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Proceedings

National Workshop on Promoting Climate Smart Agriculture in Myanmar, Yezin Agricultural University

14 September 2018

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"Sustainable cropland and forest management in priority agro-ecosystems of Myanmar" project of FAO and Yezin Agricultural University

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National Workshop on Promoting Climate Smart Agriculture

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Background

Myanmar is highly vulnerable to climate change and extreme weather conditions. According to the global climate risk index, Myanmar ranks among the top three countries most affected by weather related events, which has led to massive displacement of people and the destruction of livelihoods, crops and other food sources. In the recent years, the change in the climate has been impacting agricultural production negatively, which potentially can lead to food insecurity.

In order to build the capacity of farming and forestry stakeholders at various levels to mitigate climate change and improve land conditions, a project entitled "Sustainable cropland and forest management in priority agro-ecosystems of Myanmar" was commenced by Food and Agriculture Organization of the United Nations in Myanmar (FAO) in July 2016. The five-year project (2016–2021) is funded by Global Environment Facility (GEF) and being jointly coordinated and implemented by the Ministry of Natural Resources and Environmental Conservation (MoNREC) and the Ministry of Agriculture, Livestock, and Irrigation (MoALI), and FAO. The project is supporting the adoption of policies and practices for sustainable land management (SLM), climate-smart agriculture (CSA), and sustainable forest management (SFM).

In order to coordinate development, packaging and promotion of best practices for CSA systems and to conduct advocacy activities related to CSA/SLM, the project has supported establishment of a National CSA at Yezin Agricultural University. The National CSA Center was jointly opened by His Excellency Dr Aung Thu, The Union Minister for Agriculture, Livestock and Irrigation and myself as a FAO Representative in Myanmar on 17th 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 21 members representing DoA, DAR, DoP, DALMS, FD, I/NGO's, YAU and FAO.

One of the key activities of the National CSA Center is to organize annual workshop/conference to share ideas, opportunities and challenges with regards to CSA and SLM and to discuss on the way forwards. Such workshops will focus on different themes of CSA and SLM every year. Accordingly, the first workshop was organized by the CSA Center at YAU on 14th Sep 2018 and the theme of this workshop was "Promoting CSA in Myanmar".

The workshop was attended by more than 100 participants representing relevant Government Departments from MoALI and MoNREC, YAU, State Agriculture Institute, I/NGOs (Cesvi, AVSI, COLDA, IIRR), IRRI, JICA, JIRCAS and FAO. A total of 15 papers received from YAU, Department of Agriculture, Department of Agriculture Research, State Agriculture Institute, Forest Department and FAO, grouped into three broader topics/sessions, were presented in the workshop. The sessions on “Concept of Climate Change and CSA” covered four papers, “Resistance to Climatic Stress” covered five papers and the session on “Forestry/Agro-forestry, Disease, Pest and Nutrients Management” included six papers. The presentation and discussions were followed by a Group Work on “how to promote CSA in Myanmar (issues/challenges, opportunities and recommendations)” and on “how to make CSA Center effective and sustainable” where the recommendations from the four groups were presented in the plenary session and feedbacks were received.

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 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 (Four papers: 1, 2, 5, 6)
- Dr Htay Htay Oo, Associate Professor, Department of Agronomy, Yezin Agricultural University, Myanmar (Four papers: 3, 7, 8, 9)
- Dr Yu Yu Min, Associate Professor, Department of Plant Pathology, Yezin Agricultural University, Myanmar (Six papers: 4, 10, 11, 12, 13 and 14)
- Dr Thiha, National Sustainable Forest Management Specialist, FAO/Global Environment Facility Project (GEF) GCP/MYA/017/GFF (One paper: 15)

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

The detailed workshop agenda has been presented in Annex 1.

Opening speech by U Aye Maung Sein, Nay Pyi Taw council member, Nay Pyi Taw council

Honorable guests from FAO, 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 GEF and 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 CSA as an adaptation and mitigation strategies to a changing climate that is something threatening our agriculture and the livelihoods of many households. As you all know, climate change makes our already precarious global food security situation. Unpredictable people are facing undernourished and malnutrition all over the world. More than any other region, the people in the Asia-Pacific region are likely to be hardest hit as a result of climate change. By then, agriculture is likely to be the most vulnerable sector because of its dependence on climate and weather. From a livelihood point of view, the people in the Asia-Pacific region are mainly agrarian, with almost 60 percent of its population living in rural areas.

Myanmar is highly vulnerable to climate change and extreme weather conditions as witnessed by a series of disasters happening in the country within a short period of time. In Myanmar, there are almost 70 percent of total population depend on agriculture. This means almost 30 million people are facing the direct impacts of climate change, with disastrous consequences to their livelihoods in Myanmar. For Myanmar, climate change is already having adverse effect on our constituent's food and nutrition security status and on the livelihoods of our rural population, which is entirely dependent on agriculture, fisheries and forest products.

Ladies and Gentlemen!

