978).

Equitability (evenness) can be measured in;

$E = H / H_{max}$

Where;

E = equitability (range 0 – 1)

H = observed species diversity

H_{max} = maximum species diversity = $\log_2 S$ (Krebs, 1978)

3. Result and Discussion

3.1 Species diversity and abundance rice insect pest

According to the Shannon-Wiener function, 44 families from 7 orders such as Blattodea, Coleoptera, Dermaptera, Diptera, Hemiptera, Lepidoptera and Orthoptera of insect pest species were recorded and identified (Table 1).

The high diversity index of insect pest species was observed in 33 grid points and the medium diversity index was observed in 23 grid points among total 56 grid points. The low diversity index was not found in the study area. The criteria used by Rahayu *et al*, (2006) described that an organism species biodiversity is considered high when the value is greater than 3, medium when the value is between 1 and 3, and low when the value is less than 1. Therefore, the diversity index of insect pest species from the study area was observed as high criterion (Figure 1 (a, b)).

Smith and Wilson (1996) stated that evenness indices standardize abundance and range from near zero when most individuals belong to a few species, to close to 1, when species are nearly equally abundant. According to the results, the recorded equitability (evenness) of all grid points in the study area was nearly equally abundant (Figure 2(a,b). Among the grid points the highest diversity index (3.69) in grid point G28 and the highest equitability (0.84) in G2 grid point were recorded (Figure 1.a and Figure 2.a). The lowest diversity index (1.85) and the lowest equitability (0.43) were recorded from G18 grid point (Figure 1.a and Figure 2.a). At a broad scale, declines in arthropod diversity have been associated with pest emergence and agricultural intensification (Swift *et al*, 1996; Wilby and Thomas, 2002; Wilby *et al*, 2006).

The largest number of insect pest species documented from the grid points belonged to the order Hemiptera including 8 species and 19 genus from 13 families (Figure 9 (a,b) and Figure 10(a, b)). Among them, family Cicadellidae was observed as dominant family including 4 species. The second largest insect pest order was Diptera which included 5 species, 14 genus from 15 families, (Figure 7(a, b) and Figure 8(a, b)). Coleoptera was the third largest insect pest order including 2 species 13 genus and 7 families. Chrysomelidae family was dominant among the families from order Coleoptera (Figure 4 (a, b) and Figure 5(a, b)).

In order Blattodea, family Blattellidae, the highest mean number of *Blattella* sp. (0.86 ± 0.55 individual) was recorded from grid point G47 and highest mean number of *Periplaneta americana* (0.83 ± 0.54 individual) from family Blattidae was observed in grid point G43 (Figure 3.b). In order Coleoptera, the highest mean number of *Apion* sp. (1.83 ± 1.45 individual) from family Apionidae was observed from grid point G29 (Figure 4.b). There were five

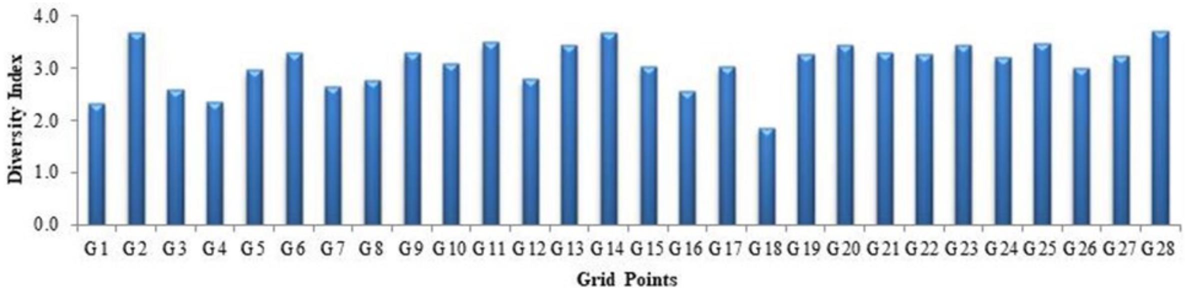
Table 1. Recorded insect pests species from the study area, Kyee Inn village, Pyinmana township, 2018

No.	Order	Family	Genus	Species
1.	Blattodea	Blattellidae	*Blattella*	sp.
2.	Blattodea	Blattidae	*Periplaneta*	*americana*
3.	Coleoptera	Apionidae	*Apion*	sp.
4.	Coleoptera	Chrysomelidae	*Longitarsus*	sp.
5.	Coleoptera	Chrysomelidae	*Aspidomorpha*	sp.
6.	Coleoptera	Chrysomelidae	*Dicladispa*	*armigera*
7.	Coleoptera	Chrysomelidae	*Lema*	sp.
8.	Coleoptera	Chrysomelidae	*Monolepta*	sp.
9.	Coleoptera	Curculionidae	*Otiorhynchus*	sp.
10.	Coleoptera	Elateridae	*Aeolus*	sp.
11.	Coleoptera	Elateridae	*Dicronychus*	sp.
12.	Coleoptera	Scarabaeidae	*Psammodius*	*asper*
13.	Coleoptera	Languriidae	*Caenolanguria*	sp.
14.	Coleoptera	Tenebrionidae	*Gonocephalum*	sp.
15.	Coleoptera	Tenebrionidae	*Ulomoides*	sp.
16.	Dermaptera	Forficulidae	*Forficula*	*auricularia*
17.	Diptera	Cecidomyiidae	*Orseolia*	*oryzae*
18.	Diptera	Ceratopogonidae	*Sphaeromias*	*longipennis*
19.	Diptera	Chironomidae	*Chironomus*	sp.
20.	Diptera	Culicidae	*Aedes*	*stimulans*
21.	Diptera	Culicidae	*Uranotaenia*	sp.
22.	Diptera	Dixidae		
23.	Diptera	Dolichopodidae	*Sympycnus*	sp.
24.	Diptera	Dolichopodidae	*Mesorhaga*	sp.
25.	Diptera	Ephydridae		
26.	Diptera	Ephydridae	*Hydrellia*	*philippina*
27.	Diptera	Ephydridae	*Ochthera*	sp.
28.	Diptera	Muscidae	*Atherigona*	*oryzae*
29.	Diptera	Muscidae	*Musca*	sp.
30.	Diptera	Platystomatidae		
31.	Diptera	Sciaridae	*Sciara*	sp.
32.	Diptera	Tanyderidae		
33.	Diptera	Tanypezidae	*Neotanypeza*	sp.
34.	Diptera	Trichoceridae		
35.	Diptera	Tethinidae		
36.	Diptera	Ulidiidae	*Ceroxys*	sp.
37.	Hemiptera	Alydidae	*Leptocorisa*	*acuta*
38.	Hemiptera	Alydidae	*Megalotomus*	sp.
39.	Hemiptera	Cicadellidae	*Cofana*	sp.

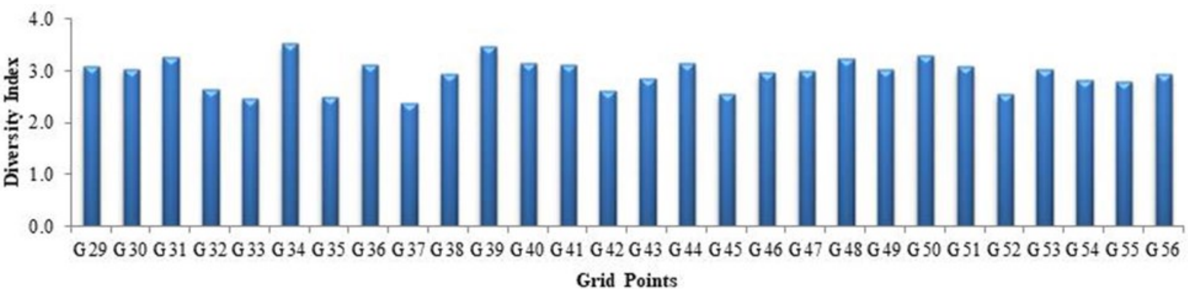
Table 1. continued.

No.	Order	Family	Genus	Species
40.	Hemiptera	Cicadellidae	*Nephotettix*	*nigropictus*
41.	Hemiptera	Cicadellidae	*Nephotettix*	*parvus*
42.	Hemiptera	Cicadellidae	*Nephotettix*	*virescens*
43.	Hemiptera	Cicadellidae	*Recilia*	*dorsalis*
44.	Hemiptera	Coreidae	*Acanthomia*	sp.
45.	Hemiptera	Cydnidae	*Pangaeus*	sp.
46.	Hemiptera	Delphacidae	*Nilaparvata*	*lugens*
47.	Hemiptera	Delphacidae	*Sogatella*	*furcifera*
48.	Hemiptera	Dictyopharidae	*Thanatodictya*	*praeferrata*
49.	Hemiptera	Hydrometridae		
50.	Hemiptera	Lygaeidae		
51.	Hemiptera	Lygaeidae	Cymus	sp.
52.	Hemiptera	Lygaeidae	*Graptostethus*	sp.
53.	Hemiptera	Lygaeidae	*Pachybrachius*	sp.
54.	Hemiptera	Lygaeidae	*Taphropeltus*	sp.
55.	Hemiptera	Membracidae	*Eufrenchia*	sp.
56.	Hemiptera	Miridae	*Capsus*	sp.
57.	Hemiptera	Ninidae	*Cymoninus*	sp.
58.	Hemiptera	Pentatomidae	*Scotinophara*	sp.
59.	Hemiptera	Pyrrhocoridae	*Dysdercus*	sp.
60.	Lepidoptera	Arctiidae	*Creatonotos*	*gangis*
61.	Lepidoptera	Amatidae		
62.	Lepidoptera	Papilionidae		
63.	Lepidoptera	Pyralidae	*Scirpophaga*	*incertulas*
64.	Orthoptera	Gryllidae	*Gryllus*	sp.
65.	Orthoptera	Tetrigidae	*Paratettix*	sp.

Figure 1. Diversity index of insect pests on rice during monsoon season in study area (a) grid points 1 to 28 (b) grid points 29 to 56

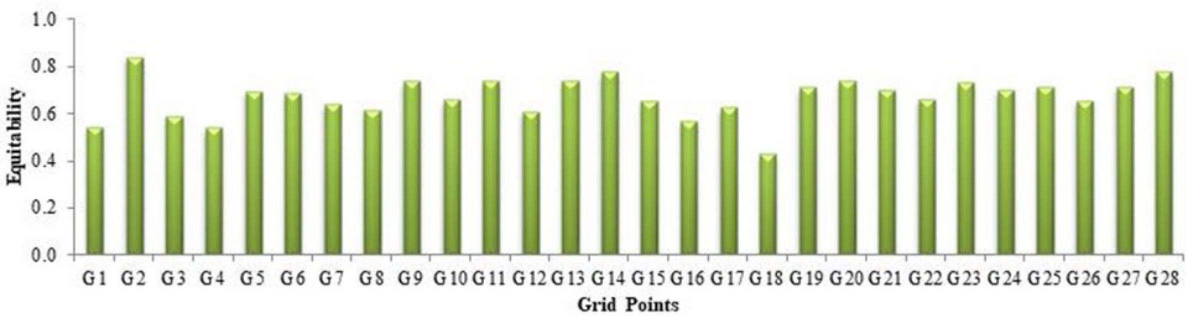


(a)

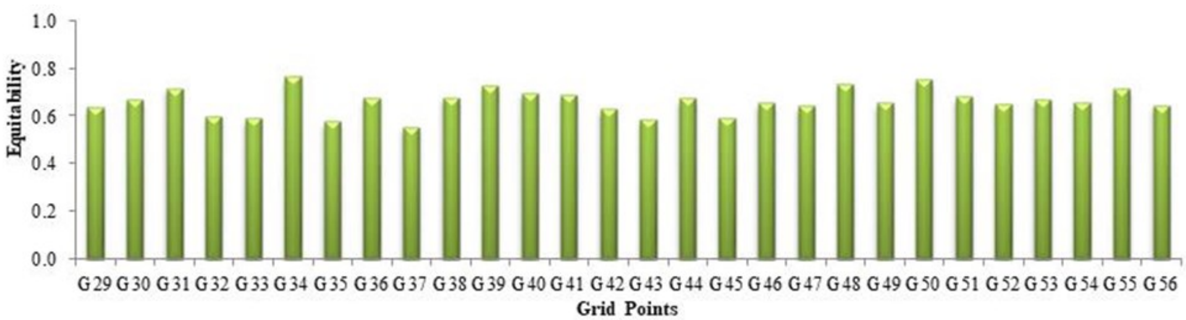


(b)

Figure 2. Equitability of insect pests on rice during monsoon season in study area (a) grid points 1 to 28 (b) grid points 29 to 56

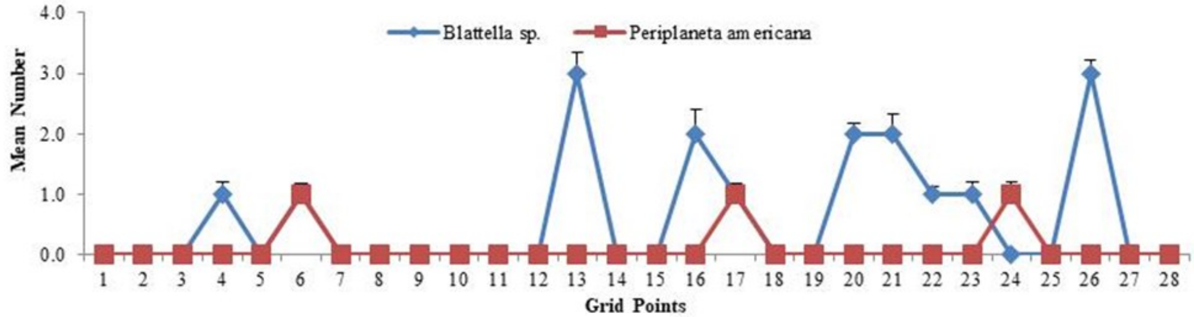


(a)

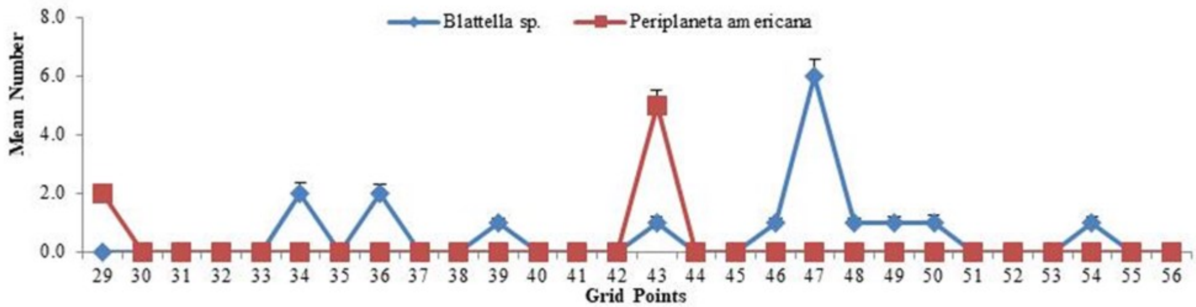


(b)

Figure 3. Season long mean numbers of insect pest species from order Blattodea (a) grid points 1 to 28 (b) grid points 29 to 56

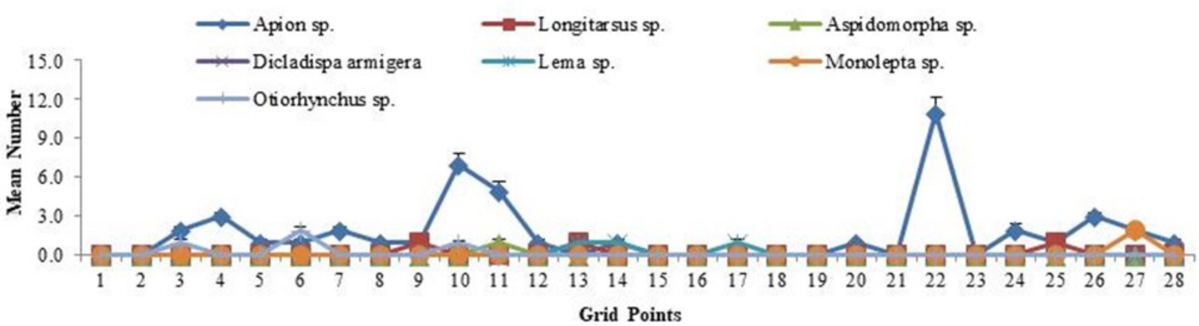


(a)

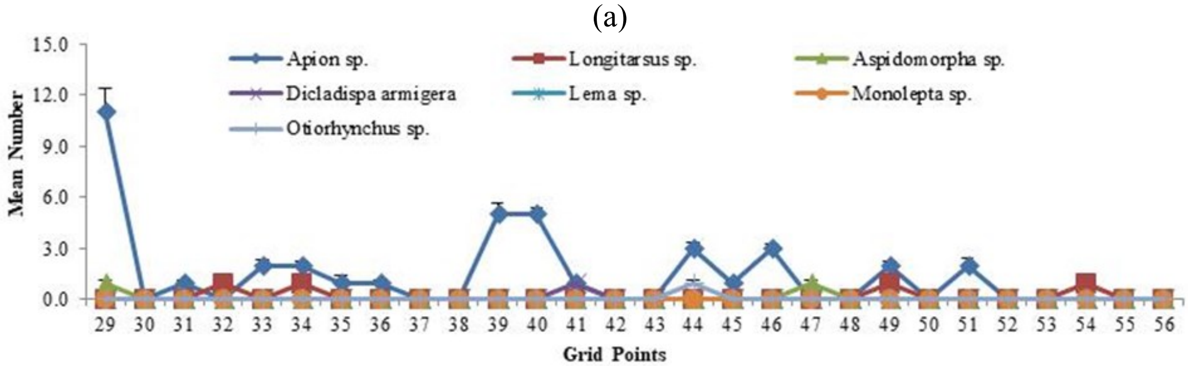


(b)

Figure 4. Season long mean numbers of insect pest species from order Coleoptera (a) grid points 1 to 28 (b) grid points 29 to 56

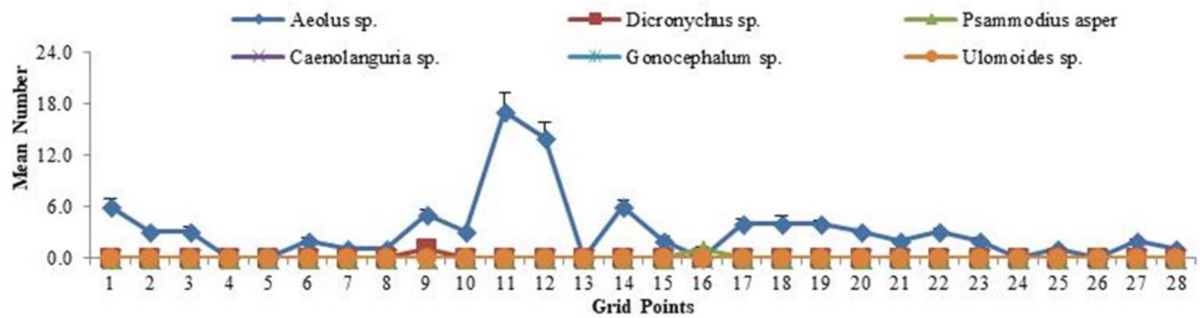


(a)

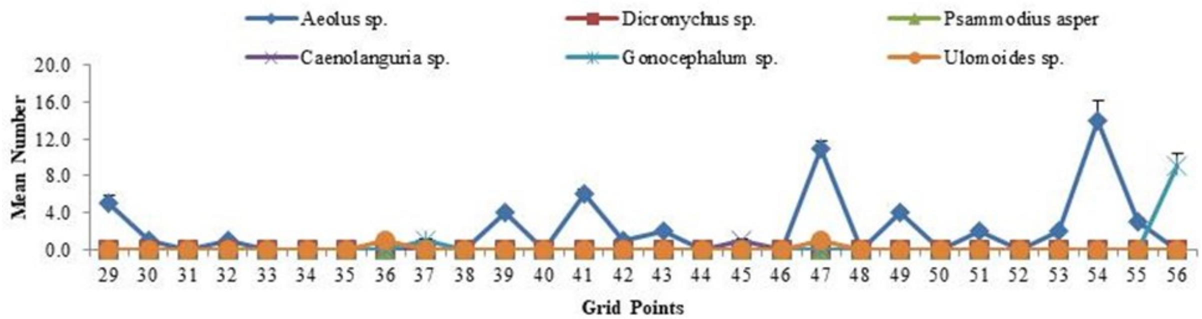


(b)

Figure 5. Season long mean numbers of insect pest species from order Coleoptera (a) grid points 1 to 28 (b) grid points 29 to 56

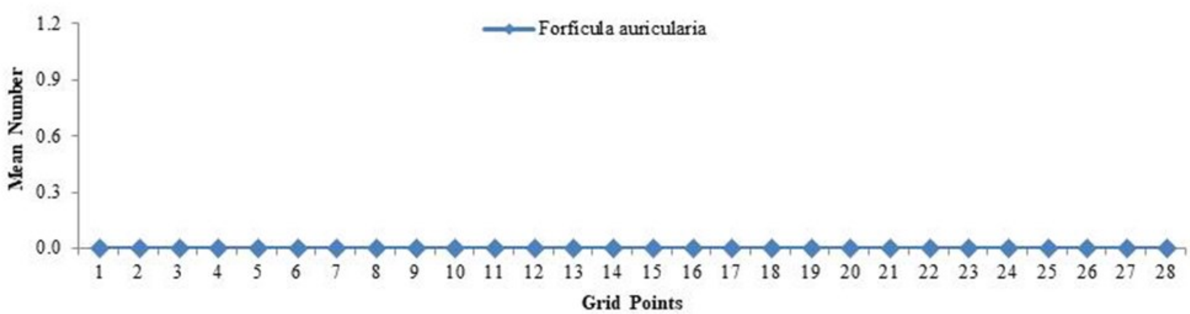


(a)