CSA will enable the continents to contribute towards mitigation efforts. CSA is a pathway towards agriculture development, Food and nutritional security which is build on three pillars namely increasing productivity and income, enhancing resilience of livelihoods and ecosystems and producing greenhouse gas emission from the atmosphere. Therefore, CSA that increase productivity in a sustainable manner through adaptation and mitigation. At the same time, it can enhance the achievement of national food security and development goals.

According to FAO, the region's population is expected to increase by another 850 million people by 2050, which will severely test the region's ability to maintain food security. Producing enough food for the increasing population in the face of decreasing resources and changing climate would be an overwhelming challenge. By adapting climate smart agricultural systems, that are more resilient to climatic trends and changes, losses in production can be reduced and food security situation can be enhanced.

In Myanmar, adapting to climate change and climate variability is all about having (1) knowledge (2) technological innovation (3) responsive action and (4) strategic partnerships. Today's workshop is attended by 15 speakers from agriculture and forestry sectors. Therefore, this workshop will provide us not only essential knowledge but also a great opportunity to share experiences both technical and regulatory issues that can promote CSA in Myanmar. At the same time, we can realize the major problems related to CSA in Myanmar and we could found the solutions. In addition, we all could predict what will be the major issue for CSA and make the future plan to be smart on climate change. I believed that we could do.

I would like to take this opportunity to express my sincere thanks to the organizers and in particular our honorable speakers. 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.

U Aye Maung Sein
Nay Pyi Taw Council member
Nay Pyi Taw Council

Opening remark by Mr Xavier Bouan, Senior Technical Adviser, FAO

Respected Nay Pyi Taw council member, U Aye Maung Sein, Director General of Department of Agricultural Research U Naing Kyi Win, the Rector of Yezin Agricultural University Dr Nang Hseng Hom, Rector from University of Veterinary Science, Rector from University of Forestry, Pro-rectors and Professors, DDGs, Directors, Deputy Directors, government officials, representative from NGOs and INGOs, FAO Colleagues. Good Morning everybody.

Ladies and Gentlemen, today I feel honored to welcome all the participants and make opening remarks on behalf of FAO Myanmar to this National Workshop on Promoting CSA in Myanmar.

As you are aware, Myanmar is highly vulnerable to climate change and extreme weather conditions as witnessed by a series of disasters happening in the country within a short period of time since the occurrence of cyclone Nargis in the Ayeyarwady in May 2008. According to the Global Climate Risk Index, Myanmar ranks among the top three countries most affected by weather related events, which has led to massive displacement of people and the destruction of livelihoods, crops and other food sources. In the recent years, the change in the climate has been impacting agricultural production negatively, which potentially can lead to food insecurity.

It can clearly be noted that Myanmar is making all the 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 national initiatives such as the national climate change policy and sector strategies such as Myanmar CSA strategy.

FAO has been collaborating with the Republic of the Union of Myanmar for the last more than 40 years to implement initiatives that contribute to livelihood improvement and economic development in Myanmar. Similarly, in order to mitigate the looming threats of climate change to which Myanmar is very vulnerable, a project entitled “Sustainable cropland and forest management in priority agro-ecosystems of Myanmar” was commenced by FAO Myanmar in July 2016. The five-year project (2016–2021) is funded by GEF and being jointly coordinated and implemented by the MoNREC and MoALI, and FAO.

The main objective of the project is to build the capacity of farming and forestry stakeholders at various levels to mitigate climate change and improve land conditions. This is being achieved by facilitating the adoption of policies and practices for SLM, CSA, and SFM. The project is also supporting to strengthen the relevant policy and regulatory frameworks and generate replicable models for CSA and for community-based forest management.

At field level, the project works through Farmer Field Schools (FFS), Community Forestry Initiatives and promoting integrated land-use planning and digital land use mapping processes in five pilot Townships from three different agro-ecological zones: upland/hill zone, central dry zone and coastal/delta zone.

In order to coordinate development, packaging and promotion of best practices for CSA systems and to conduct advocacy activities related to CSA/SLM, the project has supported establishment of a national CSA center at Yezin Agricultural University. The National CSA Center was jointly opened by His Excellency Dr Aung Thu, The Union Minister for Agriculture, Livestock and Irrigation and myself as a FAO Representative in Myanmar on 17th August 2018.

A CSA Technical Support Group (TSG) has already 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 21 members representing DoA, DAR, DoP, DALMS, FD, related I/NGO's, YAU and FAO.

One of the key activities of the National CSA Center is to organize annual workshops/conference to share ideas, opportunities and challenges with regards to CSA and SLM and to discuss on the way forwards. Such workshops will focus on different themes of CSA and SLM every year. Today I am very happy that we are organizing the first workshop of a series of workshops to be organized in future and the theme of this workshop is "Promoting CSA in Myanmar".

On behalf of FAO, I would like to extend best wishes for a successful workshop with active participation and effective contributions from all the distinguished participants to promote CSA in Myanmar. Thank you

Mr Xavier Bouan
Senior Technical Adviser
SLM-GEF Project, FAO

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

Good Morning! Honorable his Excellency U Aye Maung Sein, Professor Dr Myint Thaung, Deputy Director General U Kyaw Swe Linn, Deputy Director U Ngwe Thee, Senior consultant from JICA and Senor Technical advisor and expert from FAO and Mr Xavier, and Pro-rector, Professor and then our colleagues from IRRI, representative of different inline departments, members of technical working group, researchers and scientists, distinguish guest, ladies and gentlemen!