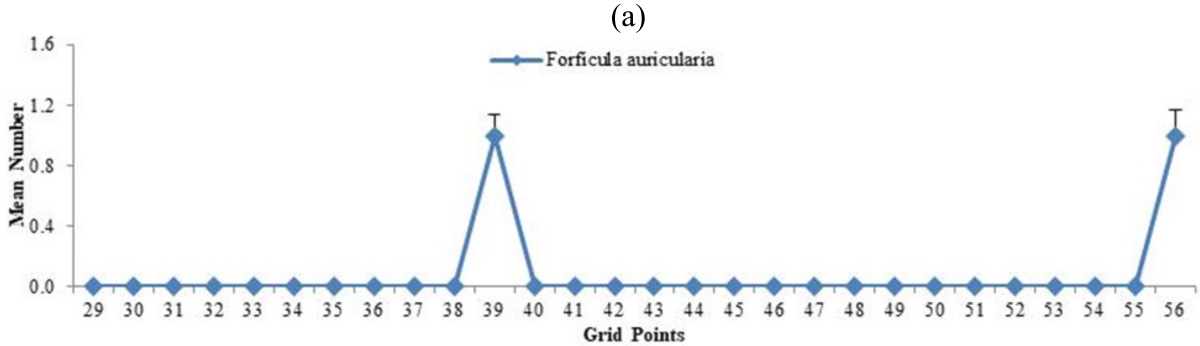


(b)

Figure 6. Season long mean numbers of insect pest species from order Dermaptera (a) grid points 1 to 28 (b) grid points 29 to 56

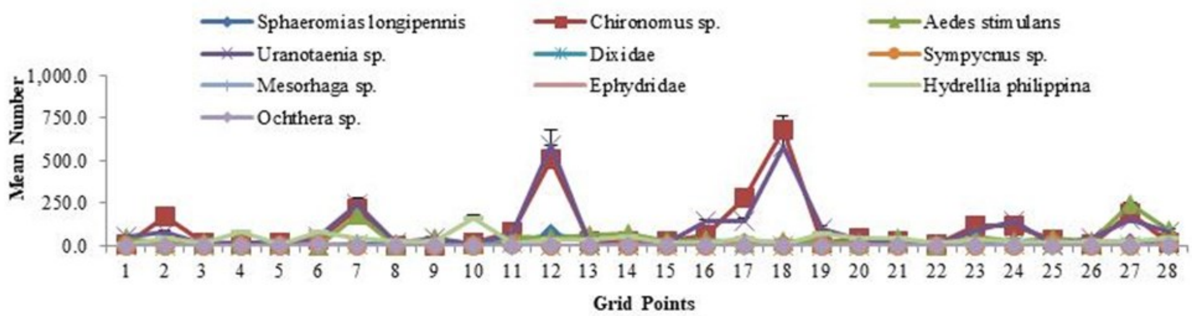


(a)

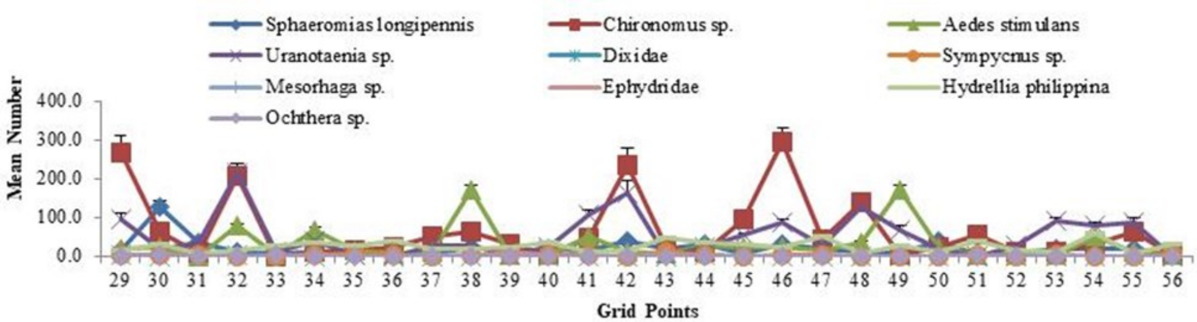


(b)

Figure 7. Season long mean numbers of insect pest species from order Diptera (a) grid points 1 to 28 (b) grid points 29 to 56

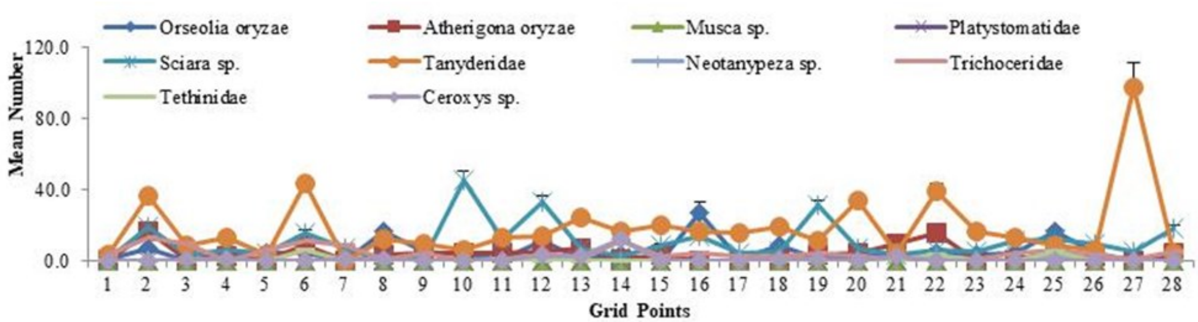


(a)

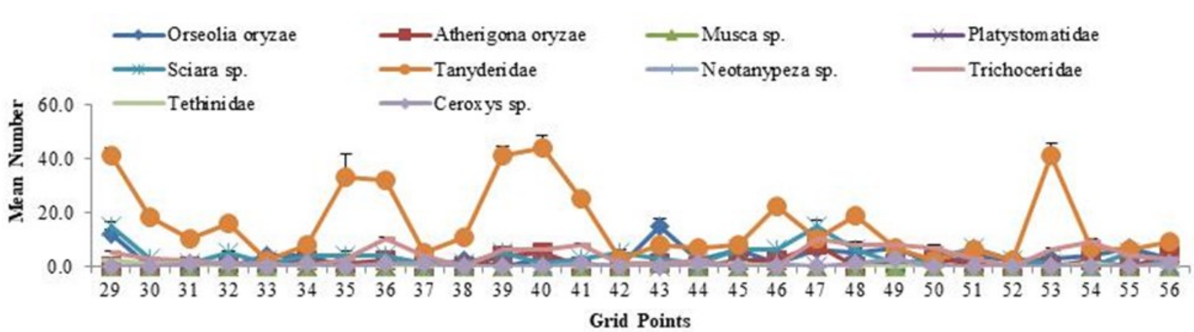


(b)

Figure 8. Season long mean numbers of insect pest species from order Diptera (a) grid points 1 to 28 (b) grid points 29 to 56

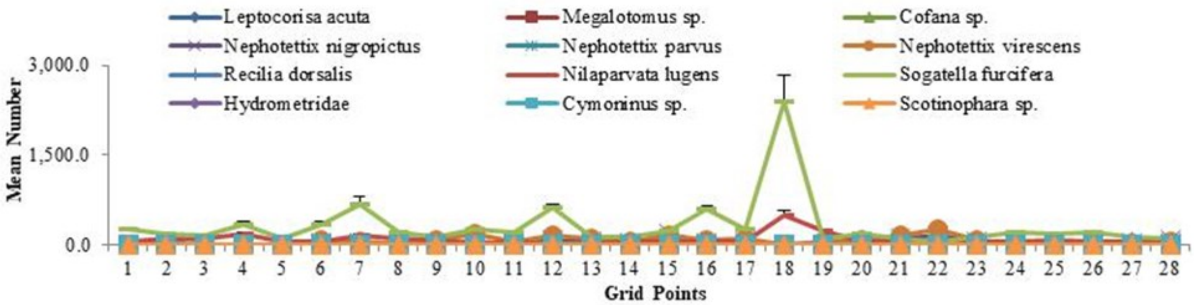


(a)

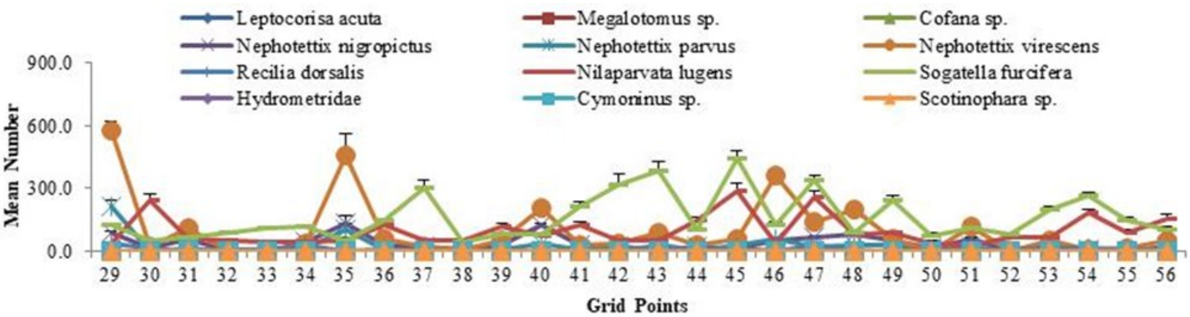


(b)

Figure 9. Season long mean numbers of insect pest species from order Hemiptera (a) grid points 1 to 28 (b) grid points 29 to 56

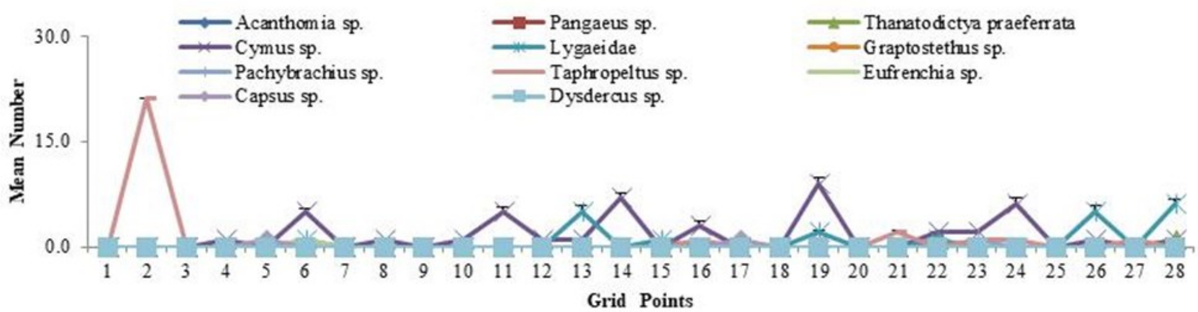


(a)

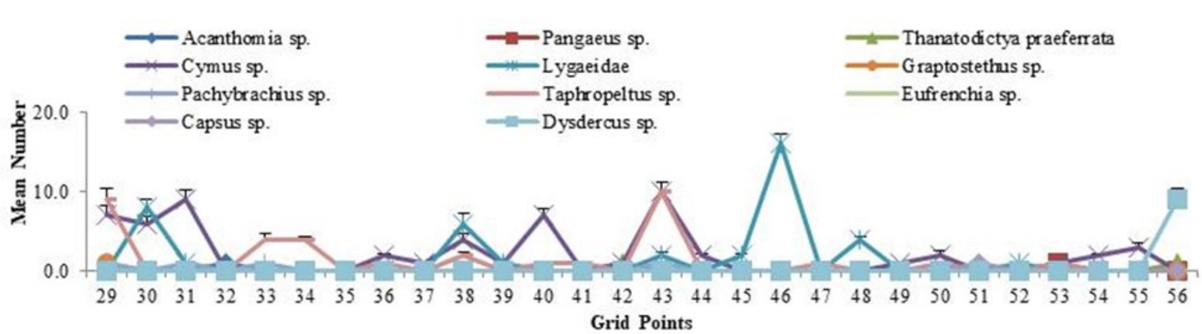


(b)

Figure 10. Season long mean numbers of insect pest species from order Hemiptera (a) grid points 1 to 28 (b) grid points 29 to 56



(a)



(b)

different insect pest species *Aspidomorpha* sp., *Dicladispa armigera, Lema* sp., *Longitarsus* sp. and *Monolepta* sp. from family Chrysomelidae recorded. Among them, the most abundant species *Longitarsus* sp. (0.20 ± 0.20) was found in G32, G34, G49 and G54 respectively (Figure 4.b). In Elateridae family, *Aeolus* sp. was more abundant than *Dicronychus* sp. and the highest mean number of *Aeolus* sp. (2.83 ± 2.26 individual) was occurred in grid point G11 (Figure 5.a). Under order Dermaptera, the highest mean number *Forficula auricularia* (0.17 ± 0.17 individual) from family Forficulidae was observed in grid point G56 (Figure 6.b).

In case of order Diptera, 15 different families such as Cecidomyiidae, Ceratopogonidae, Chironomidae, Culicidae, Dixidae, Dolichopodidae, Ephydridae, Muscidae, Platystomatidae, Sciaridae, Tanyderidae, Tanypezidae, Trichoceridae, Tethinidae and Ulidiidae were observed. Among them, the highest mean number from *Chironomous* sp. (135.60 ± 88.4 individual) belonging to family Chironomidae and the second most abundant species *Uranotaenia* sp. (116 ± 90.3 individual) from family Culicidae were observed in grid point G18 (Figure 7.a).

In the study area, 13 insect pest families of order Hemiptera, such as Alydidae, Cicadellidae, Coreidae, Cydnidae, Delphacidae, Dictyopharidae, Hydrometridae, Lygaeidae, Membracidae, Miridae, Ninidae, Pentatomidae, Pyrrhocoridae were observed. Among them, the highest mean number *Sogatella furcifera* (477.20 ± 446.68 individual) and the second highest mean number (99 ± 92.30 individual) from *Nilaparvata lugens* belonging to family Delphacidae were recorded in grid point G18 (Figure 9.a). Moreover, 4 different insect pest families: Arctiidae, Amatidae, Papilionidae and Pyralidae from order Lepidoptera were observed. Among them, the highest mean number (4.40 ± 4.15 individual) of *Scirpophaga incertulas* from family Pyralidae was observed in G2 grid point (Figure 11.a).

In order Orthoptera, the highest mean number (0.17 ± 0.17 individual) of *Gryllus* sp. belong to family Gryllidae from grid point G27 and *Paratettix* sp. (0.40 ± 0.40 individual) from family Tetrigidae in grid points, G19 and G38 were recorded (Figure 12 (a,b)).

According to the present study, the observed dominant rice insect pests species were *Sogatella furcifera* and *Nilaparvata lugens* belonging to order Hemiptera and family Delphacidae. Lee and Park (as cited in May Thet Hlaing, 2018) stated that the pest species were mainly Homoptera and dominated by Delphacidae (*Nilaparvata lugens* Stal and *Sogatella furcifera* Horvath) and Cicadellidae (*Nephotettix virescens*) which involved more than 81 percent of pest abundance.

4. Conclusion

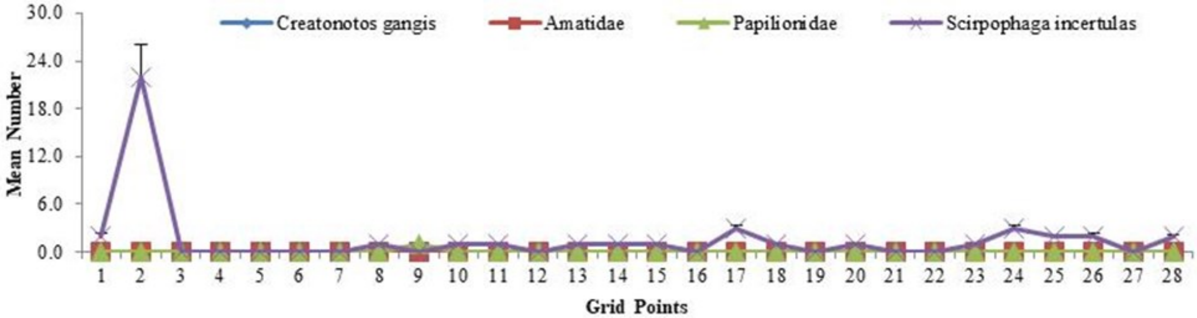
According to the calculation of Shannon-Wiener function, present study revealed that species diversity and equitability were high in all grid points throughout the period.. However, the lowest diversity index and equitability of insect pest species were found in grid point G18. Meanwhile, the highest mean population number of *Sogatella furcifera* and *Nilaparvata lugens* from order Hemiptera and family Delphacidae were recorded in grid point G18. It means that the lowest diversity and equitability favored the population builds up of major pests in that area.

The possible reasons for the abundance of insect pest population may be due to the continuous rice cultivation (monoculture) and use of agro-chemicals without manipulation of weed cover. The diversity of insect pest species varied widely according to the grid points. Moreover, these findings will provide valuable information to the rice farmers in that area for the improvement in sustainable control of rice insect pests.

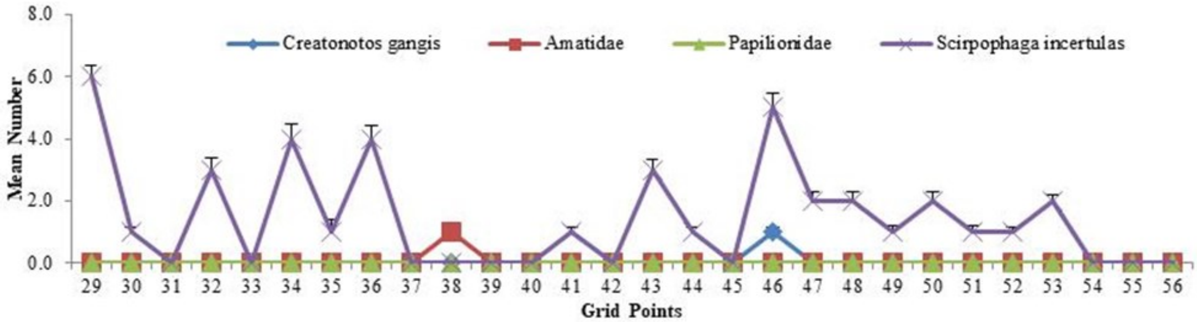
5. Acknowledgements

The authors would like to thank Japan International Cooperation Agency (JICA) Project for Capacity Development of Yezin Agricultural University (YAU-JICA TCP) for the financial and technical training support . We also extend our thanks to the authorized persons from the Department of Agriculture (DOA) and farmers for their participation in this project.

Figure 11. Season long mean numbers of insect pest species from order Lepidoptera (a) grid points 1 to 28 (b) grid points 29 to 56

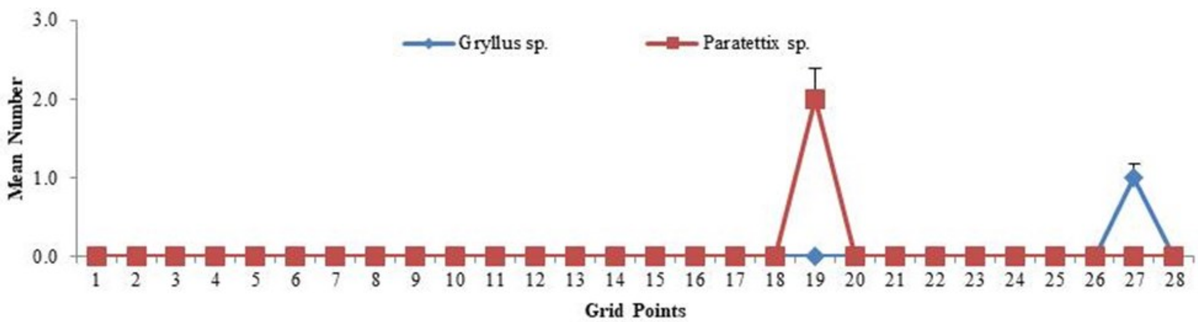


(a)

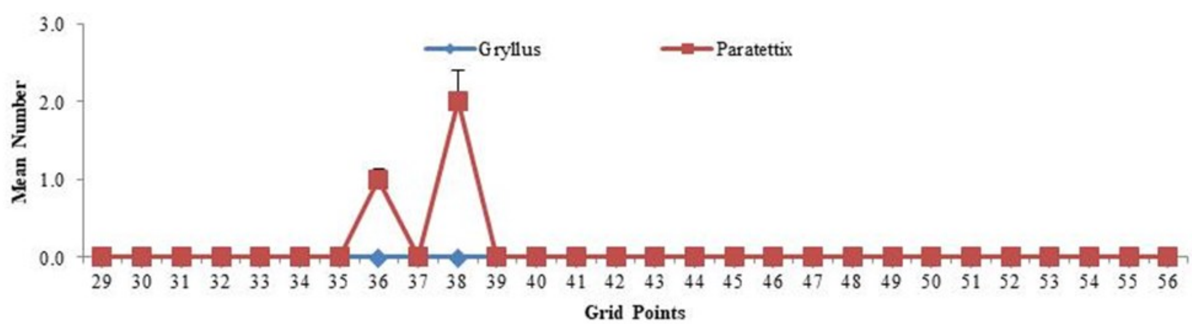


(b)

Figure 12. Season long mean numbers of insect pest species from order Orthoptera (a) grid points 1 to 28 (b) grid points 29 to 56



(a)



(b)

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Drought tolerance eggplant (*Solanum* spp.) selection by molecular markers (SSRs)

Htwe Min Thant[1], Aye Aye Thwe[2], Moe Kyaw Thu[3], Nyo Mar Htwe[4] & Khin Thida Myint[5]

Abstract

In Myanmar, the specific attempt in collection and use of molecular techniques on drought related genes of eggplant genotypes is rarely found. To confirm the presence of drought tolerance related gene (allele) among the genotypes using drought tolerance gene associated simple sequence repeats (SSR) markers, the experiments were conducted at Laboratory of Department of Horticulture, YAU from October to December 2018. Genotypes collection was done from May to November, 2016. Forty one eggplant genotypes were collected from around the country having wider range of geographical conditions in Myanmar. With the use of 19 SSR markers, seven polymorphic SSR markers can be used to detect drought tolerance related alleles in Myanmar eggplants genotypes. Some potential drought tolerance genotypes which possessed the same allele like check variety such as genotype number 1, 4, 7, 9, 10, 31 and 35 by monomorphic allele and 1, 4, 7, 9, 14, 23, 30, 31, 33, 34, 35 and 36 by polymorphic alleles. From the result of present study, potential parents can be selected for further eggplant variety improvement breeding program especially for drought stress conditions. Further collection and evaluation will be needed to cover the eggplant genetic diversity of whole country Myanmar. Screening SSR markers for the polymorphism showed that different eggplant genotypes can be represented by different allele. The use of SSR markers provided an early detection method to select and screen out plants even at an early stage of development. The seven polymorphic primers such as eme01D03, emb01G19, ecm001, emg01B17, emf11H23, emd12B05 and emf01G17 were successfully amplified the drought related genes on genotypes number 1, 4, 7, 9, 10, 13, 14, 23, 30, 31, 33, 34, 35, 36 and 42 at alleles A and B with different base pairs. Further observations are necessary with additional markers for other genotypes excluded in this study. All of these drought tolerance related genotypes can be used as parents for breeding or any crop improvement program in eggplant especially to cope with drought stress.

Key words: *eggplant, drought, genetic diversity, SSRs*

1. Introduction

Brinjal or eggplant or aubergine (*Solanum melongena* L.) is one of the non-tuberous species of the family Solanaceae. It belongs to the sub-family Solanoideae, the tribe Solaneae, the genus Solanum and the subgenus *Leptostemonum* (Dun.) Bitt., including more than 450 species distributed among 22 sections (D'Arcy, 1972). There are many constraints in eggplant production such as pests, diseases, weeds and extreme environmental conditions that cause yield losses. One severe environmental constraint is the scarcity of water (Farooq et al., 2009). The full genetic potential of the crop is not achieved when it is subjected to environmental stress conditions and the yield reduced to 70-80 percent due to water stress during reproductive stage (Tayal et al., 2004). Due to their high moisture content, vegetables are generally sensitive to extreme environmental conditions such as high temperature and limited moisture that causes low yield in the tropics (dela Pena and Hughes, 2007). Eggplant, which contains 92.7 percent moisture content (Chen and Li, 1996), has been shown to be adversely affected by drought in terms of plant height, total dry weight and fruit yield.

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Delfin et al. (2015) studied to confirm the hybridity of F_1 progenies from crosses of *S. melongena* and commercial varieties selected in a previous study for their differing response to drought. The use of DNA markers for characterization and identification of genotypes is essential for rapid and early verification of true hybrids at seedling stage. Among the DNA markers, simple sequence repeats (SSRs) or microsatellites are the most suitable for hybridity testing due to its co-dominance detecting the presence of DNA sequences corresponding to distinct alleles contributed by both parents in a specific cross (Cordiero et al., 2000).

SSR markers were utilized in eggplant for genetic diversity analyses and genetic characterization and linkage map construction (Barchi et al., 2011; Barchi et al., 2012; Cericola et al., 2014; Portis et al., 2015; Saracanlao et al., 2016; Toppino et al., 2016). Delfin et al. (2013) studied the first report in eggplant where SSR markers were used to confirm true hybrids derived from parents with differing drought response directed towards eggplant improvement for moisture stress tolerance. Being a part of origin of eggplant, Myanmar might have broad genetic background of eggplant. The search of gene of interest such as moisture stress will be a great impact for eggplant producers of dry zone area especially central part of Myanmar. The present study is the first report to identify the drought tolerance eggplant genotypes by using SSR markers in Myanmar.

2. Materials and methods

This experiment was conducted in Experiment and Lecture Building 2 (ELB2), YAU during 2018 post-monsoon season. All of the selfed germplasm from previous experiment were transplanted on each plastic bag. Young fresh leaves from each genotype were utilized for DNA extraction.

2.1 Plant materials

A total of forty-two eggplant genotypes were used in this study. The eggplant genotypes utilized in the present study were collected from different geographic locations such as Shan (South), Shan (North), Kayah, Kachin States, Magway, Tanintharyi, Mandalay, Sagaing, Bago (East) and Bago (West) Regions of Myanmar. Forty one collected genotypes and one variety (India) was used as drought tolerance check variety (Table 1). The eggplant genotypes were planted in the vinyl house, YAU and arranged on RCBD with three replications.

2.2 DNA extraction and quantification

Young, fully expanded and damage-free leaves (14 days old) of eggplant were collected from each genotype. Genomic DNA was extracted following the cetyltrimethyl- ammonium bromide (CTAB) protocol with small modifications. Approximately 2 g fresh leaf samples were ground using mortar and pestle. DNA quality and yield were determined by NANODROP 2000 spectrophotometer and adjusted to 30-50 ng/µl. Working stock for each DNA sample was prepared and stored at 4^{o} C. Stock DNA were stored at -20 ^{o}C (Plate 2).

2.3 PCR amplification and gel electrophoresis

Polymerase chain reaction (PCR) was performed using the optimized SSR amplification conditions for eggplant. Each 10 µL PCR reaction consisted of 2 ng genomic DNA, 1X PCR buffer with 1.0 mM MgCl2, 0.8 mMdNTPs, 0.1 µM each of forward and reverse primer and 0.01 U Taq DNA polymerase.

Amplifications were carried out in a PikoReal RT-PCR Thermal Cycler with the amplification conditions of initial denaturation at 95º C (30 s), 30 cycles of 95º C (30 s) denaturation, 65-68º C annealing (1 min) and 72º C (1 min) extension followed by one cycle at 72º C (5 min) final extension.

PCR amplification products were electrophoresed in 2 percent agarose gel using 0.5X Tris-borate EDTA (TBE) running buffer. Electrophoresis was carried out for 45 minutes at 30 amp/100 V. The gel was stained with RedSafe™ nucleic acid staining solution and detected under UV light using the UV Image Recorder (Plate 3.).

2.4 Screening for drought tolerance related SSR fragments

A total of 19 SSR primers pairs (Table 2) which were previously identified to be associated with drought tolerance genes in eggplant were selected (Delfin et al., 2013). The 42 eggplant genotypes were screened using selected SSR markers. The amplified DNA fragments for each SSR marker were scored visually to note the presence (+) or

Table 1. Sources of collected genotypes

Sr. No.	ACCESSIONS	SOURCE
1.	MEG16-01	Kayah
2.	MEG16-02	Bago (East)
3.	MEG16-03	Mandalay
4.	MEG16-04	Bago (West)
5.	MEG16-05	Bago (East)
6.	MEG16-06	Shan (South)
7.	MEG16-07	Mandalay
8.	MEG16-08	Shan (South)
9.	MEG16-09	Mandalay
10.	MEG16-10	Bago (West)
11.	MEG16-11	Magway
12.	MEG16-12	Kayah
13.	MEG16-13	Bago (East)
14.	MEG16-14	Kachin
15.	MEG16-15	Kachin
16.	MEG16-16	Kachin
17.	MEG16-17	Mandalay
18.	MEG16-18	Shan (North)
19.	MEG16-19	Kayah
20.	MEG16-20	Kayah
21.	MEG16-21	Kachin
22.	MEG16-22	Shan (South)
23.	MEG16-23	Mandalay
24.	MEG16-24	Bago (West)
25.	MEG16-25	Bago (East)
26.	MEG16-26	Magway
27.	MEG16-27	Kachin
28.	MEG16-28	Magway
29.	MEG16-29	Shan (North)
30.	MEG16-30	Shan (South)
31.	MEG16-31	Kachin
32.	MEG16-32	Kayah
33.	MEG16-33	Thanintharyi
34.	MEG16-34	Mandalay
35.	MEG16-35	Thanintharyi
36.	MEG16-36	Thanintharyi
37.	MEG16-37	Magway
38.	MEG16-38	Thanintharyi
39.	MEG16-39	Mandalay
40.	MEG16-40	Thanintharyi
41.	MEG16-41	Magway
42.	MEG16-42	Resistance Check (India)

Plate 1. Collected genotypes and their diversified fruit morphology

Plate 2. Flow chart for genomic DNA extraction and quantification

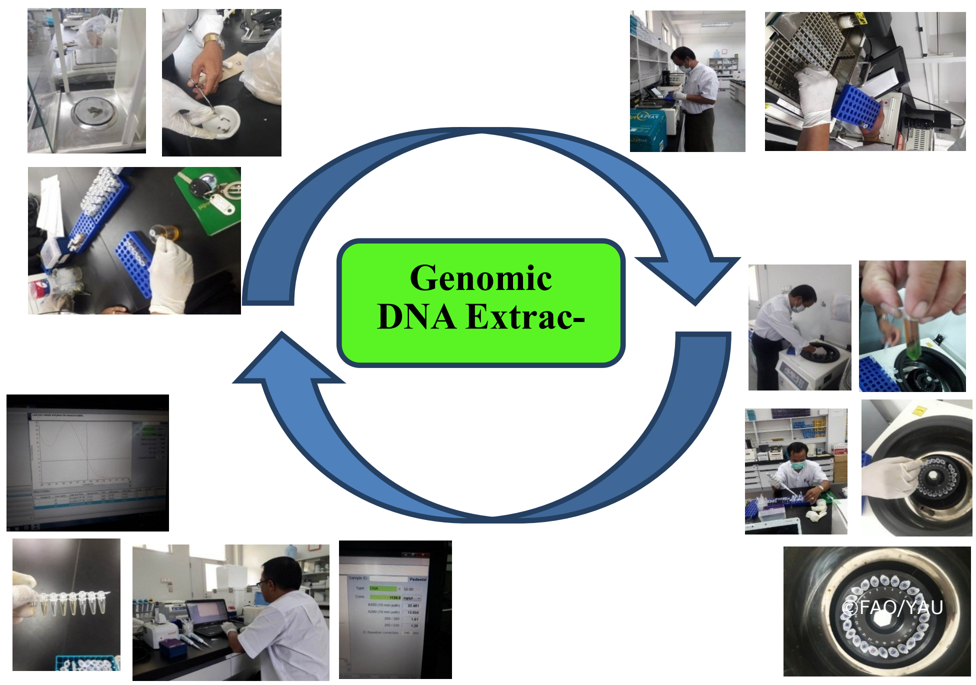

Plate 3. Flow chart of activities for drought tolerance related gene analysis

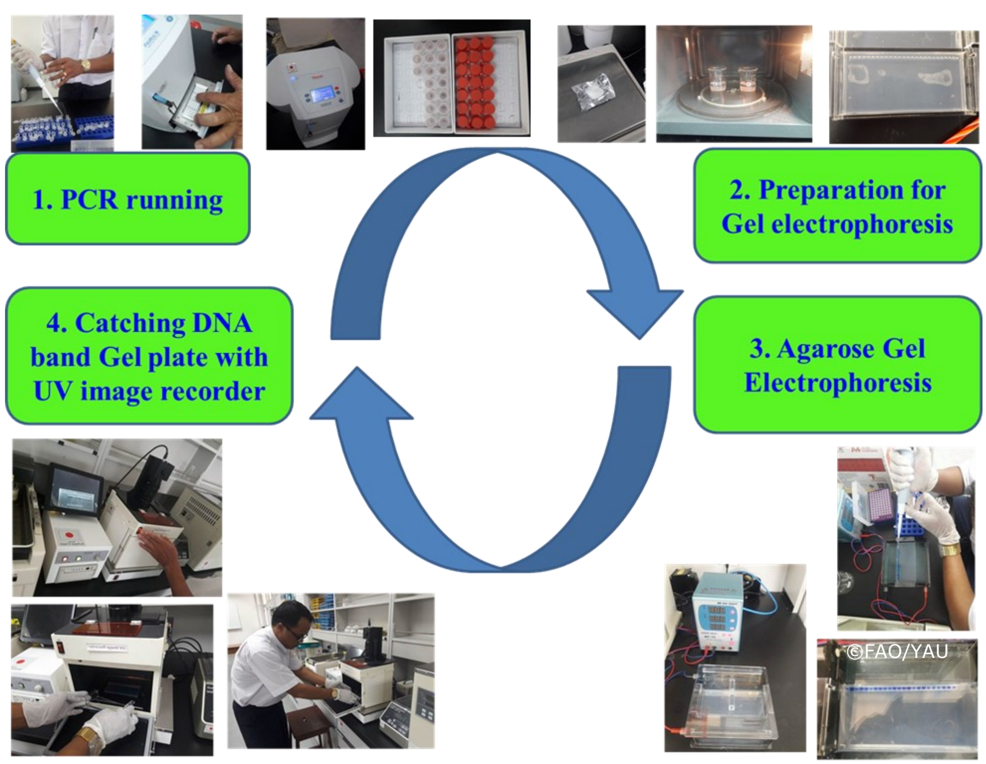

Table 2. Primer sequences, expected size, and linkage group of the nineteen selected SSR markers used for this study (Delfin et al., 2013)

Marker	Repeat type and length	Forward primer	Reverse primer	Expected product size (bp)	Linkage group	Annealing temp.
eme01D03	(AG)15	ACAAGAATCGGTCCTCTTTGCATTGT	GTTTGCTTTTCAACCTCTCCGCTATCTC	275	LG01	65
emb01G19	(CT)22	AATTAAGGCTGAGAGGGGAAGACG	AAAGGAGGAAAGGGAAAGGGAAAG	322	LG01	65
ecm001	(TC)17	ACCTTACGCAATTTACACTTCCCC	GTTTCAATGGCGTCACCTCTCTCT	229	LG03	65
emh21J12	(AG)19	ACAGAACAATTCACCAGCAGTCAA	GTTTAGGAACAGGGAAAATCGTATCGGT	303	LG03	65
emd05F05	(TA)5(TG)16	ACGGGGGTGTCTCATTACACTACTGG	GTTTACCCGTTCCTCAGCTTATAGACCC	334	LG03	65
emg01B17	(TC)3…(TC)24	ACAAGGCTCAAAGTCACAAGTCAA	GTTTGGCTCTGCCCCTAACATCTACAAA	250	LG04	65
emf11D18	(TA)10(TG)51	AGAGACAGGGAGAGTGCATTCTATG	GTTTGCAGTTCATAAGGTTGCATCAATAC	289	LG06	65
emg11D22	(TA)6(TG)12	AGGCCCATGTTTGGCATTTAT	GTTTATGGATATCTCAATGGACCTGA	291	LG06	65
eme25D01	(AC)9(AG)9	AGTCCCAACCAAAATCGTAGAGGC	GTTTCACTGAAGGATGTGGAGTGTGA	299	LG06	65
emf11H23	(TC)22	ATTCTGAAAACAAGAGCAGCCCTC	GTTTCTCAACACCTCTGTGTCTGGCAT	260	LG06	65
emf11L21	(TC)23	ATAGCCTAGGTAACGTACCCCTCG	GTTTGGCTCTATTTCCTGGGCTTTTCAT	298	LG06	65
emf21I02	(TC)20	AGTGCATTTCTCAAATCAAAAGGG	GTTTCAATTTCACAGGCTCCTGCATTA	204	LG07	65
emg11A06	(AG)22	AGTGCTAATATGCAAGGGGAATTGG	GTTTACGGTGATCTTTCCGTATTCCAAA	257	LG07	65
ecm009	(TAT)13…(CA)3	ATCTAGTACCATCAAGTCTAAGCAGCA	GTTTAACAACAGCTGAGGCCATGAAA	245	LG08	68
emd12B05	(AC)33(AT)9	ACGGAGTAGGCTCGGAGCGTGATATT	GTTTGAAAGGGCAAAAAGTCCAAACAAC	277	LG08	68
emf01G17	(AG)18	ATGGCAACTGATAATGCAGACGTG	GTTTCTCACTCTTACATGTGGCTGGC	289	LG08	68
emb01H20	(TC)21	TCTTGTTCCCAGTCTATCGCTAATCA	ATCCGAATTTAGTCGGGCTTCAAT	351	LG09	65
emg11I03	(TA)3(TG)11…(AG)23	ATTAGGCACAAGTGCCACCTGAAT	GTTTCAGCCGGGAGTCTGATAGGTAAAA	212	LG10	65
emi06F08	(TA)3…(TA)4…(AC) 12A (TA)15T(AG)13	ATAATGAACCAAAGCGAGAGCAAC	GTTTCAGGTCCATAGGGGTGGATCTATG	261	LG11	68

absence (-) and amplified at alleles A and B of each allele/band (Table 3).

3. Results and discussion

3.1 Screening for drought tolerance related genotypes

Of the nineteen polymorphic SSR primers, only seven have distinct and scorable banding patterns. These seven polymorphic markers amplified 10 alleles in the 15 eggplant genotypes. Others twelve SSR markers cannot amplified or detected null alleles among the genotypes (Plate 4.).

The eme01D03 marker amplified one allele on genotypes number 31 and 42. Genotype number 42 is a resistant check genotype and the same allele was detected (275bp) in genotype number 31. Also the primers emb01G19 and ecm001 detected genotypes number 35 and 42, and 13 and 42 at the same base pairs of 322 bp and 229 bp, respectively. The primers emg01B17 amplified one allele in 10 genotypes including check genotype. The size of the allele was 250 bp. Therefore, genotype number 31, 35 and 13 have similar alleles with drought tolerance genotype number 42 at different locus. In the phenotype data, only genotype number 35 has similar fruit character with check genotype 42. The other genotypes number 31 and 13 have different fruit character from check genotype. These three genotypes showed drought tolerance characters in phenotypic screening (Plate 4 and Table 3).

The primer emf11H23 amplified 2 alleles which were represented as allele A and allele B among seven genotypes. The genotype number 13 occupied a distinct allele, allele A which is 300 bp while the genotypes number 7, 9, 23, 33 and 34 presented allele B which is 260 bp. This allele, allele B was also detected in the check genotype, genotype number 42. Although genotype number 13 showed different allele from drought tolerance check in this locus, physiological response was the same trend with check variety (Plate 4 and Table 3).

The emd12B05 primer amplified 2 alleles also presented as allele A and B among five genotypes. Genotypes number 34 and 35 occupied allele A (size 300 bp) while genotypes number 36 and 23 possessed allele B (size 277 bp) which was the same allele with check genotype number 42. The fruit character of genotype number 36 was the same with check genotype number 42 while that of genotype number 23 was totally different. It has round and small fruits. It was strange to found the same allele in genotype number 23 with check genotype. The plant character and fruit color of these two genotypes were totally different. On the other hand, although the similar fruit types, size, shape and color are the same, genotype number 35 and 42 revealed different allele, allele A and allele B.

The emf01G17 primer amplified 2 alleles represented as allele A and allele B. All of the genotype revealed allele B which was the same base pair with check genotype 42 (size 289 bp) except genotype number 7. Genotype number 7 possessed its distinct allele, allele A (size 300 bp). It was clear that the fruit character of genotype number 7 was totally different from the others (Plate 4 and Table 3).

Four out of seven amplified primers showed monomorphic allele while the rest three primers expressed polymorphic alleles. Similar results were reported by Delfin et al. (2013), of the 50 primer pairs, 31 shown distinct monomorphic fragments while only 19 primer pairs displayed polymorphism in the selected eggplant genotypes used. The 18 polymorphic SSR markers amplified 46 alleles in the 20 eggplant accessions. Lesser number of allele (10) was found in present study compare to Delfin et al.'s result. One to two alleles per locus (1.4 in average) was seen among tested genotypes. Null allele shown in some genotypes implied the transferability of the markers used. In other means, the absent of annealing site in some of Myanmar eggplant genotypes. Nunome et al. (2003) and Tumbilen et al. (2011) also found null alleles (absence of amplified PCR products) from some SSR primers in commercial eggplant variety, Mistisa from Taiwan, *S. melongena* from Philippines and India. Higher number of accessions from a broader range of origin can explain the higher number alleles detected per primer in the study of Behera et al. (2006) and Nunome et al. (2003). So, further collection activities are still needed to get higher number of allele per locus.