On behalf of Yezin Agricultural University, first of all, let me welcome to all to Yezin Agricultural University and welcome to this promoting CSA workshop today. This workshop is jointly organized by FAO, GEF, MoNREC, MoALI and YAU. At this first initiative workshop on promoting CSA in Myanmar, all scientists and expert its bring together of knowledge, technologies and then they will find out the way to promote the CSA in Myanmar.

The objectives of the workshop are to share knowledges and experience in implementing CSA including forestry, among public civil society and development agency and promoting mainstreaming and upstreaming of the CSA. Therefore, let me begin my thank to our Nay Pyi Taw council members H.E U Aye Maung Sein, for giving your kind support and valuable encourage speech today. We also thank our former Rector, member of National Education Policy Commission Professor Dr Myint Thaung and members of steering committee, Deputy Director of Forest Department U Ngwe Thee for their continuous support for this workshop, my gratitude extent to senior technical adviser, consultant and expert from FAO and Funding agencies Global Environmental Facilities for this support, last but not the least I thanks researchers, presenters and presentative from Forestry Department, Department of Agriculture, Department of Agricultural Research, Department of Planning, IRRI and Settlement and Land Record Department and YAU for your participation. I also want to thank my team, the coordinators for their afford in preparing for this workshop. Thank you.

Dr Nang Hseng Hom
Rector
Yezin Agricultural University

Sustainable cropland and forest management in priority agro-ecosystems: Promoting climate-smart agriculture in Myanmar

Jitendra P. Jaiswal[1] and Khin San Nwe[2]

Abstract

FAO is implementing a Global Environment Facility (GEF) funded five-years (2016–2021) project "Sustainable cropland and forest management in priority agro-ecosystems in Myanmar" jointly with the MoNREC, MoALI, and FAO. The project aims to build the capacity of farming and forestry stakeholders to mitigate climate change and improve land condition by adopting policies and practices for SLM, CSA, and SFM.

The project intends to mainstream CSA in the agriculture related academic courses and trainings conducted by YAU, State Agricultural Institutes (SAI), Department of Agriculture (DoA) and Department of Agriculture Research (DAR). Accordingly, the project has supported revision/development of the curricula integrating CSA topics for Masters and Bachelor level courses on Agriculture at YAU; Diploma in Agriculture course at SAIs; one month training on CSA for the in-service or refresher course at Central Agriculture Research and Training Centre (CARTC) and one-week intensive Training of Trainers (ToT) program aiming for the researchers, extension agents and teachers of DoA, DAR and YAU.

A national CSA center has also been established at YAU to coordinate overall CSA initiatives in Myanmar. In the field, the project is promoting various relevant CSA techniques and practices in the five pilot Townships (Kyaukpadaung, Nyaung U, Mindat, Kanpetlet and Labutta), mainly using Farmer Field Schools (FFS) models. In order to apply in the FFS trainings, FFS curricula/ handbooks have been developed for three agro-ecological zones.

It is expected that through the adoption of such techniques and practices, that are more resilient to climatic trends and changes, production can be sustainably increased, and achievement of national food security and development goals will be enhanced.

1. Background

Myanmar is highly vulnerable to climate change and extreme weather conditions as witnessed by a series of disasters happening in the country within a short period of time, since the occurrence of Cyclone Nargis in the Ayeyarwady and Yangon Regions and Cyclone Giri in Arakan State (Rakhine) in 2008 and 2010 respectively. According to the Global Climate Risk Index by Kreft et al. 2015, Myanmar ranks among the top three countries most

[1]Jitendra P. Jaiswal, CSA Specialist (International), SLM-GEF Project, FAO Myanmar
[2]Khin San Nwe, CSA Specialist (National), SLM-GEF Project, FAO Myanmar

affected by weather related events, which has led to massive displacement of people and the destruction of livelihoods, crops and other food sources. In the recent years, the change in the climate has been characterized by changing rainfall patterns, increasing temperatures and extreme weather throughout the country. Another impact of climate change is sea level rise (SLR) causing river bank erosion, salinity intrusion, flooding, damage to infrastructures, crop failure, fisheries destruction, loss of biodiversity, etc. in the low lying coastal areas and Deltas. Consequently, climate change is impacting agricultural production negatively, which potentially can lead to food insecurity.

In order to mitigate the looming threats of climate change to which Myanmar is very vulnerable, a project entitled "Sustainable cropland and forest management in priority agro-ecosystems of Myanmar" was commenced by FAO in July 2016. The five-year project (2016–2021) is funded by GEF and being jointly coordinated and implemented by MoNREC, MoALI, and FAO.