Plate 4. Gel photos of PCR product resulted by seven polymorphism SSR markers

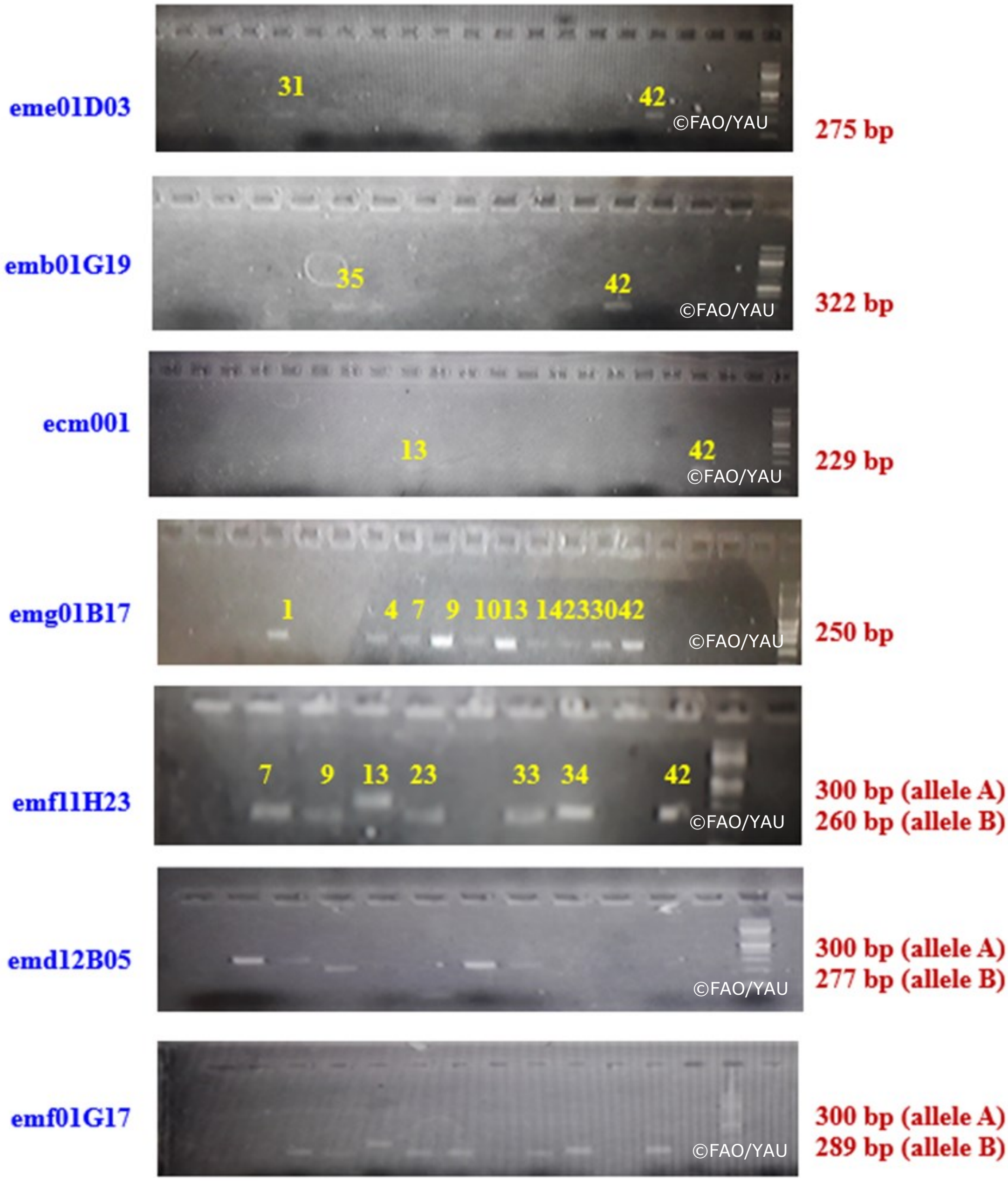

Table 3. Polymorphic bands detected by seven SSR markers among fifteen eggplant genotypes

Genotypes / SSR primers	1	4	7	9	10	13	14	23	30	31	33	34	35	36	42
eme01D03	-	-	-	-	-	-	-	-	-	+	-	-	-	-	+
emb01G19	-	-	-	-	-	-	-	-	-	-	-	-	+	-	+
ecm001	-	-	-	-	-	+	-	-	-	-	-	-	-	-	+
emg01B17	+	+	+	+	+	+	-	-	-	-	-	-	-	-	+
emf11H23	-	-	B	B	-	A	B	B	B	-	B	B	B	-	B
emd12B05	-	-	-	-	-	-	-	B	-	-	-	A	A	B	B
emf01G17	B	B	A	B	-	-	B	-	B	B	-	-	-	-	B

+ presence (amplified PCR product), - absence (amplified PCR product), A, B (presence different alleles)

4. Conclusion

Based on the findings, with the use of 19 SSR markers, seven polymorphic SSR markers can be used to detect drought tolerance related alleles in Myanmar eggplants genotypes. Some potential drought tolerance genotypes which possessed the same allele like check variety such as genotype number 1, 4, 7, 9, 10, 31 and 35 by monomorphic allele and 1, 4, 7, 9, 14, 23, 30, 31, 33, 34, 35 and 36 by polymorphic alleles. From the result of present study, potential parents can be selected for further eggplant variety improvement breeding program especially for drought stress conditions. Further collection and evaluation will be needed to cover the eggplant genetic diversity of whole country Myanmar.

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Genetic variation for salinity tolerance in rice (*Oryza sativa* L.) genotypes at seedling stage

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Abstracts

The present investigation was carried out to select the salt tolerance varieties and to find out the genetic diversity among the ninety-three genotypes based on agronomic parameters under salt sensitive at seedling stage. Augmented design with 6 replications was used at the Department of Plant Breeding, Physiology, and Ecology. Growth parameters like shoot length, root length, plant biomass, survival percent, and visual injury score were measured after 10 days exposure with electro conductivity (ECe) of 10 dSm^{-1} (decisiemens per metre) saline solution. Significant genotypic variation and correlations were found in shoot length, fresh weight, dry weight, and survival percent. According to cluster analysis, cluster III was allocated as highly tolerance with score 1 (HT), the salinity reaction of known genotypes and classified most of the tested genotypes into tolerant groups, excluding for eight and six varieties positioned in the tolerant and moderately tolerant groups, respectively. Among 93 genotypes, cluster I consisted of 78 genotypes along with sensitive check (IR 29) and shoot length mean value was 18.94 cm. Three genotypes of Shwe At, Maung Lay and Yaw Shwe War (score 1) were included in Cluster III including Pokkali and other four genotypes of YAU-1214-183-3-3-1-1-1, Nga Sar Kay, Pyawe Gaung, and Mya Waddy Pathein (score 3) were included in cluster II including IR64 saltol. Cluster III had mean value of shoot length 26.54 cm and cluster II had 22.36 cm. Therefore, these seven genotypes were considered as promising salt tolerant genotypes to be utilized in rice breeding program.

Keywords: *Salinity tolerance, Electro conductivity* (*ECe), saline solution*

1. Introduction

Myanmar is an agricultural country and national economy is based on agricultural sector. Rice is one of the staple foods of Myanmar (MOALI, 2018). Nowadays, the estimated population of the Republic of the Union of Myanmar is 53.86 million. Yearly growth rate in Myanmar is 0.91 percent (Tun Thein, 2018). It is needed to increase the productivity of rice for growing population in Myanmar. This is a challenge because there is very little potential for future extension of arable lands, whereas environmental stresses affecting crop production are increasing (Tester and Langride, 2010).

Biotic and abiotic stresses restrict its productivity worldwide, among which abiotic stress alone contributes to 50 percent of the total yield losses. Salinity is one of the most severe abiotic stresses of rice production in many areas of the world (Munns and Tester, 2008). Breeding for salt tolerance is afor rice breeders that are required to select tolerant lines for breeding. Salt tolerance screening in the field is problematic as soil salinity is dynamic. The level of salt diverges both horizontally and vertically in the soil profile and has dissimilarities with time. These environmental trepidations are overcome by testing in hydroponics systems in a stable environment (Lafitte, Ismail and Bennett, 2004).

Rice is very sensitive to salinity stress and presently listed as the most salt sensitive cereal crop with a

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threshold of 3 dSm^{-1} for most cultivated varieties (USA, 201. EC_e (electro conductivity of its saturation extract) is as low as 3.5 dSm^{-1}, rice losses about 10 percent of its yield and 50 percent yield loss was noted for rice at 7.2 dSm^{-1} (Umail, 1993). Therefore, it is important to develop rice tolerance varieties to salinity stress that permits this staple crop to provide sufficient food for rice-consuming communities.

Rice has been reported to be relatively salinity tolerance during germination, active tillering and maturity, but is very salt sensitive during early seedling stage (2-3 leaf stage) and during pollination and fertilization stages (Zeng, Shannon and Lesch, 2001). Screening of genotypes for salt tolerance at early stage plays a very important role as a there considerable saving in time (Mass and Grieve, 1994, Zeng et al., 2002, Ferdose et al., 2009). Screening in seedling stage agreements the opportunity of pre-selection of breeding lines, progeny and cultivars before field evaluation.

The genetically dissimilar parents belonging to different clusters would be provided for useful hybridization programme involving an opportunity for carrying together gene groups of unlike nature (Chanbeni, Lal, and Rai, 2012). It can be promised hybrid derivatives resulted probably due to interaction of divergent genes in parents. The cluster analysis using Eucledian distance offers a useful statistical tool for measuring the genetic diversity in germplasm collections with deference to the characters considered together. The selection of different parents for hybridization programme can be effective by the identification of characters responsible for the genetic diversity among the populations (Singh and Chaudhary, 1977). Keeping above facts in view, the current experiment was conducted to select salt tolerant varieties among 93 rice genotypes according to the traits related to salinity tolerance at seedling stage by using cluster and correlation analysis.

2. Materials and methods

2.1 Growing conditions

A total of 93 rice genotypes including YAU promising lines, local varieties of Myanmar and three check varieties (Pokkali, highly salt-tolerant), (IR-64 salto, tolerant) and (IR-29, sensitive) were used in the experiment. Genotypes under this study were evaluated for seedling stage salinity tolerance using modified Yoshida's nutrient solution (Yoshida, Fomo, Cock, and Gomez, 1972) at the Department of Plant Breeding, Physiology, and Ecology. Seed dormancy of rice seeds was broken for 5 days at 50°C. The seedlings were established in netted holes on Styrofoam floats in buckets filled with 5 liters of nutrient solution.

The experimental design used was an augmented design (Federer, 1956). The design divides the experimental area into a number of blocks of test plots, and two check varieties were chosen as checks in each block. The checks were replicated but not the experimental test lines. Measurements of the experimental lines were adjusted for block differences, which were measured by the check varieties. In this study, there were totally 6 blocks and 18 lines including tolerant check (Pokkali, highly salt-tolerant), (IR-64 salto, tolerant) and susceptible check (IR-29, sensitive) comprised the entries in each block. After 4 days, the seedlings were salinized with NaCl at the electrical conductivity (EC) of 6 dSm^{-1} (deci Siemens per meter). After that, salinity EC was gradually increased to 10 dS/m. Everyday pH of salinized solution was maintained at 4.9-5.6 by using NaOH solution and HCl solution daily. Salinity screening data for percent survival and damaged leaf area was recorded following the SES (Standard Evaluation Score system) for rice (IRRI, Gregorio et al 1997) (Table 1). The initial and final scoring of the seedlings in nutrient solution was taken at EC 10 dSm^{-1} after 10 days of salinity treatment.

2.2 Statistical analysis

In this study, shoot length, root length, fresh weight, dry weight, scoring and survival percent were evaluated. Then observations mean for each trait was used for statistical analysis. Statistical analysis and a cluster analysis using STAR, (Statistical Tools for Agricultural Research version 2.0.1, 2014) were performed.

3. Results and discussion

Analysis of variance was done to test the significance differences among genotypes studied in salin-

Table 1. Standard Evaluation Score system (SES) based on visual symptoms of salt injury (Gregorio, Senadhira and Mendoza, 1997) and leaf damaged area at seedling stage in response to salinity.

Leaf Damage	Score	Remarks
<10 percent	1	Highly tolerant
10–30 percent	3	Tolerant
30–50 percent	5	Moderately tolerant
50–70 percent	7	Moderately susceptible
>70 percent	9	Susceptible

ity stress (10 dSm^{-1}). The analysis of variance revealed significant differences among genotypes for all the characters studied, indicating there is a presence of enough genetic variation among all the genotypes (Table 2). This can give an opportunity for plant breeders to improve those traits through selection and hybridization to improve the desired traits upon response of salinity stress.

Upon addition of sodium chloride at 10 dSm^{-1}, most of the rice genotypes showed leaf rolling after 24 hrs., followed by chlorosis and leaf bleaching from the tip of the leaf blade of the leaf base on the 4th or 5th day. By the 7th to 10th day post salinization, susceptible seedlings of IR29 were dead. Tolerant varieties also showed the same early response to salinity stress, but 3th or 4th day after stress, it showed some signs of recovery, such as leaf greening and growing of the youngest leaf.

3.1 Correlation of traits related to salinity tolerance

To better recognize agronomic characters in response to salinity tolerance, all characters were analyzed for correlation analysis to observe the relationship among them (Table 3). Individual correlation of traits showed that correlation among all traits was positively and highly correlated with each other.

Table 2. Analysis of variance of 93 genotypes for agronomic parameters at seedling stage

Source of variation	df	Shoot length (cm)	Root length (cm)	Fresh Weight (mg)	Dry Weight (mg)	Survival percent
Total	17	52.94^{**}	11.77^{ns}	1.916^{**}	0.019^{*}	1905.47^{**}
Blocks	5	4.89^{ns}	6.298^{ns}	0.027^{ns}	0.003^{ns}	88.05^{ns}
Checks	2	429.08^{**}	62.88^{**}	15.975^{**}	0.125^{**}	15682.56^{**}
Error	10	1.733	4.284	0.049	0.006	58.773
CV percent		5.05	24.8	5.4	19.15	6.7

ns = non significant, * = significant at 5 percent level, ** = significant at 1 percent level

Table 3. Pearson correlation matrix of agronomic parameters in response to salinity stress at 10 dSm^{-1} of 93 genotypes at seedling stage

	Shoot Length	Root Length	Fresh Weight	Dry Weight	Survival percent
Shoot Length	1	0.4856 **	0.5098**	0.5808**	0.3612**
Root Length		1	0.7604**	0.766**	0.3018**
Fresh Weight			1	0.9116**	0.3517**
Dry Weight				1	0.4312**
Survival					1

** = significant at the 0.01 probability level

Correlation of fresh weight and dry weight were higher than others with the value of 0.9116. Root length and dry weight, shoot length and dry weight were also closely correlated. It could be indicated that there is a strongly correlated among all the traits. These traits are important parameters to be considered to utilize the promising genotypes for breeding program in response to salinity stress.

3.2 Cluster analysis of 93 rice genotypes for salinity Tolerance

Cluster analysis of 93 rice genotypes was performed on the basis of traits related to salinity stress (Figure. 1) where rice genotypes were grouped in three clusters. First cluster with 78 genotypes was the largest cluster and included most of YAU promising lines, Paw San, Hmaw Bi 2, etc. and also included sensitive check (IR 29). Cluster II included 6 genotypes such as YAU-1215-B-B-B-52-3-1, YAU-1214-183-3-3-1-1-1, Nga Sar Kay, Pyawe Gaung, and Mya Waddy Pathein along with salt tolerant check IR 64 salto. Cluster III consisted of 9 genotypes such as Sar Ngan Khan 4, Shwe At, Maung Lay, Kywe Chae Myaning, Yaw Shwe War, Kaung Myo Khin, Kalar Lay and Phat Chae War along with highly tolerant line, Pokkali.

In this study, the traits were examined in order to create clusters of mean comparing of all clusters (Table 4). Therefore, cluster III was found to have the highest values in shoot length (26.54 cm), root length (11.67 cm), fresh weight (495.56 mg) and dry weight (85.56 mg) characters except survival percent. Higher survival percent was observed in both clusters II and III. The lowest value of shoot length, fresh weight, dry weight, and survival percent were found in cluster I.

Figure 2 showed number of rice genotypes for shoot length. There are 6 genotypes which had shoot length between 31 cm and 35cm; 12 genotypes between 26 cm and 30cm; 19 genotypes between 21 cm and 25 cm, 33 genotypes between 16 cm and 20 cm; 21 genotypes between 11cm and 15 cm; and 2 genotypes between 5 cm and 10 cm. For the root length, one genotype was observed in the range from 16 cm to 20 cm; 9 genotypes from 11 cm to 15cm; 80 genotypes from 6 cm to 10 cm; and 3 genotypes from 1cm to 5cm (Figure 3). Number of genotypes for fresh weight and dry weight are shown in Figure 4 and Figure 5, respectively.

Among all genotypes, 8 genotypes were observed survival percent between 75 and 100; 3 genotypes between 50 and 75; 14 genotypes between 25 and 50; and other 75 genotypes between 0 and 25 (Figure 6). Score of genotypes based on standard evaluation system were 1, 3, 5, 7, and 9 with highly tolerant, tolerant, moderately tolerant, sensitive, and highly sensitive their relevant (Figure 7). Pokkali, Shwe At, Maung Lay and Yaw Shwe War were scored as 1 (highly tolerant) and IR 64 salto, YAU-1214-183-3-3-1-1-1, Nga Sar Kay, Pyawe Gaung, and Mya Waddy Pathein as score 3 (tolerant). It could be suggested that these genotypes would be regarded as the promising salinity tolerant varieties to be able to use in breeding program.

4. Conclusion

In conclusion, salinity stress induced morphological changes of all tested traits in all rice cultivars during their seedling stage. The highest cluster mean values were observed in Cluster III followed by Cluster II. Cluster group position of genotypes based on traits correlated to salinity can be useful in salinity tolerance breeding to evaluate salinity tolerance.over conventional methods. Three genotypes of Shwe At, Maung Lay and Yaw Shwe War (score 1) were included in Cluster III including Pokkali and other four genotypes of YAU-1214-183-3-3-1-1-1, Nga Sar Kay, Pyawe Gaung, and Mya Waddy Pathein (score 3) in cluster II including IR64 salto. Cluster III had mean value of shoot length 26.54 cm and cluster II had 22.36 cm. Therefore, these seven genotypes were considered as promising salt tolerant genotypes which could be utilized in rice breeding program. Among 93 genotypes, YAU-1215-B-B-B-52-3-1, YAU-1214-183-3-3-1-1-1, Nga Sar Kay, Pyawe Gaung, and Mya Waddy Pathein, Sar Ngan Khan 4, Shwe At, Maung Lay, Kywe Chae Myaning, Yaw Shwe War, Kaung Myo Khin, Phat Chae War and Kalar Lay could be identified as promising salinity tolerant genotypes for future use in breeding programmes.

5. Acknowledgements

The authors would like to acknowledge the financial support of Myanmar Awba Group Co.,Ltd.. The

Figure 1. Clustering of 93 genotypes based on Euclidean distance of five agronomic traits responses to salinity stress

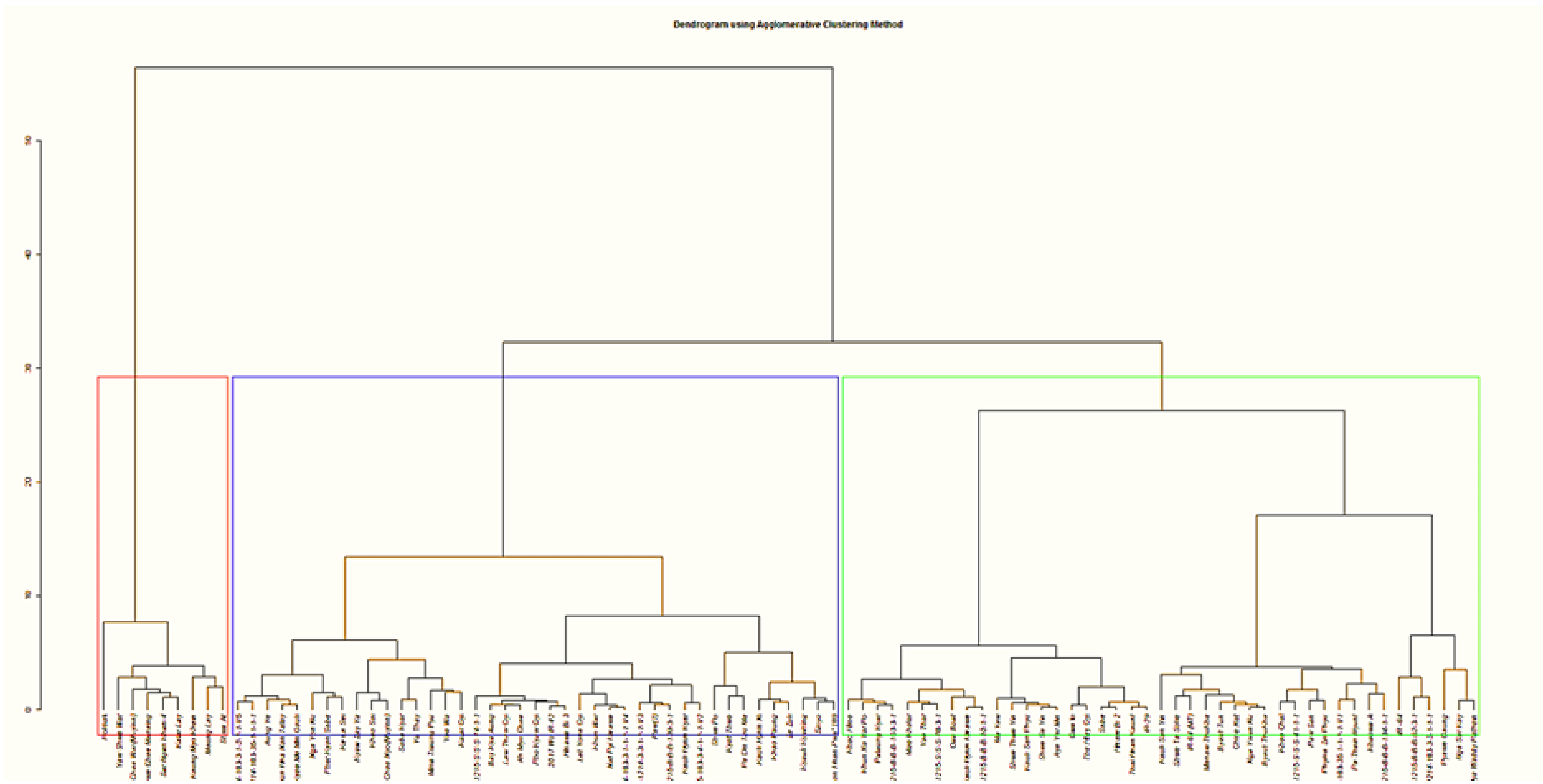

Table 4. Comparing average of tested traits according to cluster analysis

	Cluster I	Cluster II	Cluster III
Shoot Length (cm)	18.94	22.36	26.54
Root Length (cm)	7.33	7.06	11.67
Fresh Weight (mg)	149.87	440.00	495.56
Dry Weight (mg)	37.44	41.67	85.56
Survival Percent (percent)	11.85	93.83	62.00