The main objective of the project is to build the capacity of farming and forestry stakeholders to mitigate climate change and improve land conditions. This will be achieved by facilitating the adoption of policies and practices for SLM, CSA, and SFM. The project addresses the key barriers for Myanmar to effectively cope with the impacts of land degradation and climate change. The project is also supporting to strengthen the relevant policy and regulatory frameworks and generate replicable models for CSA and for community-based forest management. The CSA project activities will be implemented following the concept and definition of CSA by (FAO, 2013);

- sustainably increasing agricultural productivity and incomes;
- adapting and building resilience of agricultural livelihoods to climate change; and
- reducing and/or removing greenhouse gas emissions, where possible.

2. Project components

The project is structured into the following four interlinked components.

3. Project coverage and focus of interventions
(Project document of FAO, 2015)

At field level, the project is active in the following five pilot townships from three different agro-ecological zones.

- Upland/hill zone pilot site: Mindat and Kanpetlet Townships, Chin State
- Coastal/delta zone pilot site: Labutta Township, Ayeyarwady Region
- Central dry zone Pilot Site: Kyaukpadaung and Nyaung U Townships, Mandalay Region

In upland/hill zone of Chin State, focus is on community-based forest management, shifting cultivation and addressing the forest and cropland components through complementary strategies.

In the delta, the primary focus is on climate smart paddy farming, alternative crops, water management and mangrove protection.

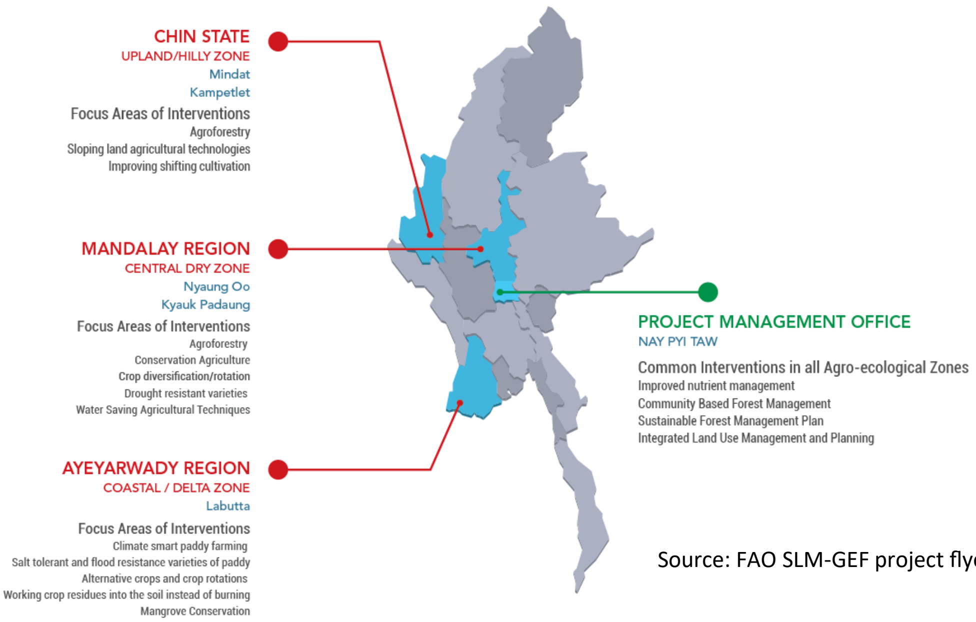
In the Central Dry Zone, focus is on reforestation and afforestation, water saving agricultural techniques, agroforestry and annual crops.

4. Description of the activities on promoting CSA

The "Models for CSA practices demonstrated and enhancing carbon storage in three priority agro-ecosystems " (component 2) is an integral part of the project. Under this component the project has been implementing the following activities.

4.1 Develop curricula for academic courses and training programmes

The FAO SLM-GEF project intends to establish a national CSA/SLM training program mainstreaming CSA/SLM in the agriculture related training conducted by Department of Agriculture (DoA), State Agricultural Institutes (SAI), Department of Agriculture Research (DAR) and Yezin Agricultural University



Source: FAO SLM-GEF project flyer

(YAU). The project is working with the following institutions to integrate CSA within their agricultural courses, research, training and development programs: DoA, SAIs, DAR and YAU.

The project, with supports from AVSI Foundation, as a Service Provider, has reviewed the existing situation and developed/ revised the following academic and training curricula to be adopted by the above mentioned organizations conducting agricultural courses, research, training and extension activities.

i. Develop/revise course curricula for BAgr.Sc and MAgr.Sc degree at YAU integrating CSA/SLM (Module 1).

ii. Develop/revise course curriculum for Agriculture Diploma Course at State Agricultural Institutes integrating CSA/SLM (Module 2).

iii. Develop CSA/SLM Training Curriculum for in-service training programmes (Module 3).

iv. Develop/revise training curriculum for Extension Agents training integrating CSA/ SLM (Module 4).

In order to finalize the training curricula for the above-mentioned modules, discussions were held and feedbacks were received from FAO, DoA, SAI, DAR and YAU. The revised version was then presented in a validation workshop in Nay Pyi Taw with relevant stakeholders and were further updated incorporating the comments from the workshop participants.