Figure 2. Number of rice genotypes based on the range of shoot length (cm)

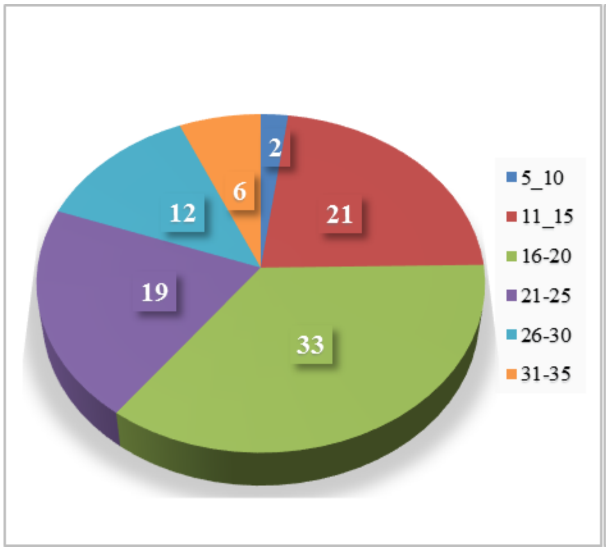

Figure 3. Number of rice genotypes based on the range of root length (cm)

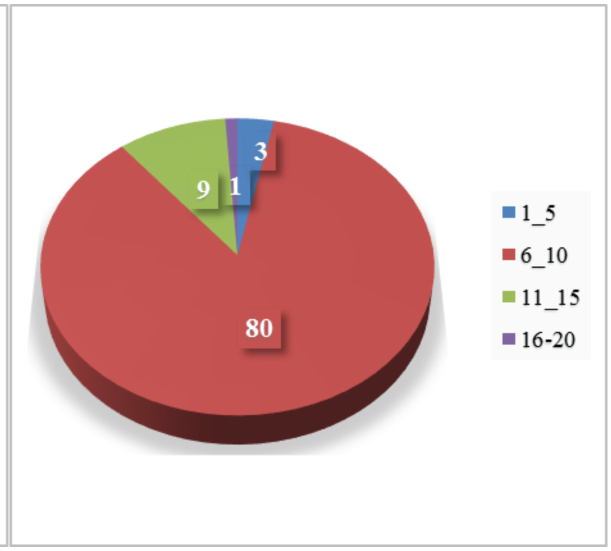

Figure 4. Number of rice genotypes based on the range of fresh weight

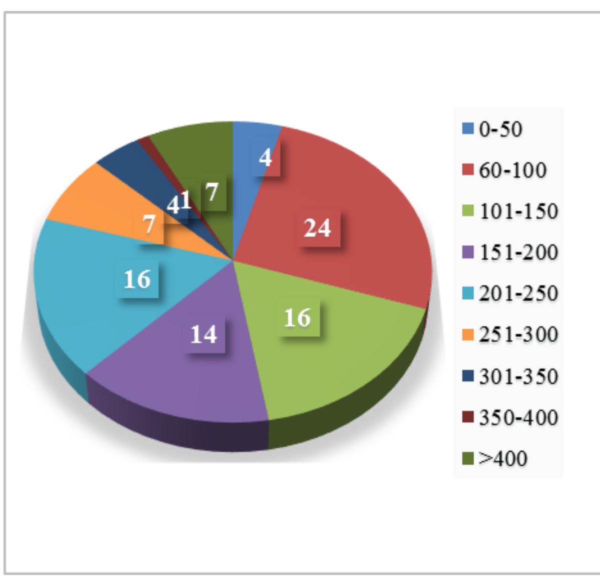

Figure 5. Number of rice genotypes based on the range of dry weight

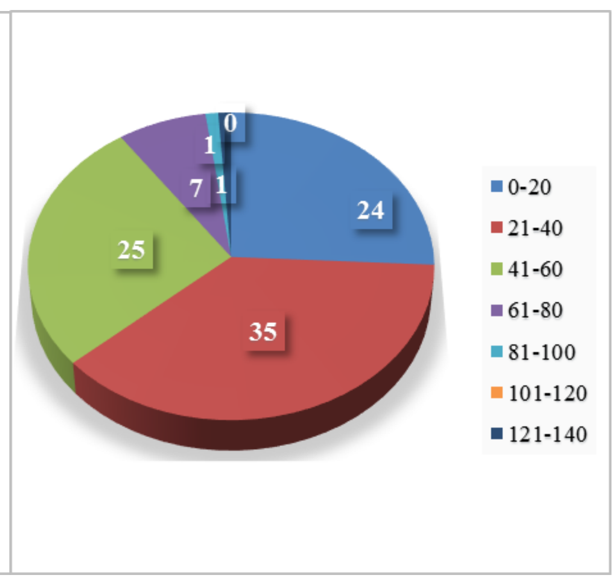

Figure 6. Number of rice genotypes based on the range of survival percent (percent)

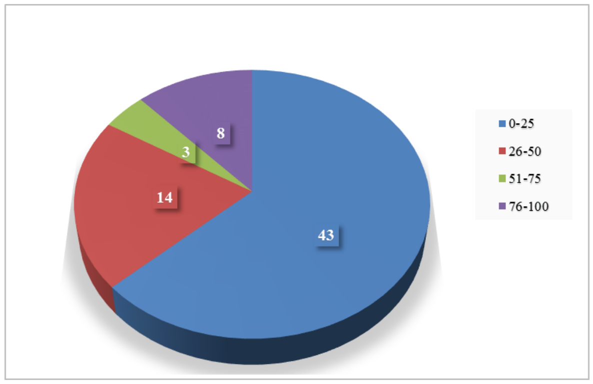

Figure 7. Appearance of Pokkali (score 1), Mya Waddy Pathein (score 3), and IR 29 (score 9) at seedlings stage under salinity stress condition

Figure 8. Appearance of Pokkali (score 1), YAU-1214-183-3-3-1-1 (score 3), and IR 29 (score 9) at seedlings stage under salinity stress condition

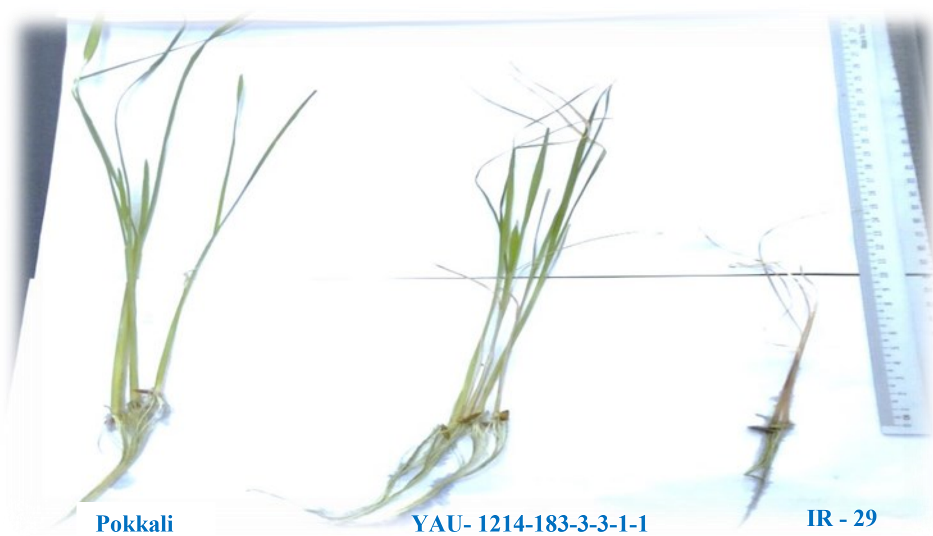

Figure 9. Appearance of Pokkali (score 1), Pyawe Gaung (score 3), and IR 29 (score 9) at seedlings stage under salinity stress condition

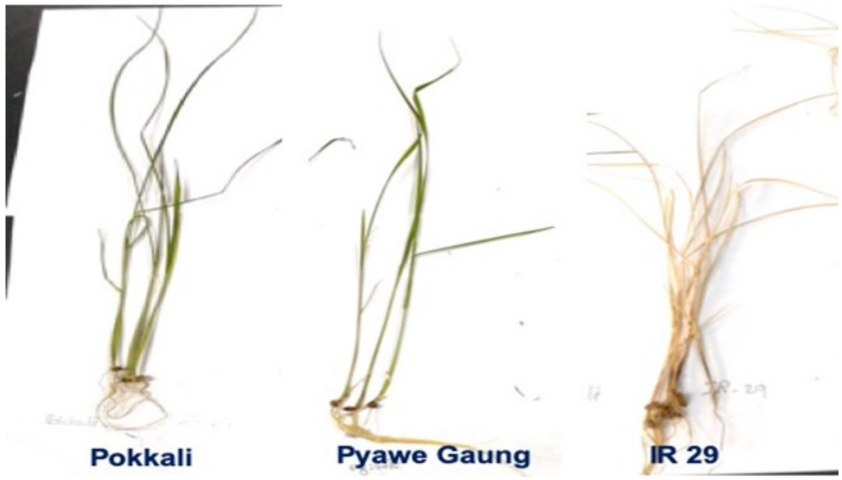

Table 5. Rankings of genotypes for their relative salinity tolerance at seedling stages in 93 rice genotypes

Salt sensitive (Cluster I)	Salt Tolerance (Cluster II)	Highly Salt Tolerance (Cluster III)
IR-29, YAU-1215-B-B-B-134-1-1, YAU-1215-B-B-B-52-3-1, YAU-1214-183-3-3-1-1-1, YAU-1214-183-35-1-1-1-1-V1, YAU-1215-S-S-S-74-1-1, YAU-1215-S-S-S-41-1-1, YAU-1215-B-B-B-10-1-1, YAU-1215-B-B-B-153-3-1, YAU-1215-S-S-S-78-3-1, YAU-1215-B-B-B-139-3-1, YAU-1214-3-3-1-1-1-V3, YAU-1215-183-3-4-1-1-1-V2, YAU-1214-183-3-1-2-1-1-V5, YAU-1214-183-35-1-1-1-1, YAU-1214-183-3-1-1-1-1, Yoe Wa, Kauk San Phyu, Khao Sai, Saba Kyar, Gwa lo, Ya Thay, Phat Chae Nyo (Muyinn), Yae Thar, Ma Yaw, Khao Chal Saba, Nga Ywan Nu, Pa Thein Nyunt, Khun Na Yar Po, Thar Htay Gyi, Shwe Se Yin, Paw San, Hmaw Bi 2, Phyine Zin Phyu, Chine Nat, IR-64, Byaut ThuKha, Thai Hnan Kaunt, Shwe Thwe Yin, Aye Yar Min, Byaut Tun, , Shwe Po, Mae Khalar, 2017 Ws IR-42, Kyet Thwe, Bay Kya Aung, Kauk Hynin Kyar, Hmawe Be, Kauk Hynin Hmawe, Khao Paung, Kauk Hynin Ni, Pa Din Thu Ma, Pho Kyaw Gyi, Sinyo, Chun Hna Nan Talay, Paw(1), Law Thaw Gyi, Kyee Me Min Gauk, Khun War, Ah Myo Chae, Nat Pyi Hmawe, Oae Boat, Za Zuk, Palaung Kyar, Let Yone Gyi, Thon Hnan Pwa, Kalar Gyi, Kyaw Zay Ya, Aung Ye, Nga Yon Nu, Hmawe Bi 3, Kauk San Yin, Phar Kyan Saba, Kyauk Kyaining, Manaw ThuKha, Mine Traung Pyu, Ka La Sei Khao Hline, Khaowa A, Shwe Ta Soke,	IR 64 salto, YAU-1215-B-B-B-52-3-1, YAU-1214-183-3-3-1-1-1, Nga Sar Kay, Pyawe Gaung, and Mya Waddy Pathein	Pokkali, Sar Ngan Khan 4, Shwe At, Maung Lay, Kywe Chae Myaning, Yaw Shwe War, Kaung Myo Khin Kalar Lay and Phat Chae War

Table 6. Observed data of morphological and physiological traits for rice seedling stage.

Code	Genotypes name	ShootL	RootL	FreshWt	DryWt	Survival	Score
1	Khao Hline	8.28	4.33	0.07	0.02	0	9
2	Khaowa A	19.93	6.78	0.03	0.05	50	5
3	Shwe Ta Soke	24.57	6.27	0.04	0.03	33	5
4	YAU-1215-B-B-B-134-1-1	17.13	5.08	0.07	0.04	50	7
5	YAU-1215-B-B-B-52-3-1	15.25	5.25	0.06	0.03	100	5
6	YAU-1214-183-3-3-1-1-1	12.25	4.05	0.05	0.03	100	3
7	YAU-1214-183-35-1-1-1-1	14.08	5.9	0.04	0.02	50	5
8	Yoe Wa	26.57	9.6	0.13	0.05	14	7
9	Kauk San Phyu	18.36	5.54	0.07	0.02	13	7
10	Nga Sar Kay	30.49	7.04	0.15	0.05	88	3
11	Khao Sai	33.35	9.3	0.13	0.04	0	9
12	Saba Kyar	29.58	7.34	0.17	0.04	50	5
13	Gwa lo	22.63	5.41	0.05	0.02	0	9
14	Ya Thay	32.08	8.48	0.17	0.05	50	5
15	Phat Chae Nyo(Muyinn)	31.55	7.76	0.14	0.04	0	9
16	Yae Thar	13.13	7.41	0.06	0.02	0	9
17	Ma Yaw	11.94	5.25	0.06	0.02	13	7
18	Khao Chal	14.28	8.01	0.05	0.02	13	7
19	Saba	18.96	5.88	0.06	0.02	0	9
20	Nga Ywan Nu	20.86	7.01	0.09	0.03	25	5
21	Pa Thein Nyunt	14.48	6.15	0.06	0.02	25	5
22	Khun Na Yar Po	13.35	4.68	0.06	0.02	0	9
23	Tha Htay Gyi	24.75	5.14	0.07	0.02	0	9
24	Shwe Se Yin	15.5	5.35	0.07	0.02	13	7
25	Paw San	19.13	7.78	0.07	0.02	17	5
26	Hmaw Bi 2	19.63	5.93	0.08	0.02	0	9
27	Phyine Zin Phyu	16.46	9.13	0.07	0.02	25	5
28	Chine Nat	22.04	7.41	0.11	0.03	25	5
29	IR-64	23.06	6.37	0.09	0.03	0	5
30	Byaut ThuKha	19.76	7.14	0.09	0.03	25	5
31	Thai Hnan Kaunt	16.64	5.76	0.05	0.02	0	9
32	Shwe Thwe Yin	14.74	6.08	0.06	0.02	13	7
33	Aye Yar Min	16.56	5.36	0.06	0.02	13	7
34	Byaut Tun	18.11	6.66	0.1	0.03	25	5
35	Mya Waddy Pathein	31.18	6.06	0.15	0.04	100	3
36	YAU-1215-S-S-S-74-1-1	11.99	8.48	0.1	0.04	0	9
37	Shwe Po	19.66	9.86	0.12	0.06	40	5
38	Mae Khalar	11.89	6.69	0.04	0.03	0	9
39	2017 Ws IR-42	16.24	7.79	0.16	0.04	0	9
40	Kyet Thwe	20.48	12.95	0.22	0.05	25	5
41	Kywe Chae Manaing	22.57	10.8	0.35	0.07	25	5
42	Bay Kya Aung	14.58	7.4	0.15	0.04	0	9
43	Kauk Hynin Kyar	16.85	9.86	0.2	0.04	0	9
44	Hmawe Be Kauk Hynin Hmawe	13.28	6.26	0.12	0.03	0	9
45	Khao Paung	13.25	8.23	0.23	0.05	25	7
46	Kauk Hynin Ni	17.16	8.71	0.23	0.04	14	7

Table 6. Continued.

Code	Genotypes name	ShootL	RootL	FreshWt	DryWt	Survival	Score
47	Pa Din Thu Ma	17.26	11.93	0.24	0.05	14	7
48	Pho Kyaw Gyi	14.37	8.1	0.17	0.03	0	9
49	Sinyo	21.29	7.1	0.25	0.06	14	7
50	Chun Hna Nan Talay	23.67	8.31	0.25	0.06	0	9
51	Paw(1)	21.56	6.99	0.14	0.04	0	9
52	Phat Chae War(Muyinn)	21.9	10.94	0.39	0.08	63	5
53	Law Thaw Gyi	13.92	6.82	0.19	0.04	0	9
54	Kyee Me Min Gauk	24	7.98	0.31	0.06	0	9
55	Khun War	18.7	7.95	0.26	0.05	0	9
56	Ah Myo Chae	13.31	7.58	0.2	0.04	0	9
57	Nat Pyi Hmawe	19.47	7.69	0.24	0.05	0	9
58	Yaw Shwe War	24.9	9.7	0.46	0.04	63	1
59	Oae Boat	17.12	5.42	0.16	0.04	0	9
60	Za Zuk	14.18	7.5	0.21	0.04	17	7
61	Palaung Kyar	11.68	5.16	0.11	0.02	0	9
62	Let Yone Gyi	18.94	6.96	0.23	0.07	0	9
63	Thon Hnan Pwa*189	18.75	6.88	0.25	0.05	25	7
64	Sar Ngan Khan-4	26.13	10.66	0.47	0.08	50	5
65	Kaung Myo Khein	25.2	12.68	0.66	0.1	40	5
66	Kalar Lay	29.06	11.47	0.41	0.08	29	5
67	Kalar Gyi	24.39	7.93	0.24	0.05	29	5
68	YAU-1215-S-S-S-41-1-1	13.38	8.58	0.11	0.03	20	7
69	YAU-1215-B-B-B-10-1-1	14.06	6.16	0.13	0.03	0	9
70	YAU-1215-B-B-B-153-3-1	10.1	5.2	0.08	0.02	0	9
71	YAU-1215-S-S-S-78-3-1	12.09	6.4	0.09	0.02	0	9
72	YAU-1215-B-B-B-139-3-1	19.73	7.53	0.16	0.04	0	9
73	YAU-1214-3-3-1-1-1-V3	19.63	7.3	0.13	0.03	0	9
74	YAU-1215-183-3-4-1-1-1	19.71	9.06	0.21	0.04	0	9
75	YAU-1214-183-3-1-2-1-1	21.97	9.46	0.23	0.05	0	9
76	Kyaw Zay Ya	27.23	6.51	0.15	0.04	0	9
77	YAU-1214-183-35-1-1-1-1	23.89	9.87	0.29	0.06	0	9
78	Aung Ye	26.66	8.56	0.29	0.05	0	9
79	Pyawe Gaung	27.68	12.21	0.18	0.05	75	3
80	Nga Yon Nu	27.43	8.48	0.34	0.07	38	9
81	Maung Lay	26.18	12.76	0.41	0.08	100	1
82	Hmawe Bi 3	16.06	7.84	0.2	0.04	0	9
83	Kauk San Yin	18.4	7.62	0.19	0.04	0	9
84	Phar Kyan Saba	24.28	7.26	0.26	0.05	38	9
85	Kyauk Kyaining	19.7	8.08	0.33	0.06	25	7
86	Manaw ThuKha	17.24	7.76	0.16	0.04	25	5
87	Mine Traung Pyu	28.43	7.6	0.29	0.06	0	7
88	YAU-1214-183-3-1-1-1-1	20	7.43	0.23	0.05	0	9
89	Ka La Sei	20.73	8.92	0.26	0.06	33	9
90	Shwe At	29.1	9.7	0.53	0.1	88	1
91	Pokkali	33.79	16.34	0.78	0.14	100	1
92	IR 64 salto	17.34	7.76	0.25	0.05	100	3
93	IR-29	17.45	5.45	0.07	0.02	0	9

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Effect of Growing Seasons on Yield and Agronomic Characters of Some Diseases Resistant Mungbean Genotypes

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Abstract

Growing seasons and adapted genotypes in specific growing season are the most important criteria for the high productivity of mungbean. This study was conducted in post-monsoon (2017) and monsoon (2018) seasons to investigate the effect of genotypes and growing seasons on yield and agronomic characters of some mungbean genotypes. Based on the effect of growing seasons and genotypes on the yield performance of mungbean; plant height at maturity was controlled by the main effect of season, days to flowering, pod bearing branches, pods per plant and 100 seed weight by the effect of genotype, and seeds per pod and seed yield per plant by the effect of genotype × season effect. . Monsoon season provided more vigorous growth of mungbean plant due to the available amount of rainfall and post-monsoon season gave bigger seed size. Monsoon season is the most favorable season in Yezin area to get high yield. Among the tested genotypes, 7635, 7642 and 10731 performed as better yielding genotypes and could be grown in monsoon growing season which are better than the standard check varieties such as Yezin-1, Yezin-9, Yezin-11 and Yezin-14.

Keywords: *Mungbean, Season and Genotype*

1. Introduction

In Myanmar, many pulse crops such as mungbean, blackgram, pigeonpea, chickpea, soybean, butterbean, kidney bean, cowpea, lablab bean, sultani and sultapya are grownin different related agroecological areas and seasons. Monsoon and post-monsoon season are the mainly growing seasons for pulses crop in specific different agro-climatic zones such as Bago and Kachin Riverside Land; Central Dry Zone; Delta and Costal Lowland Zone (Han et al, 2001). Mungbean (*Vigna radiata* L. Wilzcek) is one of major pulses crop of Myanmar and cultivated in an area of 1.24 million hectares with average yield of 1.27 metric tons per hectare and total produced of about 1.57 million metric tons in 2017- 2018 (MOALI, 2018). In general, mungbean is widely grown in different regions of Myanmar form lower part to upper part of Myanmar and mostly grown in two seasons: (i) monsoon season (May-July), and (ii) post-monsoon season after harvest of rice (October-December). Moreover, mungbean is also grown in summer (February-May) with availability of irrigation (Han et al, 2001). Various environmental factors such as temperature, relative humidity, available rainfall etc control the plant growth (Gordon and Bootsma, 1993). According to Miller et al. (2001), plants need a certain amount of temperature units or growing degree days to develop from one to the next growth phase and the different heat requirements of each genotype will cause variation in growth and yield. Farmers faced many constraints when preparing the most appropriate planting schedule due to unpredictable climate change at many regions in the world that generates global climate change, which causes prolonged dry season (El Nino) or rainy season (La Nina) (Jennings and Magrath 2009). The plant growth, phenology, and productivity are changed by unpredictable season changes (White et al. 2003; Cleland et al. 2007; Rai 2015). Hence, it is necessary to evaluate mungbean varieties in different growing seasons to know the factors that affect the variation of growth and yield

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and to observe the more potential variety. The objective of this research was to study the effect of growing season on yield and agronomic characters of several mungbean varieties.

2. Materials and methods

This study was conducted in a randomized complete block design with three replications at Food Legumes Section, Department of Agricultural Research, Myanmar (19º 51′ N latitude and 96º 7′ E longitude at 97 m altitude). A total of 18 mungbean genotypes were utilized to evaluate the performance of yield and agronomic characters compared to Yezin-1, Yezin-9, Yezin-11 and Yezin-14 in post-monsoon (2017) and monsoon (2018) and their salient characters were presented in Table 1. The plot size was 2 m x 0.5 m with 1 row. The row length was 2 m long and 45 cm and 10 cm distances between rows and plants, respectively. The fertilizers were applied at the time of soil preparation with the rate of 62 kg per hectare of triple super phosphate, 62 kg per hectare of muriate of potash and one packet (150 g) of rhizobium. Normal cultural practices and plant protection measures were followed as necessary. Grain yield and agronomic characters were recorded on five randomly selected plants from each genotype in each replication. Analysis of variance for each season, combined analysis of variance across the tested seasons were analyzed by using CROPSTAT, version 7.2.

3. Results and discussion

The meteorological data (maximum and minimum temperature, rainfall and relative humidity) at the

Table 1. List of tested mungbean genotypes, sources and their salient characters

No.	Genotypes	Origin	MYMV	CLS	Powdery
1.	4145	Phillipine	HR	R	HS
2.	7618	India	S	MR	S
3.	7628	USA	S	MR	HS
4.	7635	AVRDC	MS	MR	HS
5.	7639	Phillipine	HR	MR	S
6.	7642	Myanmar	S	MR	S
7.	7643	AVRDC	MR	MR	S
8.	7668	Myanmar	HS	MR	S
9.	8960	AVRDC	HS	MR	S
10.	8964	AVRDC	R	MR	S
11.	10266	Myanmar	HR	MR	HS
12.	10271	AVRDC	MR	MR	HS
13.	10272	Myanmar	MS	MR	S
14.	10731	India	S	MR	HS
15.	10733	Pakistan	HR	MR	HS
16.	10734	Parkistan	HR	MR	HS
17.	10735	Parkistan	R	MR	S
18.	10736	Pakistan	HR	MR	S
19.	Yezin-1	Indonesia	HS	MR	S
20.	Yezin-9	AVRDC	HS	HS	HS
21.	Yezin-11	Parkistan	HR	MR	HS
22.	Yezin-14	Myanmar	R	MR	HS

S = Susceptible, HS = Highly Susceptible, MR = Moderately Resistant, R = Resistant and HR = Highly Resistant growing season are presented in Fig. 1. During the growing seasons, the available amount of rainfall during monsoon season was 7 times greater than post-monsoon season and relative humidity gradually decreased in post-monsoon season whereas steadily increased was observed in monsoon season. In addition, the largest difference was found in post-monsoon between the minimum and maximum temperature and the smaller difference was also found in the monsoon season.

Mean squares for yield and agronomic characters of tested mungbean genotypes in 2017 post-monsoon and 2018 monsoon season are presented in Table 2 and Table 3, respectively. In 2017 post-monsoon, days to 50 percent flowering, days to maturity and 100 seed weight showed highly significant differences at 1 percent probability level and seeds per pod showed significant differences at 5 percent probability, respectively. This reflected variations for these characters among the genotypes except plant height at flowering and maturity, pod bearing branches, pods per plant and seed yield per plant in 2017 post-monsoon. Among the observed characters, all recorded characters except seed per pod were significantly different at the 1 percent probability level, whereas seeds per pod showed significant differences at the 5 percent probability level in the 2018 monsoon season. However, the non-significant difference was observed in seeds per pod (Table 4). This fact showed that all the tested mungbean genotypes showed variations in all recorded characters.

The combined analysis of variance and percent of sum of square for yield and agronomic characters were shown in Table 4 and Table 5. Analysis of variance across season revealed highly significant genetic variation among tested mungbean genotypes for all recorded characters except for maturity and plant height at flowering. Although the season is the major controlling factor of some characters such as plant height at maturity, the effect of genotype × season interaction showed significant difference at 1 percent probability in days to 50 percent flowering, pods per plant, seeds per pod and yield per plant. Among the characters, plant height at maturity was controlled by the main effect of season. In addition, the main effect of genotype accounted in days to flowering, pod bearing branches, pods per plant, 100 seed weight with the percentage of 51.54, 61.93, 35.4 and 71.95, respectively. This indicated that the effect of genotype provided more variation of these characters among tested genotypes. Moreover, the effect of genotype × season was pointed out as the main effect on the performance of seeds per pod and seed yield per plant according to the larger value of percent of sum of square (62.05 and 43.79) when compare to the effect of seasons and genotypes. Significant G × E interaction was also reported by Arshad et al. (2003), Atta and Tariq (2009) and Bakhsh et al. (2006) in chickpea, by Abbas et al. (2008) and Abeytilakarathna (2010) in

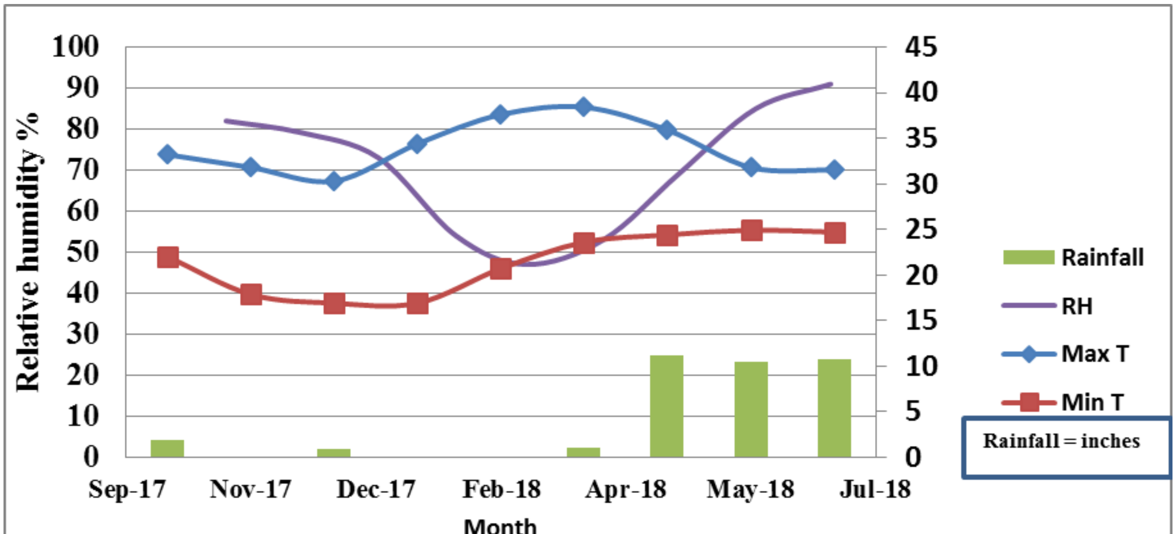

Fig 1 Rainfall, Temperature and Relative Humidity at growing season

Table 2. Mean squares of yield and agronomic characters for tested mungbean genotypes in 2017 post-monsoon season

Source of Variation	d.f.	Mean Squares								
		DF	DM	PHF	PHM	PBB	PPP	SPP	100SW	SYPP
Genotype	21	14.78**	29.12**	34.64	39.32	0.99	21.50	1.67*	4.07**	2.52
Replication	2	4.40	1.27	227.06 **	225.18 **	1.65	37.22	0.72	0.013	5.88
Error	42	5.96	8.06	19.57	29.03	0.65	15.27	0.92	0.14	2.29

ns, *, ** = non significant, significant at 5 percent and 1 percent probability levels, respectively

DF = Days to 50 percent flowering (days), DM = Days to maturity (days), PHF = Plant height at Flowering (cm), PHM = Plant height at Matyrity (cm), PBB = Pod bearing branches (no.), PPP = Pods per plant (no.), , SPP = Seeds per pod (no.), 100SW = 100 seed weight (g), SYPP = Seed yield per plant (g)

Table 3. Mean squares of yield and agronomic characters for tested mungbean genotypes in 2018 monsoon season

Source of Variation	d.f.	Mean Squares								
		DF	DM	PHF	PHM	PBB	PPP	SPP	100SW	SYPP
Genotype	2	83.48**	83.67**	298.92**	371.23**	1.05**	89.53**	1.60*	2.77**	12.87**
Replication	21	108.92**	33.65	73.32	329.93**	0.196	26.75	2.14	0.005	0.27
Error	42	15.82	20.93	37.58	60.75	0.22	26.61	0.7	0.18	3.15

ns, *, ** = non significant, significant at 5 percent and 1 percent probability levels, respectively

DF = Days to 50 percent flowering (days), DM = Days to maturity (days), PHF = Plant height at Flowering (cm), PHM = Plant height at Matyrity (cm), PBB = Pod bearing branches (no.), PPP = Pods per plant (no.), , SPP = Seeds per pod (no.), 100SW = 100 seed weight (g), SYPP = Seed yield per plant (g)

Table 4. Mean squares for combined analysis of variance (yield and agronomic characters) of tested mung-bean genotypes in different seasons

Source of Variation	d.f.	Mean Squares								
		DF	DM	PHF	PHM	PBB	PPP	SPP	100SW	SYPP
Season	1	122.19**	65.52	68.63	14801.4**	3.34*	1506.94**	19.7**	46.87**	121.194**
Rep	2	70.00**	13.56	413.96	864.42**	0.68	17.73	5.88*	0.037	4.32
Genotypes	24	54.8**	30.43	54.10	94.11	1.24**	63.58**	1.768	6.99**	7.05**
Genotypes × Season	24	43.45**	46.49	84.75	101.58	0.49	56.57**	4.33**	0.256	9.34**
Residual	98	11.65	71.99	64.13	113.256	0.52	22.72	1.57	0.18	2.74

ns, *, ** = non significant, significant at 5 percent and 1 percent probability levels, respectively

DF = Days to 50 percent flowering (days), DM = Days to maturity (days), PHF = Plant height at Flowering (cm), PHM = Plant height at Matyrity (cm), PBB = Pod bearing branches (no.), PPP = Pods per plant (no.), , SPP = Seeds per pod (no.), 100SW = 100 seed weight (g), SYPP = Seed yield per plant (g)

Table 5. Percentage of sum of square for combined analysis of variance (yield and agronomic characters) of tested mungbean genotypes in different seasons

Source of Variation	d.f.	percent of Sum of Square						
		DF	PHM	PBB	PPP	SPP	100SW	SYPP
Season	1	7.32	78.99	11.30	32.62	11.07	21.38	22.38
Genotypes	24	51.54	10.13	61.93	35.40	26.88	71.95	33.83
Genotype × Season	24	41.14	10.88	26.77	31.98	62.05	6.68	43.79

DF = Days to 50 percent flowering (days), DM = Days to maturity (days), PHF = Plant height at Flowering (cm), PHM = Plant height at Maturity (cm), PBB = Pod bearing branches (no.), PPP = Pods per plant (no.), SPP = Seeds per pod (no.), 100SW = 100 seed weight (g), SYPP = Seed yield per plant (g)

mungbean, by Ali and Sarwar (2008) in cowpea and by Karasu et al. (2009) in soybean. This finding indicated that genotypes were not only genetically variable but some of them also exhibited a different response to variable environments or seasons.

Sowing seasons had a great influence on yield and agronomic characters except days to maturity and plant height at flowering time. Monsoon season provided greater performance than post-monsoon season especially in days to flowering, plant height at maturity, pod per plant, seed per pod and seed yield per plant. However, the post-monsoon season supported to get the high value of pod bearing branches and 100 seed weight (Table 6).

Most of the genotypes showed late flowering except genotypes 10733, 10734 and Yezin 11 in Monsoon season. Similarly, the same pattern was found in days to maturity (Figure 2 and 3). Among the tested genotypes, 7668 provided a greater difference of days to flowering and maturity between these two seasons. Imrie and lawn, 1990 and Aggarwal and Poehlman, 1977 described that the flowering time of mungbean genotypes varies appreciably depending on the genotype, and the day lengths and temperatures existing during the growth period.

Maximum average plant height 59.40 cm was recorded when planted in monsoon season and genotype 7668, 7642, 10731 and Yezin 1 were the tallest varieties among tested genotypes (Table 6, Fig. 4 and 5). This finding was also supported by the findings of Gebologlu et al. (1997), Ram and Dixit (2000) and Soomro and Khan (2003) who revealed the considerable effect of different sowing dates on plant height of mungbean. Moreover, the findings of the monsoon season revealed that the mean performance of plant height was higher than post-monsoon season and this may be the effect of water stress in post-monsoon season (Fig. 5). Ranawake et al. 2011 reported that water stress significantly affects the growth parameters such as plant height, number of leaves, number of floral buds, dry matter weight of shoot system, number of lateral roots, length of tap root, number of root nodules, and dry matter weight of root system in mungbean.

Pods per plant, 100 seed weight and yield per plant are important contributing characters to support the improvement of grain yield. This result revealed that the maximum number of pods per plant was provided by monsoon growing season where 31 and 30 pods were produced by genotypes 7642 and 10731 respectively (Table 6 and Fig. 7). Moreover, one of the characters such as 100 seed weight was quite different from other characters that provided as a bigger seed in the post-monsoon season than monsoon season. Among the tested genotypes, the highest seed/grain weight of 6.69g per 100 seed was found in Yezin 9 followed by genotypes 10271 with the seed/grain weight of 6.60g (Table 6 and Fig. 9). Mean performances of seed yield per plant among tested mungbean genotype across environment showed highly significant difference where 2018

Table 6. Effect of different seasons and genotypes on yield and agronomic characters on mungbean

	DF	DM	PHF	PHM	PBB	PPP	SPP	100SW	SYPP
Season									
2017 Post-monsoon	41.14	68.05	28.18	38.22	1.71	11.23	10.73	5.13	4.58
2018 Monsoon	43.06	66.64	29.62	59.40	1.39	17.98	11.50	3.94	6.49
5 percentLSD	1.18	ns	ns	3.68	0.25	1.65	0.43	0.15	0.57
Genotypes									
4145	41.50	66.83	32.21	53.65	1.17	11.33	10.67	5.20	5.16
7618	43.50	66.00	25.15	49.73	2.00	17.50	11.17	3.56	5.44
7628	42.17	71.00	26.19	47.14	1.67	14.83	10.83	3.16	4.22
7635	41.50	66.67	27.13	46.54	1.83	16.83	11.17	4.87	6.85
7639	43.00	67.17	29.74	50.64	1.50	18.17	10.83	3.32	5.24
7642	42.33	67.50	26.59	52.43	2.00	22.00	11.33	3.22	6.43
7643	42.33	68.17	31.69	49.97	1.33	14.67	11.50	3.63	5.96
7668	52.33	63.83	37.13	52.57	2.33	13.17	9.50	1.92	3.53
8960	45.00	71.17	29.79	52.53	1.50	16.83	12.00	3.83	6.36
8964	40.67	68.50	27.56	47.05	1.50	12.83	11.17	5.24	5.48
10266	41.17	66.67	26.52	45.94	1.00	11.67	11.17	5.53	4.93
10271	40.83	65.83	29.68	47.67	1.17	14.17	10.83	5.62	4.95
10272	41.33	67.33	25.54	50.99	1.33	13.83	11.83	5.20	7.25
10731	42.00	67.67	28.38	52.51	2.33	21.50	10.67	3.36	7.81
10733	37.00	64.33	26.94	39.39	1.00	17.00	11.33	5.23	5.64
10734	37.00	63.50	26.36	42.65	1.17	10.83	11.83	5.20	4.55
10735	42.83	69.67	29.66	50.59	1.33	11.83	11.17	5.12	5.12
10736	39.00	65.67	28.37	46.40	1.50	10.00	10.67	4.90	4.34
Yezin-1	43.67	69.83	33.53	54.96	1.83	13.33	11.00	5.27	4.71
Yezin-9	44.17	70.00	32.56	50.22	2.50	14.50	11.50	6.09	7.27
Yezin-11	41.17	69.67	26.52	42.18	1.00	13.33	10.67	4.87	5.15
Yezin-14	41.67	64.50	28.50	47.98	1.17	11.17	11.67	5.45	5.39
5 percentLSD	3.92	ns	ns	ns	0.83	5.47	ns	0.49	1.90
Season x Geotype (5 percent LSD)	5.53	ns	ns	ns	ns	7.73	2.03	ns	2.68

ns, = non significant

Figure 2. Effect of growing seasons on days to flowering of mungbean Genotypes

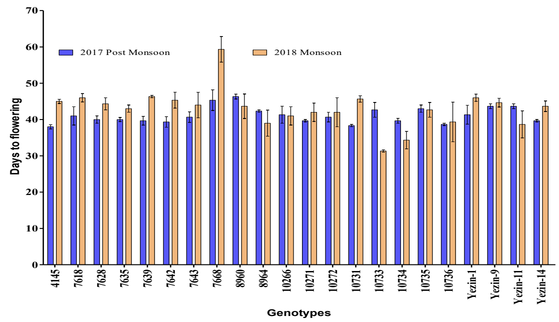

Figure 3. Effect of growing seasons on days to maturityof mungbean genotypes

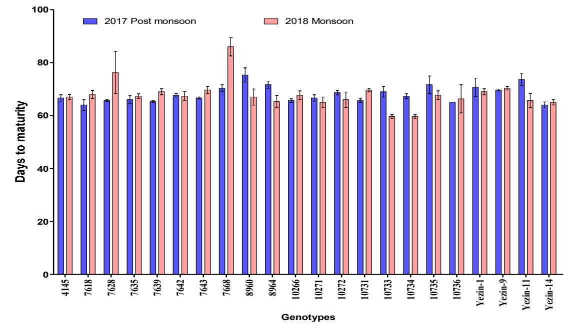

Figure 4. Effect of growing seasons on plant height at flowering of mungbean genotypes

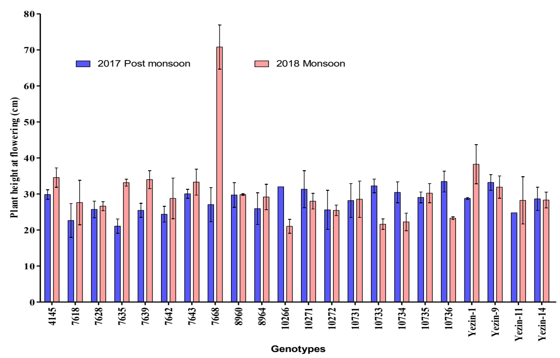

Figure 5. Effect of growing seasons on plant height at maturity of mungbean genotype

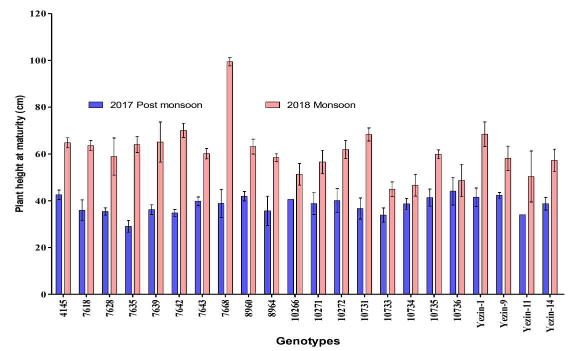

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Figure 6. Effect of growing seasons on no. of pod bearing branches of mungbean genotypes

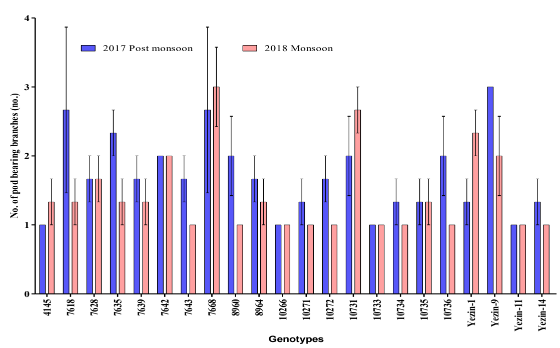


Figure 7. Effect of growing seasons on no. of pods per plant of mungbean genotypes

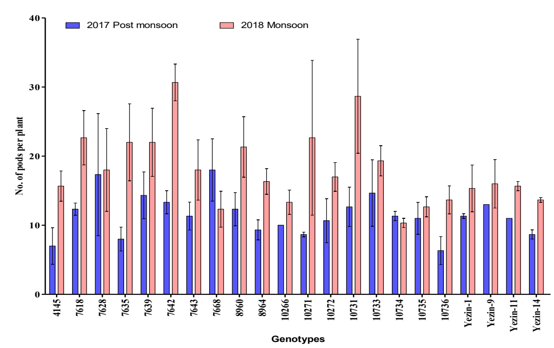


Figure 8. Effect of growing seasons on seed per pod of mungbean genotypes

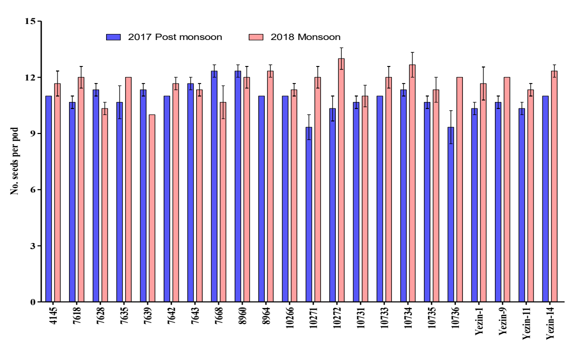


Figure 9. Effect of growing seasons on 100 seed wt. of mungbean genotypes

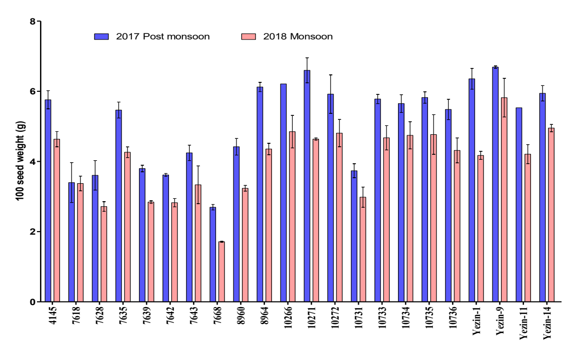
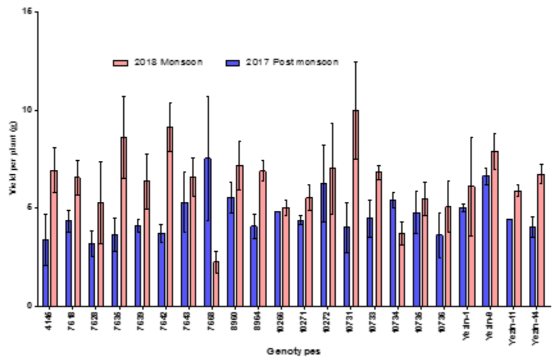


Figure 10 Effect of growing seasons on yield per plant of mungbean genotypes



monsoon season proved to be the best season for some genotypes such as genotype 7635, 7642 and 10731 with 10.06, 9.14 and 11.61 g, seed/grain weight respectively (Table 6 and Fig. 10). These results were similar by findings of Gebologlu et al. (1997), Borah (1997), Dhanjal et al. (2000) and Soomro and Khan (2003).