4.2 Develop CSA Handbook and Conduct ToT on CSA

The Project with supports from AVSI Foundation as a Service Provider, is developing a CSA/SLM handbook (training manual) covering principles and techniques/practices for CSA and SLM both in English and Myanmar languages including a general section and separate sections for each training curriculum for the four modules explained above. The handbook is intended to be used by the BSc and MSc students (agriculture) at YAU, Agriculture Diploma students at SAIs, DoA and DAR staff, newly recruited Extension Officers and farmers depending on the various modules.

For each module the handbook will reflect CSA techniques/practices to build knowledge of practical adaptation and mitigation practices for increased productivity and crop diversification to enhance food security and improved nutrition.

The Project has a plan to conduct a one-week Training of Trainers (ToT) on Module 3 "CSA/SLM Training Curriculum for in-service training programmes" covering the basic principles and techniques/practices associated with SLM and CSA targeting staff from DoA, CARTC, DAR, SAI and YAU.

4.3 Establish/Operationalize National CSA Centre

The Project Team developed a Concept Note for the establishment and operationalization of a National CSA Center, shared to the relevant stakeholders and received feedback. Based on

National CSA Centre Launching Ceremony (17/8/2018)

the initial consultation with relevant stakeholders during the project inception phase, it was agreed to establish the National CSA Center at Yezin Agriculture University (YAU). Accordingly, the CSA Center has been established at and operationalized by YAU with supports from the two key institutions under MoALI: Department of Agriculture (DoA) and Department of Agricultural Research (DAR).

The National CSA Center was jointly opened by His Excellency Dr Aung Thu, The Union Minister for Agriculture, Livestock and Irrigation and Ms. Xiaojie Fan, FAO Representative in Myanmar on 17th August 2018.

The FAO SLM-GEF Project provides necessary supports during project implementation phase for the establishment and operationalization of a CSA Center with the following objectives.

Vision: A center to lead CSA initiatives and to build capacities of concerned Government personnel and other stakeholders on CSA as an effective tool for climate change mitigation and adaptation in Myanmar.

Mission: Lead the development, dissemination and utilization of gender sensitive, inclusive climate-smart agriculture systems and technologies for different agro-ecological zones of Myanmar.

Goal: To sustainably increase agricultural productivity and farmers' income while enhancing resilience and reducing greenhouse gases (GHGs) in support of achieving the national food security and development goals.

Objectives:

- To coordinate development and packaging of best practices for CSA systems, - information and - technologies;
- To demonstrate and disseminate knowledge on CSA and SLM technologies and practices and
- To conduct advocacy activities related to CSA/SLM and climate change in coordination with appropriate organizations (DoA, DAR, YAU and other relevant organizations).

A National CSA Technical Support Group (TSG) has already been established 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 the following members representing DoA, DAR, Department of Planning (DoP), Department of Agricultural Land Management and Statistics (DALMS), Forest Department (FD), related I/NGO's, YAU and FAO. The CSA TSG has already met three times and made some important decisions.

The CSA Center, through the National CSA TSG, is responsible for overall coordination of CSA initiatives and serve as a focal point for the advancement of knowledge, monitoring of impacts, and adoption of CSA/SLM practices. The specific roles and responsibilities of the CSA Center are as follows.

- Vetting training programs, increasing access to national and international expertise, and generating linkages and alignment among concerned institutions.
- Facilitate integration of best CSA practices in the curriculum for under-graduate and Post-graduate degree programmes at YAU, Agriculture Diploma Courses at State Agricultural Institute (SAI), and in-service training and demonstration level learning (at DAR and DoA). This information will be used to promote wide application of CSA practices.
- Act as the national CSA knowledge repository and catalyst. The CSA Centre will take lead in gathering and storing CSA/SLM related documents (books and other published documents) and electronic materials for information sharing to all concerned. This information will be used to promote wide application of CSA practices.
- Contribute actively to the development, review and implementation of national Agriculture Development Strategy (ADS) and the CSA Strategy.
- Take lead on national upscaling and awareness raising on CSA practices including agro-forestry and coordinate CSA related activities at existing research institutions (DAR).
- Establish demonstration plots at some selected sites to demonstrate best CSA/SLM practices/technologies.
- The center will participate actively in curriculum development at all levels and development and maintenance of a CSA tool kit for use at local level.
- Serve as a clearinghouse for best practices and foci for the development and exchange of information and knowledge.
- Work closely with the Department of Agriculture to sustain and improve Farmer Field Schools (FFSs).
- Help to organize and facilitate the annual CSA/SLM workshops/conference. Each workshop will focus upon a different theme of CSA/SLM. By project close, the progress workshop will be shifted to become an annual CSA/SLM conference.

National CSA TSG Composition:

S.N.	Name	Title	Organization/Departments	Responsibility in CSA Centre
1	Dr Myo Kywe	Chairman	National Education Policy Commission	Chairman
2	Dr Nang Hseng Hom	Rector	Yezin Agriculture University (YAU), MoALI	Deputy Chairman
3	Dr Nyo Mar Htwe	Deputy Director	Advanced Centre for Agricultural Research and Education (ACARE), YAU, MoALI	Secretary
4	U Kyaw Lwin	Director	Department of Planning, MoALI	Member
5	Dr Nay Myo Aung	Head(Admin)	YAU, MoALI	Member
6	Dr Yu Yu Min	Professor(head)	Department of Agricultural Microbiology, YAU, MoALI	Member
7	Dr Shwe Mar Than	Deputy Director	ACARE, YAU, MoALI	Member
8	DrHtayHtay Oo	Associate Professor	Department of Agronomy, YAU, MoALI	Member
9	Daw Kyi Kyi Shwe	Assistant Lecturer	Department of Soil and Water Management, YAU, MoALI	Member
10	U Myo Than Tun	Lecturer	Department of Entomology , YAU, MoALI	Member
11	Daw Nang Ei Mon The	Lecturer	Department of Agricultural Economics, YAU, MoALI	Member
12	U Oo Kyaw Nyunt	Assistant Director	Department of Land Management and Statistics (DALMS), MoALI	Member
13	Dr Mar Mar Win	Assistant Research Officer	Department of Agricultural Research (DAR), MoALI	Member
14	DrZar Chi Hlaing	Staff Officer	FRI, Forest Department, MoNERC.	Member
15	Dr Thin Nwe Htwe	Staff Officer	Department of Agriculture (DoA), MoALI	Member
16	Dr Khin San Nwe	CSA Specialist (National)	SLM-GEF Project, FAO Myanmar	Member
17	Mr Jitendra P. Jaiswal	CSA Specialist (International)	SLM-GEF Project, FAO Myanmar	Member
18	Dr Han Phyo Aung	Assistant Lecturer	Department of Horticulture, YAU,MoALI	Member
19	Dr Ei Ei Theint	Deputy Staff Officer	DoA, MoALI	Member
20	Mr Xavier Bouan	Senior Technical Advisor	SLM-GEF Project, FAO Myanmar	Member
21	U Soe Moe Naing	Knowledge Management Specialist	SLM-GEF Project, FAO Myanmar	
22	Dr Einn Gin Khine		FRI, Forest Department, MoNERC.	

- A critical function of the Center will be monitoring of CSA/SLM activities. The Center will monitor and catalog best practices nationally. This will be done in agreement with other concerned agencies, particularly the Department of Agriculture.
- Arrange events in support of promoting and upscaling CSA good practices including national best practices competitions, involving schools and youth in connection with World Environment day and/or World Food Day.

In addition, the center established a demonstration plot at YAU compound on early rice in Feb 2018 on Effect of Different Nitrogen Fertilizer Application on Methane Emission in Shwe Thwe Yin Rice Variety. The second round of demonstration has been established on "Effect of Rice Varieties (HZZ-3-SAL 4-Y1-Y1, Manawthuka and GW-1) on Methane Emission" where the seedlings were transplanted in the field on 30 July 2018.

4.4 Develop FFS Curricula on CSA for Three Agro-ecological Zones

At field level, the project is promoting various relevant climate smart agricultural techniques and practices in all the five pilot Townships from three different agro-ecological zones mainly using Farmer Field Schools (FFS) models.

FAO with support from AVSI Foundation, as a Service Provider, has developed FFS Curricula for three agro-ecological zones adopting the following key steps.

4.4.1. Identify and prioritize the potential crops and conduct needs assessment.

The team visited all five pilot Townships and discussed with respective District/Township DoA Offices and other relevant stakeholders, including communities, to identify and prioritize the main crops being grown and major cropping systems/cropping patterns being practiced in the areas as well as potential future crops and possibilities for CSA. The team also conducted a market assessment in each pilot area to verify the market situation (demand/supply/price) of the prioritized crops. A village needs assessment (five villages in each pilot Townships) was conducted to know the main technical and commercialization/business related problems/issues for the selected crops.

4.4.2. Conduct basic assessments of value chain and business models for the identified crops.

The team consulted with the relevant value chain stakeholders of the selected crops/commodities in each pilot Township, including input suppliers, producers, processors, retailers, wholesalers, private sector actors, financing institutions, and Government to identify their challenges to growth and operation along the value chain.

A workshop (one at each pilot Township level) with above mentioned value chain stakeholders was organized to verify the findings of the value chain analysis and receive feedback. Finally, five value chain assessment reports, one each for five Townships, with concrete recommendations were produced.

4.4.3. Develop FFS curriculum/module for each Agro-ecological Zone.

FFS curriculum/module for each of the three agro-ecological zones were developed in both English and Myanmar version incorporating solutions to the major problems identified during the need assessment and also considering the findings of value chain analysis.

In order to finalize the FFS curricula/ modules, feedbacks were received from FAO, DoA and DAR. The revised version of FFS curricula/modules and Value Chain Reports were then presented in a validation workshop in Nay Pyi Taw with relevant stakeholders and were further updated incorporating the comments from the workshop participants.

4.5. Develop FFS Handbook for each Agro-ecological Zone

The AVSI Foundation, as a Service Provider, has developed a handbook (training material), both in Myanmar and English languages, for each FFS curriculum/module (one each for three agro-ecological zones) detailing best CSA practices for the selected agricultural crops and Agro-forestry systems. This manual is intended to be used by the FFS Facilitators and FFS Committee to build farmer knowledge of practical adaptation and mitigation practices for increased productivity and crop diversification to enhance food security and improved nutrition.