Meteorological data suggests that monsoon season provided more vigorous growth of mungbean plant due to the available amount of rainfall and post-monsoon season gave bigger seed size that may be due to the occurrence of better photosynthesis system for seed development.

4. Conclusion

Based on the observation, the growing season is one of the important factors that control yield contributing traits of mungbean genotypes. Monsoon season provided more vigorous growth of mungbean plant due to the availability of adequate amount of rainfall. Monsoon season should be adapted to obtain a high yield in Yezin area. Among the tested genotypes, 7635, 7642 and 10731 genotypes performed better than the standard check varieties such as Yezin-1, Yezin-9, Yezin-11, and -14 for yield in the monsoon season. Therefore, those genotypes should be grown in the monsoon growing season.

5. Acknowledgements

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Additional PowerPoint presentations

Accelerating agroforestry adoption for restoration and resilience in Myanmar's Central Dry Zone

Delia C. Catacutan
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Seventy-three percent of the population of Myanmar are employed in agriculture, which contributes 36 precent to GDP and up to 30 precent of exports. The Central Dry Zone (CDZ), of approximately 7.5 million ha, has a population of over 12.3 million and the highest rates of poverty and food insecurity. Approximately 45 precent of the populations of Mandalay, 27 precent of Sagaing and 44 precent of Magway regions live below the poverty line. Lack of land and small landholdings are also significant, affecting around 43 precent of the population. In the CDZ, smallholding agriculture is the most important socioeconomic activity but farmers face considerable challenges, making them highly vulnerable to climate change and markets. Rainfall variability is high; water-use efficiency is low; vegetation cover is sparse and soil degradation due to erosion, salinity and nutrient and organic matter decline is widespread. Infrastructure is limited and underdeveloped. The Government aims to boost agricultural production, improve the living conditions of vulnerable communities, and become at par with its neighbours in the region.

Agroforestry, the interaction of agriculture and trees, can be a solution to the problems. Interactions between trees and other components of agriculture — such as seasonal crops, livestock, fish and other aquatic species — is important at a range of scales: in fields (where trees and crops are grown together), on farms (where trees may provide fodder for livestock, fuel, food, shelter or income from products, including timber) and landscapes (where agricultural and forest land-uses combine in determining the provision of ecosystem services). At national and global scales, policies relating to land use and trade and are important to address climate change and other environmental issues. Agroforestry embraces an agro-ecological approach emphasising multi-functionality and management of complex systems rather than monocultures, providing multiple benefits.

However, wide-scale adoption remains low in Myanmar. A recent study of expert opinion on why there remains a gap in meeting policy commitments to 'green' agriculture documented three dominant discourses, referring to a lack of i) appropriate incentives; ii) clarity of land-use regulations; and iii) knowledge, technology and extension. All three issues have to be addressed simultaneously. Many factors hinder wider adoption, most of which relate to the lack of a dedicated policy. ICRAF research suggests that for the CDZ and the rest of Myanmar, the following actions are necessary.

Eliminating legal and institutional constraints on agroforestry.

Supporting positive outcomes of agroforestry.

Supporting household decision-making with technical knowledge, weather information, and understanding agroforestry's contribution to buffering climate risks.

Compensating farmers for the delay in returns.

The Government is embarking on a major effort to develop a roadmap for agroforestry to fulfil Myanmar's commitment to the *Vision and Strategic Plan for ASEAN Cooperation in Food, Agriculture and Forestry 2016–2025*. The Roadmap will involve various sectors, true to the spirit of the Union of Myanmar, in inclusive, reflective and collaborative manner.

Accelerating Agroforestry Adoption for Restoration and Resilience in Myanmar's Central Dry Zone

2nd Workshop on Green Ecology in Myanmar
Yezin Agricultural University, NPT
29th August 2019

Delia C. Catacutan, PhD
Acting Regional Coordinator,
World Agroforestry Centre-Southeast Asia Programme
Bogor, Indonesia

Land resources in Myanmar's Central Dry Zone are under pressure to:

- provide agricultural livelihoods to smallholder farmers
- conserve land resources
  – Maintenance of soil fertility
  – Maintenance of water infiltration
  – Prevention of erosion
  – Prevention of salinity

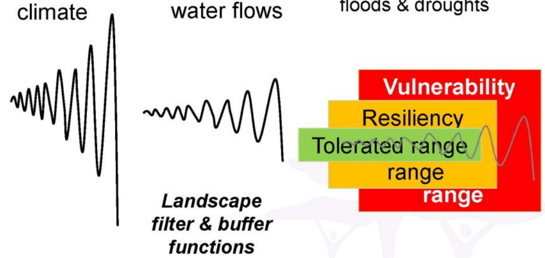
ACIAR Project: Land Evaluation of the Central Dry Zone of Myanmar (Anthony Ringrose-Voase)

Challenges faced by smallholder farmers

- Bio-physical, socio-economic and technical
  – Low and variable rainfall
  – Low water use efficiency
  – Sparse vegetation cover
  – Degradation of soil resources by
    - Erosion
    - Nutrient and organic matter decline
    - Salinity
- These increase risks
  – Farmers are reluctant to invest in inputs or new crops
    - Leads to further depletion of resources
    - Declining productivity
    - Poverty
    - Increasing vulnerability

ACIAR Project: Land Evaluation of the Central Dry Zone of Myanmar

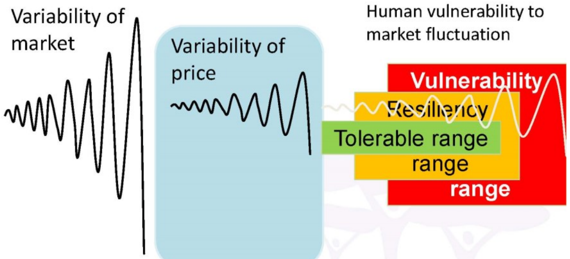
Variability of climate | Variability of water flows | Human vulnerability to floods & droughts



Currently increasing ⟷ Currently decreasing ⟷ Need for 'adaptation strategies'?

Not only the climate is changing and variable……….

Variability of market | Variability of price | Human vulnerability to market fluctuation



Currently increasing? ⟷ Currently decreasing? ⟷ Need for 'adaptation strategies'?

Can agroforestry help?

Trees on farm offer options for diversification that can *reduce production risks* for smallholders while *enhancing basic ecosystem functioning,* thereby *increasing resilience of farming systems, livelihoods, and landscapes*

Agroforestry is a climate-smart agriculture technology that addresses:

- low adaptive capacity
- poverty (increases income)
- food insecurity (diversifies products and incomes)
- land degradation
- shortage of fodder, fuel, etc.
- lack of capital
- climate change, etc.

Agroforestry for livelihoods, climate change mitigation and adaptation (Mbow et al., 2014)

Agroforestry	Livelihood	Mitigation	Adaptation
Carbon benefit	[Income]	+++	+
Wood energy	[Asset]	+++	++
Buffer climate risks/ water recycling	[Asset]	++	+++
Improve ecosystem resilience/microclimate/ soil fertility	[Asset-Income]	+	+++
Ecosystem services: Food /fruits/medicine	[Asset-Income]	-	+++
Reduce pressure on natural forest	[Asset-Income]	+++	+

+++: high positive impact; ++: positive impact;
+: limited positive impact; -: zero positive or potential negative impact

Growing body of knowledge and experience

- 30% of the world's rural populations are using trees. Trees are present in 46% of all agricultural lands ('trees outside forest')
- In the past, smallholder farmers have responded to changes by gradually changing their practices ('indigenous resilience')
- Traditional approaches of mixing crops with trees to reduce the risks of crop failure with changing seasonal patterns

(Lasco et al., 2014)

From mono-cropping to agroforestry for resilience and livelihoods

Teak agroforestry

Rehabilitation of Central Java & Yogyakarta

- 1950's severe poverty & land degradation
- Treeless, soil erosion, agriculture failing
- Drought induced famines
- 'Agroforestation' with teak
  - Rehabilitating soils, landscapes, incomes
  - Major source of industrial timber
  - From 2 to 28% tree cover
  - 68% smallholder farms; teak 56% of trees

(Roshetko *et al.*, 2013)

Similar cases

- Laos (Midgley *et al* 2007)

Tree cover on agricultural Land

- **In 2000, over 43% of the world's agricultural land has ≥10% tree cover**
- **The highest tree cover on agricultural land (>45%)** was found in the humid regions – particularly in **Southeast Asia.**
- The total C storage is estimated to reach **45.3** billion tons of C, with**75% coming from trees** (34 billion tons C).
- More than 1/3 of agricultural land now has greater than **75 t C ha−1**
- Current global annual increase in tree biomass carbon is 740 mt CO2 eq
- **There is enormous opportunity for 'tree integration' or 'agroforestry' in different production systems employed both in agriculture and forestry sectors.**

Publications

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The contribution of agroforestry to global and national carbon budgets

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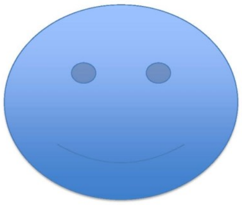
Policy Briefs

ASEAN series on agroforestry options

- Agroforestry in Southeast Asia: Bridging the forestry-agriculture divide No 1
- Swidden-fallow agroforestry for sustainable land use No 2
- Agroforestry for sustainable mountain management No 3
- Agroforestry on peatlands No 4
- *Agroforestry in coastal zones*
- *Agroforestry in rice production landscapes*
- *Agroforestry in uplands*
- *Agroforestry in peri-urban areas*
- …



How to scale up the benefits of agroforestry?

How to accelerate adoption of agroforestry?

www.worldagroforestry.org

1. Eliminate legal and institutional constraints on agroforestry

Effective agroforestry techniques should not be impeded by regulatory constraints and limitations in land ownership, markets and extension. Policy revision is critical to wider adoption.

2. Support positive outcomes of agroforestry

Provide financial support to farmers to introduce trees onto their farms in the form of payment for environmental services because agroforestry, especially at landscape level, produces many benefits for local communities and, on a larger scale, for ecosystems upon which whole populations depend.

Financial support is greatly needed to address the delayed returns of tree investment on farms.

www.worldagroforestry.org

3. Support household decision making

Provide technical knowledge, accurate weather information, understanding of agroforestry contribution to buffering against climate risks.

- Smart Agroforestry: The right tree, at the right place, for the right purpose

www.worldagroforestry.org

Photo credit: USDA National Agroforestry Center

- Use land resource and climate information to underpin evidence-based land use planning

– Ensure agricultural investments are targeted at appropriate parts of the landscape
– Choice of alternative crops or cropping systems
  - More productive
  - More nutritious
  - Less risky
– Choice of land management practices to overcome limitations
– Identification of areas prone to degradation

ACIAR Project: Land Evaluation of the Central Dry Zone of Myanmar

www.worldagroforestry.org

Why is a roadmap for agroforestry development necessary?

- Despite the recognition of agroforestry in global and regional strategies/programs such as forest landscape restoration, Nationally Determined Contributions (NDC), Land Degradation Neutrality (LDN), many countries do not have clear policy support and programs on agroforestry.
- There are serious barriers to agroforestry development in both agricultural and forest lands.
- Agroforestry involves many sectors: forestry, agriculture, livestock, fishery, land, rural development----coordinated efforts are needed.
- A joint or 'collective' roadmap toward removing barriers, can effectively guide and set the direction of different sectors, toward achieving the benefits of agroforestry.

www.worldagroforestry.org

Agroforestry Development Roadmap of Myanmar

- To lay out the elements for scaling up the benefits of agroforestry across the country.
- To identify necessary policy, institutional and extension support, and investments for agroforestry
- To develop a coherent strategy for accelerating impacts on the ground to improve adaptive capacity, land restoration, and achieve resilience.
- Aligns with the Vision and Strategy of ASEAN Cooperation on Food, Agriculture and Forestry (2015-2025)

www.worldagroforestry.org

Thank you!

Contributions from Anthony Ringrose-Voase, Ingrid Oborn, Rodel Lasco, Elisabeth Simelton, Leimona Beria, Jim Roshetko & Rachmat Mulia are acknowledged.

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The World Agroforestry Centre is a member of the CGIAR Consortium

Enabling resilient and inclusive smallholder farming systems through improved agricultural water management (AWM)

Phay Ko U
International Water Management Institute

Myanmar is classified as ‘extreme high risk’ economy with regards to climate change. Over 37 million out of 53.4 million people depend on climate-sensitive livelihood systems. About 70 precent of the total population in Myanmar is engaged in agricultural activities.

Current irrigation efficiency is very low with less than 5 precent of water abstracted actually transpired by crops. Rapid development and change is putting pressure on water resources, with emerging risks of cross-sectoral competition, over exploitation and pollution.

Many technologies on agricultural water management (AWM) remain out of reach of smallholder farmers. There are some complex challenges related to the accessibility to AWM by small holder farmers such as high up-front investment costs; poorly developed supply chains; high taxes and transaction costs; lack of information on irrigation, seeds, marketing and equipment information on irrigation, seeds, marketing and equipment etc. Solar energy could be an appropriate option and can provide clean power off-grid for multiple uses. Bundling irrigation technologies such as solar with climate risk insurance should be given special consideration. Possibility of the use of solar pumps should be explored and promoted which can reduce greenhouse gas emissions, enhance sustainable use of groundwater and result in higher incomes for farmers.

In order to ensure enhanced resilience in Myanmar’s agriculture the following actions should be taken: identify and test promising AWM bundles of technologies, practices and strategies for food security; support upscaling of AWM technologies through business models and modelling with no or minimal environmental impact; ensure gender and youth inclusiveness in technology development, adoption and benefits; improve the knowledge base on irrigation extent/access/impacts and provide digital extension: increase access/support of AWM across scales.

Enabling resilient and inclusive smallholder farming systems through improved agricultural water management (AWM)

Phay Ko U,
International Water Management Institute
12th of August 2019

IWMI A water-secure world www.iwmi.org

Climate change in Myanmar: Impacts on water in agriculture

- Myanmar is classified as ‘extreme high risk’ economy w.r.t climate change
- Over 37mill out of Myanmar 53.4 mill depend on climate-sensitive livelihood systems
- 70% of the total population engaged in agricultural activities
- fewer very wet days; more dry days; heightened frequency of floods and droughts
- Monsoon crops at higher risk of drought in the dry zone;
- Current irrigation efficiency is very low with less than 5% of water abstracted actually transpired by crops.
- Rapid development and change is putting pressure on water resources, with emerging risks of cross-sectoral competition, over exploitation and pollution.

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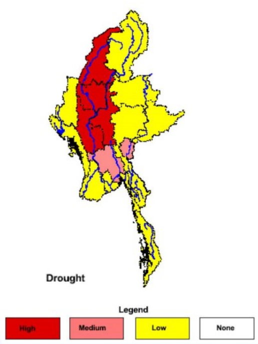
Climate vulnerability

Changes in precipitation patterns will

- increase the likelihood of short-term crop failures & long-term production declines
- Affect water availability in irrigation systems
- Increase the demand of irrigation



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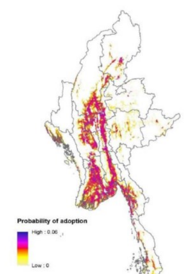
(source NAPA, 2012)

Smallholder AWM: Complex challenges

Many technologies remain out of reach of smallholder farmers. Women and resource-poor farmers are particularly disadvantaged.

- **Technology access:** high up-front investment costs, absence of proper financing tools.
- **Market access:** poorly developed supply chains; high taxes and transaction costs.
- **Knowledge access:** information on irrigation, seeds, marketing and equipment
- **Labor requirements:** family labor requirements often not included in cost-benefit analyses.
- **Sustainability concerns:** economic and environmental perspectives.



(source IFPRI, 2018)

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Resilient smallholder farming systems through irrigation

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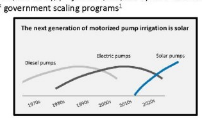
Solar pumps are spreading fast

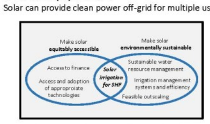
Clean accessible energy, falling costs and the water-food-energy impact of solar contribute to its uptake

In India, solar is spreading rapidly: ~4,000 in 2012; ~135,000 today; projected 2,750,000 by 2027 as a result of government scaling programs[1]



Solar drops the marginal cost of lifting water to zero: a hazard for groundwater sustainability

Myanmar government aims to distribute electricity to 50% of the country by end-2019
Solar can provide clean power off-grid for multiple uses



In Ethiopia, solar PV pumps could transform 18% (3.7m ha) of the country’s rainfed agricultural land and replace 11% of the current hydrocarbon fuel pumps[3]

Sources: [1]Government of India (2018);
Lefthand figure from Shah (2018) unpublished, an historical observation not data-based; Righthand figure from Closas et al. (2019 forthcoming).

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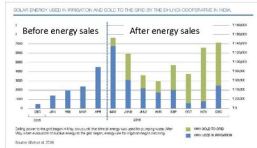
Business scenario: Solar pump irrigation collective (on-grid, western India)



The context

- India has 130,000 MW of installed pumping capacity in the form of electric and diesel tube wells
- States subsidize solar pumps as "green solution"
- Solar pump subsidies could incentivize over-pumping

Solution: Solar Pump Irrigation Cooperative

- Sustainable solar irrigation pumps with feed-in tariff for selling excess electricity to the grid
- Reduction in greenhouse gas emissions
- Sustainable use of groundwater
- Higher incomes for farmers

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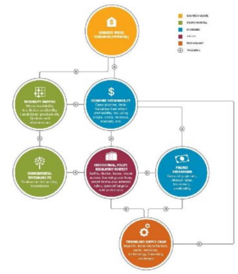
Business model framework for solar based irrigation

- Spatial suitability of technology
- Access and incentives for finance mechanisms
- Economic sustainability
- Technology supply chain
- Institutional, policy and regulatory context
- Environmental sustainability



Otoo, M., et al. 2018. IWMI Research Report 172)

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Promising technologies: Closing the water productivity gap

- **Fuel saving – motorized pumps**: 50 -150$/ha
- **Labor saving per season**: 1.5-2.5 person days/ ha
- **Fertilizer saving:** 20% Nitrogen and 54% Phosphorus
- **Yield increases**: 5-30% / 100%
- **Irrigation volume decreased**: 15 %
- **Irrigation volume increased**: 30%
- **Water productivity increases:** 20-58 %

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Bundling irrigation technologies such as solar with climate risk insurance

Low Tech Trap

Four components of the bundled solutions

Flood / Drought Resistant Seeds	Index Insurance covering drought / flood risks
Package of Practices on agronomy, fertilizers and water management	Advisory based on Climate and weather information

Increase agricultural production and income

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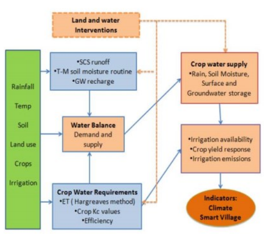
Establishing Climate Smart Villages (CSV)

Framework to prioritize CSV interventions

- Develop manual for establishing climate smart villages in four states of India
- Tool developed to prioritize interventions using water budgeting in two villages

Next step

- Developing compendium of climate smart technologies for South Asia
- Develop strategy and framework for scaling out CSVs



Only combination, not standalone individual practices, of supply, demand and moisture conservation practices have a significant impact in improving village productivity, resilience and GHG emissions reduction

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Prospects for enhanced resilience in Myanmar's agriculture

- Identify and test **promising AWM bundles of technologies**, practices and strategies for food security
- Support upscaling of AWM technologies through **business models** and **modelling** with no or minimal environmental impact
- Ensure **gender and youth inclusiveness** in technology development, adoption and benefits
- Improve the knowledge base on **irrigation extent/access/impacts**
- Provide **digital extension:** increase access/support of AWM across scales

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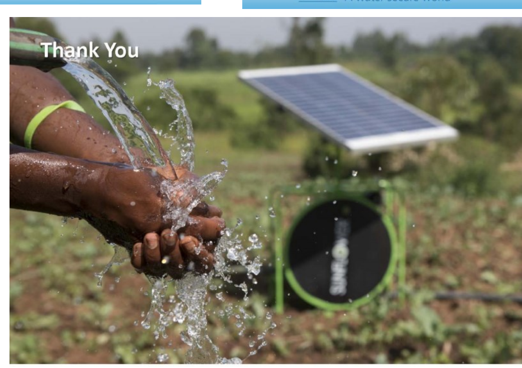

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Agro-ecology Concept and FAO's Work on Agroecology

Pierre Ferrand, Agriculture Officer (Agroecology), FAO Regional Office, Bangkok
and
Jitenda Jaiswal, Climate Smart Agriculture Specialist, FAO Myanmar

Agroecology is an effective approach to tackle climate change and the interconnected challenges facing food security and nutrition. Agroecology offers a unique approach to meet the needs of future generations while ensuring no one is left behind. Agroecology seeks to transform food and agriculture systems, addressing the root causes of problems and providing holistic and long-term solutions based on co-creation of knowledge, sharing and innovation, including the combination of local, traditional, indigenous and practical knowledge with multi-disciplinary science. Agroecology contributes directly to multiple SDGs through integrated practices that cut across many areas.