4.6. Establish Model Farmer Field Schools in Three Priority Agro-ecosystems

The project aims to demonstrate best practices for CSA through FFS, to increased carbon sequestration in the practices to be promoted is common for all. In addition the focus areas for promoting climate smart agricultural techniques under each of the three agro-ecological zones include, but are not limited to:

1. Hilly/Upland Zone (Chin State): agroforestry practices with annual crops, conservation agriculture, perennial crops, sloping land agricultural technologies (SALT) and improving shifting cultivation.
2. Central Dry Zone (Mandalay Region): climate smart farming of pulses and oilseed crops, conservation agriculture, composting, crop diversification/rotation, improved nutrient management, drought resistant varieties, increasing soil organic matter water saving agricultural techniques (WSAT) and agro-forestry.
3. Coastal/Delta Zone (Ayeyarwady Delta): climate smart paddy farming, alternate wetting and drying technique, improved seeds and varieties, crop rotations, improved nutrient management, working crop residues into the soil instead of burning, agroforestry, aquifer replenishment, mangrove conservation through promoting innovative alternative livelihoods (e.g. seaweed cultivation).

As the first phase implementation of FFS, the Project established 16 FFSs on chickpea, green gram and sesame crops involving 336 households in 13 villages of two pilot Townships of the Central Dry Zone: Nyaung-U and Kyaukpadaung. In addition to this, a training of

Farmer Field School Meeting/Training in Nyaung-U

trainers (ToT) on "CSA and FFS Establishment and Operationalization" was conducted in Nyaung-U on 25-27 September 2017 for representatives from DoA, Service Provider (Cesvi Myanmar) and FAO.

The Project organised second round of training of trainer (ToT) on CSA and FFS in three pilot sites (Mindat, Nyaung-U and Labutta) during April/May 2018 for the representatives from respective District/Township DoA Offices and representatives from Service Providers.

Additionally, 55 new FFSs were established in five pilot Townships under three agro-ecological zones during the monsoon season. The FFSs are being implemented in collaboration with District/Township DoA Offices with support from COLDA (in Upland/hills zone), Cesvi Myanmar (in Central Dry zone) and AVSI (in Coastal/Delta zone) as Service Providers.

In order to establish and operationalize the FFS, the respective Service Providers followed the following steps.

1. Village selection for the establishment of FFS.

Ten villages in each of the pilot Townships, except 15 villages in Labutta, were selected jointly by the respective Township DoA Office, Service Provider and FAO Field Officer using the set criteria. The selection was further validated and confirmed by visiting each village and confirming matching with the criteria. The village list was then endorsed by the concerned General Administrative Department (GAD).

2. Village profiling and formation of FFS committee

Village profiling exercise was organized in each target village using agreed tools/templates. A FFS Committee comprising of 30 members, including a Lead Farmer, has been formed in each target village, either through the formation of new groups or strengthening of existing groups.

The summary of the FFS implemented in three agro-ecological zones is presented in the table below.

Summary of Farmers Field School (FFS) implemented in three agro-ecological zones.

Township	No. of FFS	No. of Villages	No. of HHs	Crops	Remarks
Upland/Hill Zone of Chin State					
Mindat	10	10	300	Elephant Foot Yam, Coffee and Avocado will be grown intercropping on the same demo plot	Silver oak planted as wind break
Kanpetlet	10	10	300		
Total	**20**	**20**	**600**		
Central Dry Zone of Mandalay Region					
Nyaung-U	4	4	120	**Rainfed area:**Groundnut + Pigeon pea + Green gram (July)	The crops will be grown with Shaw-byu *(Sterculia versicolor)* as agro-forestry. Saplings of multipurpose-*Gliricidiasepium*will also be planted as windbreaks.
	4	4	120	**Irrigated area:** Chick pea (Nov) – Green gram (Feb)	
	2	2	60	**Irrigated area:** Winter groundnut (Nov) – Green gram (Feb)	
Sub-total	***10***	***10***	***300***		
Kyaukpadaung	10	10	300	Pigeon Pea + Mid monsoon Groundnut (July)	
Sub-total	***10***	***10***	***300***		
Total	**20**	**20**	**600**		
Coastal/Delta Areas of Labutta Township of Ayeyarwady Region					
Labutta	9	9	270	Monsoon Paddy – Green Gram	
	6	6	180	Monsoon Paddy	
Total	**15**	**15**	**450**		
Grand Total	**55**	**55**	**1,650**		

3. Establishment and operationalization of FFS.

A FFS has been established in each target village where a demonstration plot has been established with the improved CSA technologies/ practices in a selected Lead Farmers' field to compare current practices with improved/ alternative practices recommended in the FFS curriculum. Regular FFS (trainings/meetings) are organized as per the agreed FFS Module.