Many successful agroecological approaches are today being scaled up through the support of public policies, networks of knowledge exchange, and by strengthening rural institutions and improving access to markets. By bringing together the valuable knowledge, capacities and experience of diverse actors including governments, research, civil society and producer organizations, international institutions and the private sector, FAO's engagement is adding strength to agroecology. In September 2014, FAO hosted the 1st International Symposium on Agroecology for Food Security and Nutrition. Similarly, FAO has been organizing a series of regional meetings to better understand the different contexts and specific local needs of agroecology. FAO is also ready to support countries develop a policy environment and frameworks to promote agroecological approaches.

This presentation will introduce briefly how agroecology has been integrated into the work program of FAO over the past years, and what FAO means by agroecology. This also presents the outline of the scaling up agroecology initiative (which was launched by FAO in May 2018) and concludes by highlighting the challenges for academia and research organizations for scaling up agroecology.

The Scaling Up Agroecology Initiative and Challenges for Research & Academia

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National Workshop on Climate Smart Agriculture, Sustainable Land Management and Sustainable Forest Management , 29 august 2019, Nay Pyi Taw, Myanmar

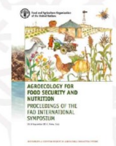
A rather new area of work within FAO…

- Agroecology is not new but it has been included in FAO work stream only recently
- **18 - 19 September 2014**: 1st International Symposium on Agroecology for Food Security and Nutrition in FAO HQ, Rome, Italy

→ First time FAO ever officially and directly addressed the topic of **Agroecology**

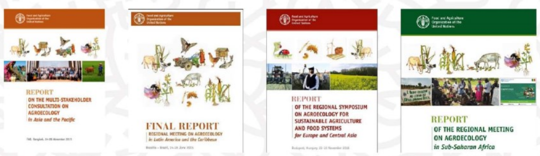
→ **50 experts**, including academic professors, researchers, private sector, government officials and leaders of civil-society organizations,

→ Attended by more than **400 people**

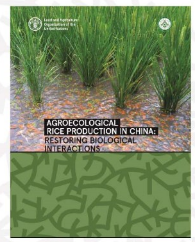


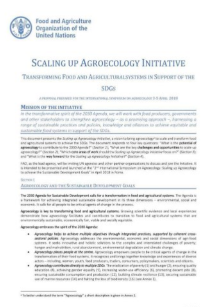
2014-2017: A four-year process of political dialogue about the benefits of AE covering all regions of the world

→ FAO played a leading role in facilitating global and regional dialogue on AE through **9 regional** and **international** multi-stakeholder meetings, bringing together more than **2,100 participants** from **170 countries**. These meetings helped identify needs and priorities to scale up AE as a strategic approach to achieve **Zero Hunger** and the **SDGs**.



- Two regional symposia were held in **Asia** in November 2015 (**Bangkok**, Thailand) and in August 2016 (**Kunming**, China).
- The Symposium held in China called on stakeholders to: *"Identify and develop **indicators on environmental, social, cultural and economic dimensions of Agroecology at different spatial scales** (farm, society, national level) and gather data on Agroecology, including on the very long term. FAO should establish a working group to contribute to this task".*





SCALING UP AGROECOLOGY INITIATIVE

TRANSFORMING FOOD AND AGRICULTURALSYSTEMS IN SUPPORT OF THE SDGs

MISSION OF THE INITIATIVE

In the transformative spirit of the 2030 Agenda, we will work with food producers, governments and other stakeholders to strengthen agroecology – as a promising approach –, harnessing a range of sustainable practices and policies, knowledge and alliances to achieve equitable and sustainable food systems in support of the SDGs.

SECTION 1

AGROECOLOGY AND THE SUSTAINABLE DEVELOPMENT GOALS

…backed by a strong political mandate

- **October 2018**: 26th Session of the **FAO Committee on Agriculture** (COAG) welcomed the **Scaling up Agroecology Initiative,** supported the **10 Elements of Agroecology** emanating from the regional seminars and requested FAO to develop an **action plan** with partners, taking into account country needs and capacities
- **December 2018**: 160th Session of the **FAO Council** endorsed the COAG decision
- **2019**: Committee of World Food Security will discuss the outcomes of a **HLPE report** on **"Agroecological approaches and other innovations for sustainable agriculture and food systems** that enhance food security and nutrition"

→ Summary & Recommendations released on June 19th 2019 (available on FAO Website)

What is Agroecology for FAO?

- An **integrated approach** that simultaneously applies **ecological & social concepts** to the design and management of **food & agricultural systems.**
- Optimize **interactions** between **plants, animals, humans and the environment** while taking into consideration the **social aspects** for a sustainable and fair food system.
- Based on **bottom-up** and **territorial processes**, helping to deliver **contextualized solutions** to local problems.
- AE innovations are based on the **co-creation of knowledge**, combining science with the traditional, practical and local knowledge of producers.
- By enhancing their autonomy and adaptive capacity, AE empowers **producers** and **communities** as key **agents of change**.

Harmonizing Principles and Levels

5 Agroecology principles (Altieri, 1995)

Recycling biomass; Favourable soil conditions; Minimising losses; Species & Genetic Diversification; Ecological processes & services

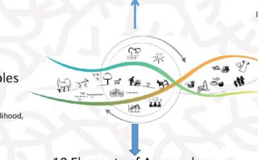
Literature review, Feedback from International/FAO experts Global, Regional Conferences

5 Agroecology levels (Gliessman, 2015)

Increase efficiency of practices / Substitute alternative practices / Redesign agroecosystem (ecological processes) / Producers - consumers linkages / Equity, participation & justice in Food Systems

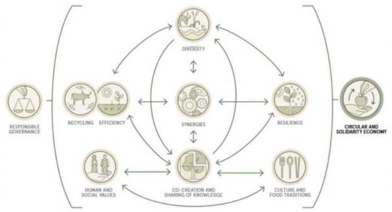
5 Sustainable Food and Agriculture principles (FAO, 2014)

SNRM, Efficient Use of Resources, Livelihood, Resilience, Governance



10 Elements of Agroecology (FAO, 2018)

The 10 Elements of Agroecology

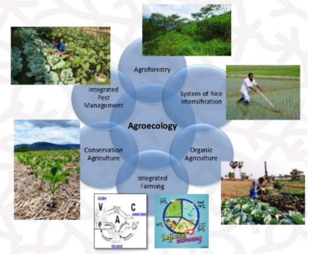


- An **analytical tool** to operationalize AE
- A guide for policymakers, practitioners and stakeholders in **planning, managing and evaluating AE transitions**
- Describing Characteristics of AE systems, foundational practices & innovation approaches / Context features / Enabling environment

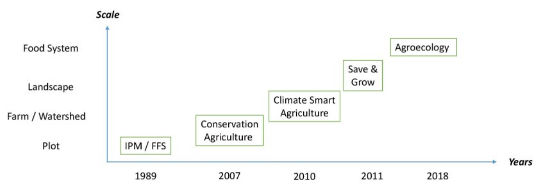
What is Agroecology for FAO?

Concept of AE as an **overarching umbrella** under which many different approaches can exist as long as they are moving towards **sustainable food systems**

- **Production practices**: e.g. Agroforestry, SRI, IPM, Organic, Conservation Agriculture…
- **Environmental dimension**: Biodiversity, Climate Resilience…
- **Economic dimension**: PGS, Farmer's markets, Value addition…
- **Social dimension**: Farmers organization, Social movements, Focus on decent work…



Evolution of concepts over time



(Ferrand, 2019)

The Scaling Up Agroecology Initiative (SAI)

- A strategic approach to bring Agroecology to scale and **transform food and agricultural systems** to **achieve the SDGs**
- Aims to accompany and support **national Agroecology transition processes** through policy and technical capacity building that creates synergies between countries
- Explicit focus on **building alliances** among different stakeholders, **strengthening networks**, fostering the **co-creation and sharing of knowledge** within a territorial approach that is tailored to particular contexts
- Developed in alignment with other initiatives such as the **2030 Agenda**, the UN **Decade of Family Farming**, the UN **Decade of Action on Nutrition**, and the **Global Initiative on Decent Jobs for Youth**…
- The Initiative focuses on three interrelated Areas of Work and five Key Actions to harness opportunities and overcome challenges to scale up Agroecology

The Scaling Up Agroecology Initiative

Three areas of work

1. *KNOWLEDGE AND INNOVATION FOR SUSTAINABLE FOOD AND AGRICULTURAL SYSTEMS*
   - *1.1 Strengthening formal and informal education on Agroecology at all levels*
   - *1.3 Co-Innovation and participatory research on Agroecology, combining producer's knowledge and interdisciplinary scientific knowledge, and recognizing, preserving and utilizing traditional and indigenous knowledge*
2. *POLICY PROCESSES FOR TRANSFORMATION OF FOOD AND AGRICULTURAL SYSTEMS*
3. *BUILDING CONNECTIONS FOR TRANSFORMATIVE CHANGE*
   - *3.4 Build connections with research institutions and academia*

The Scaling Up Agroecology Initiative

5 Key actions to scale up Agroecology:

- *Strengthen the central role of family farmers and their organizations in safeguarding, utilizing and accessing natural resources;*
- *Foster experience and knowledge sharing, collaborative research and innovations;*
- *Promote markets for agroecology based products for health, nutrition and sustainability;*
- *Review institutional, policy, legal and financial frameworks to promote agroecological transition for sustainable food systems;*
- *Take Agroecology to scale through integrated and participatory territorial processes.*

Scaling up agroecology: Challenges for Academia and Research Organizations

Agroecology is:
- knowledge intensive: replacing external inputs with knowledge
- Context specific and embrace complexity
- Holistic with a transformative agenda (vs conformative)

→ 6 main challenges

1) Developing family farmer-led and participatory research and co-innovation:
- Farmers involved throughout the research cycle: builds collective capacities to solve systemic problems
- Development of on-farm and action oriented research
- Respecting and promoting traditional knowledge and their knowledge systems and combine with modern innovations

Scaling up agroecology: Challenges for Academia and Research Organizations

2) Developing interdisciplinary and transdisciplinary research and filling research gaps
- « *Approaches that value and integrate different types of knowledge systems, which can include scientific or academic disciplines, as well as different types of knowledge systems as well as adopt a problem-based focus* » (Mendez et al.,2015)
- Importance of social sciences to support the transition
- Creating time and space for deep exchanges as multi-stakeholder cooperation platforms for collaboration between farmers and researchers (at local, national, regional and global levels)
- Filling research gaps: ecosystem processes, design of agrocological diversified and integrated systems, closing the biogeochemical cycles (nutrient, water, organic matter, energy flows) and all complex interactions related to the systems, landscape approach, taking into account the long term effects of agricultural impacts, climate change adaptation, soil health and biodiversity, synergies with organic farming in a co evolution, livestock and agroecology, innovative markets, policy and decision processes …

Scaling up agroecology: Challenges for Academia and Research Organizations

3) Promoting technical, social and institutional innovations

- Innovation systems at the center of the debate in agricultural paradigms
- Promoting innovation for sustainable agriculture is not just inventing new technologies or products, but also facilitating innovation processes that can stimulate new ideas, technologies, products and practices from a variety of actors (and particularly from farmers) around the world
- Innovations should:
  - ➢ Be people centered and locally adapted
  - ➢ Be low cost and adaptable (appropriate technologies)
  - ➢ Enhances family farmers' autonomy and livelihoods
  - ➢ Be climate resilient and uses natural resources sustainably

Results of an online survey: "What are, or should be, the main characteristics of agroecological innovations? "(2018)

Scaling up agroecology: Challenges for Academia and Research Organizations

5) Investing in massive capacity development

- Including support for agroecology training initiatives among grassroots' organizations
- Agroecology in training and educational curricula from primary schools to universities

4) Developing a new framework to assess the performance of food and agricultural systems

- *Developing new methodologies and indicators for sustainable food systems that are not solely based on yield,* documenting the **social, economic, health, nutrition, resilience and social justice** benefits of agroecology, including qualitative and quantitative data

6) Governance and data management

- Training and methods of evaluation of researchers
- Moral contract or legal protection of farmers' knowledge
- Preserving the public nature of environmental knowledge and data
- Developing open source technologies to foster data exchange and collaboration

Need to **push the boundaries of science**: Go further, Think different, Act different

The Global Knowledge Product on Agroecology: an opportunity for collaboration

- Expected outputs
  - ➢ A **multi-dimensional analytical framework** for policy-makers, researchers, producers and other stakeholders, including guidelines on its application
  - ➢ Global – participatory- **online database** capturing quantitative, qualitative and spatial data on AE
  - ➢ Implementation of **regional case studies**
  - ➢ Established **community of practice** on AE with improved capacity of stakeholders to assess agroecological systems
  - ➢ Strengthened **FAO AE Knowledge Hub** (Publication of resources, experiences and events on AE)

Way forwards…

- **FAO AE knowledge Hub**
  - To share existing **studies, success stories** and other documentations on AE
- **GKP on AE**
  - Regional workshop on the Application of the FAO Global Analytical Framework for the multidimensional assessment of Agroecology (24-26 September 2019, Bangkok)
  - To join the **community of practice** on AE to assess agroecological systems in Myanmar
  - To **join / co-organize events on AE** (and Family Farming under the UNDFF)
- Scaling AE Initiative
  - To develop specific **regional program addressing AE and Higher Education Institutions**

Food and Agriculture Organization of the United Nations | SUSTAINABLE DEVELOPMENT GOALS

working for Zero Hunger

http://www.fao.org/agroecology

United Nations Decade of FAMILY FARMING 2019-2028

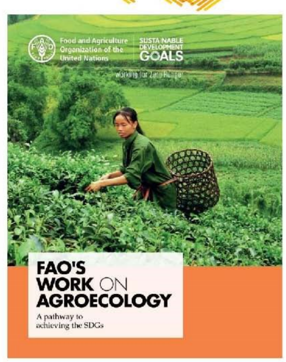


Photo Records

Opening speech delivered by Dr. Aung Thu, Union Minister, Ministry of Agriculture, Livestock and Irrigation

Opening remark delivered by Ms. Xiaojie Fan, Food and Agriculture Organization (FAO) Representative in Myanmar

Words of Acknowledgement and Objective of the Workshop delivered by Dr Nang Hseng Hom, Rector, Yezin Agricultural University

Group photo of honorable guest

Group photo of honorable guest

Group photo of speakers

Chair by Dr Hla Than on the sectionof CSA/ SLM/SFM concept/techniques and Agroforestry

Chair by Mr. Xavier Bouan on the section of Water Saving Techniques and Irrigation

Registration Photo

Audience

Presentation by the speakers on Green Ecology in Myanmar related topic

Question and answer by the participants and speakers

Group discussion and presentation by participants

Award the certificate of participation to the speakers

Presentation by Jitendra Jaiswal, Climate Smart Agriculture Specialist, FAO

Closing remarks by Mr. Xavier Bouan, Senior Technical Adviser, FAO

Annex 1 - Workshop agenda

THE 2ND WORKSHOP ON GREEN ECOLOGY IN MYANMAR
Auditorium, Yezin Agricultural University
Thursday, 29th August 2019

WORKSHOP PROGRAM

INAUGURATION SESSION	8.30 – 9.00	Workshop Registration
	9.00 – 9.10	Welcome Address and Opening Speech By Union Minister, Ministry of Agriculture, Livestock and Irrigation
	9.10 – 9.20	Opening Remark By FAO Representative in Myanmar
	9.20 – 9.30	Words of Acknowledgement and Objective of the Workshop By Rector, Yezin Agriculture University
	9.30 – 9.40	Workshop Photography
	9.40 – 10.00	**Morning Refreshments**
TECHNICAL SESSION 01 (Presentation & Q/A)		**CSA/SLM/SFM concept/techniques and Agroforestry** Session Chair: Dr. Hla Than
	10.00 – 10.15	Socio-Technical Methodologies in Establishing Climate Smart Villages in Myanmar as Platform to Promote Climate Smart Agriculture *Wilson John Barbon, Chan Myae, Su Myat Noe, Julian Gonsalves (IIRR)*
	10.15 – 10.30	Factors Influencing Farmers' Adoption of Soil Conservation Practices in Hakha Township, Chin State *Kay Thwe Moe, Shwe Mar Than and N.V Kumbhrae*
	10.30 – 10.45	Changes of Rice Production System at Central Dry Zone of Myanmar: A Case study in Meiktila Township *Ohnmar Minn Khin, Nang Ei Mon The, Nyein Nyein Htwe, Hla Than and Kyaw Kyaw Win*

	10.45 – 11.00	Accelerating Agroforestry Adoption for Restoration and Resilience in Myanmar's Central Dry Zone. *Delia C. Catacutan, ICRAF*
TECHNICAL SESSION 02 (Presentation & Q/A)		**Water Saving Techniques and Irrigation** Session Chair: Xavier Bouan
	11.00 – 11.15	Enabling Resilient and Inclusive Smallholder Farming Systems Through Improved Agricultural Water Management (AWM), *Phay Ko U, IWMI*
	11.15 – 11.30	Effect of Different Water Regimes on Growth, Yield and Water Use Efficiency of Groundnut (Arachis hypogaea L.) Varieties *Kywae, Nang Ohn Myint, Aung Naing Oo, Khin Thidar One, Kyaw Ngwe*
	11.30 – 11.45	Effect of Straw and Nitrogenous Fertilizer Application on Methane and Nitrous Oxide Emissions from Rice Production Under Different Water Regimes *Lae Lae Mon, Nang Ohn Myint, Aye Aye Than, Ei Phyu Win, Kyaw Ngwe*
	11.45 – 12.00	Effects of Alternate Wetting and Drying (AWD) and Rice Varieties on Methane Emissions from a Paddy Field *Ye Zar Ne Ko Ko Htwe, Hayman Soe, Nyo Mar Htwe, Ei Phyu Win*
	12.00 -12.15	Relationship between Water Absorption and Carbohydrate Metabolism in Germinating Seed of Anaerobic Germination Tolerant Rice Genotypes *Thu Zar, Khan, M.I.R., Cruz, P.C.S and Ismail, A.M*
	12.15 – 13.15	**Lunch Break**
TECHNICAL SESSION 03 (Presentation & Q/A)		**Agroecology** Session Chair: Dr. Khin Lay Swe
	13.15 – 13.30	Agroecology Concept and How FAO Is Working On Agroecology *Pierre Ferrand and Jitenda Jaiswal, FAO*
	13.30 – 13.45	Diversity and Abundance of Insect Pests in Intensive Monsoon Rice Growing Areas of Nay Pyi Taw

		Nwe Ni Win, Moe Hnin Phyu, Thi Tar Oo and Kyaw Kyaw Win
	13.45 – 14.00	Drought Tolerance Eggplant (Solanum spp.) Selection by Molecular Markers (SSRs) *Htwe Min Thant, Aye Aye Thwe, Moe Kyaw Thu, Nyo Mar Htwe, Khin Thida Myint*
	14.00 – 14.15	Genetic Variation for Salinity Tolerance in Rice (Oryza Sativa L.) Genotypes at Seedling Stage *Saw Nandar Tun, Su Latt Phyu, Soe Win*
	14.15 – 14.30	Effect of Growing Seasons on Yield and Agronomic Characters of Some Diseases Resistant Mungbean Genotypes *Kyaw Swar Win, Soe Win, Than Myint Htun and Nang Kyu Kyu Win*
PREWORKING SESSION	14.30 – 14.45	**Group Division (3 groups) and Clarification on the Tasks** *Facilitated by FAO (Jitenda P. Jaiswal, Khin San Nwe, ThiHa)*
	14.45 – 15.15	**Afternoon Refreshments**
WORKING SESSION	15.15 – 16.00	**Group Discussions:**
		Issues/challenges, opportunities, recommendations for promoting the followings in Myanmar *Facilitated by FAO (Jitenda P. Jaiswal, Khin San Nwe, ThiHa)* Group 1: CSA/SLM/SFM techniques and practices Group 2: Agroforestry, Water saving/efficient techniques Group 3: Agroecology
	16.00 – 16.45	Presentations by 3 Groups and discussions/Q&A
CLOSING SESSION	16.45 – 17.00	**Closing Remarks** **YAU & FAO**

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