While the assigned DoA staffs from the respective Township are responsible for conducting regular FFS training/meeting as Facilitators and taking part in other related activities, the Service Providers are responsible for finalization of target villages, beneficiary selection, FFS Committee formation, village profiling, procurement and distribution of necessary inputs, coordinating FFS training/meetings, monitoring and reporting.

Farmer Field Day Events in Dry Zone for FFS on Chickpea

5. Conclusion

The project facilitates the adoption of CSA policies and practices that will help to sustainably increase productivity and income, enhance resilience (adaptation) and reduce/remove GHGs (mitigation). The project has also supported establishment of a National CSA Center, FFS curriculum development, academic courses and CSA training curriculum development, establishment of FFS and is supporting the capacity building efforts at various level on climate-smart agriculture, sustainable land management and sustainable forest management techniques and practices.

It is expected that through the adoption of such techniques and practices, that are more resilient to climatic trends and changes, production can be sustainably increased, and achievement of national food security and development goals will be enhanced.

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Farmers' practices and understanding of Climate-smart Agriculture in the Pyin Oo Lwin district of Myanmar

San Hla Htwe*

Abstract

Myanmar is an agricultural based country and climate change is a major challenge on agricultural production. Therefore, Myanmar has committed to apply CSA to contribute to regional food security and environmental protection during 24th ASEAN summit. Currently, the information on farmers' agriculture systems and CSA practices are very limited and it needs further assessment. A study was carried out in Pyin Oo Lwin Township to examine the farmers' current agriculture practices, to assess farmers' perception of climate change impact and willingness to adopt CSA. The results indicated that 82.2% of respondents have heard about climate change and of those 79.2% have clearly understood and 46.9% of respondents mentioned that they have intensively practiced changed crop management due to climate change effect. However, only 9.4 % of respondents have heard about the CSA practices, and there were no training and workshop about climate change and CSA in the study area. It can be concluded that further capacity building and knowledge sharing, and demonstration programs on CSA are really needed.

Keywords: perception, willingness, CSA

Introduction

Myanmar is an agricultural-based country and cultivates more than 60 different crops including tropical and temperate varieties. Flooding, uncommon onsets of monsoon season, heavy rain, increasing temperature are common climate events that have been found in the recent years. Moreover, climate change is emerging as a major threat on agricultural production all over the country. Although Myanmar is self-sufficient in food production at national level, there is still food insecurity in some areas, especially in rural area (MOAI, 2015). To achieve food security and agricultural development goals, adaptation to climate change will be necessary (FAO, 2013). Myanmar has committed to apply climate-smart agriculture strategies to contribute to regional food security and environmental protection during the 24th ASEAN summit on May 10, 2014 (MOAI, 2015). Climate-smart agriculture is composed of three main pillars: sustainably increasing agricultural productivity and incomes, adapting and building resilience to climate change, and reducing and/or removing greenhouse gases emissions where possible (FAO, 2013).

CSA has resulted in higher yields and in-

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creased income among smallholder farming household and reduce poverty (Maguza-tembo et al., 2016). However, for farmers to adapt to climate change, rural communities need access to better information, inputs like fertilizer, machinery, seeds, and to well-functioning output markets, and linking farmers to new sources of information on climate change will be important (FAO, 2012). Climate-smart agriculture interventions are location specific and to a large extent their adoption needs to be well-suited to the farmers in terms of willingness, ability to practices, knowledge and their investment capacity (Taneja et al., 2014). In Myanmar, due to very limited information related to the agricultural practices and CSA, it is needed to assess further the current farmers' agricultural practices. This study examines the farmers' current agricultural practices and assess the perception of climate change impacts and their willingness to adopt CSA in the flower city of Myanmar, Pwin Oo Lwin.

Materials and Method

Study Area

The study was conducted in Pyin Oo Lwin Township, Pyin Oo Lwin district. The study has different landscapes and various crops are being cultivated such as rice, wheat, maize, coffee, avocado, vegetables and flowers. The area is famous not only in horticultural crops production but also for flowers because of that it is well known as the flower city. The study area is characterized by mountainous and undulating topography with an altitude of 1169 m above sea level. The mean annual rainfall is 1484 mm, mean annual temperature ranges from 14 to 27 °C and mean relative humidity percent is 78%. The study area was selected based on the representativeness in terms of biophysical characteristics, accessibility of the areas, socio-economic activities and diversity of crop cultivation.

Data collection and analysis

Data for this study was collected from 64 randomly selected households in the 5 villages namely: Wetwon, Nyaungthayar, Mogyo, Anisakhan, and Kywalnahtaut. A structured questionnaire was administered to collect information on farmers' perception of climate change and variability impact, current agricultural practices, perception of CSA and, whether there was trainings and workshops on climate change and CSA conducted in the rea or not. Moreover, focus group discussions about CSA were conducted with the farmers and some additional data on willingness to practice CSA was collected. Descriptive statistics were used for comparison purpose on variables of interest to explain the phenomenon.

Results and Discussion

Awareness of climate change

The result indicates that 82.8% of respondents have heard of climate change from different sources and the remaining 17.2% of respondents have not heard about climate change (Figure 1).

The respondents were asked about the understanding of climate change. It was revealed that hearing about climate change does not

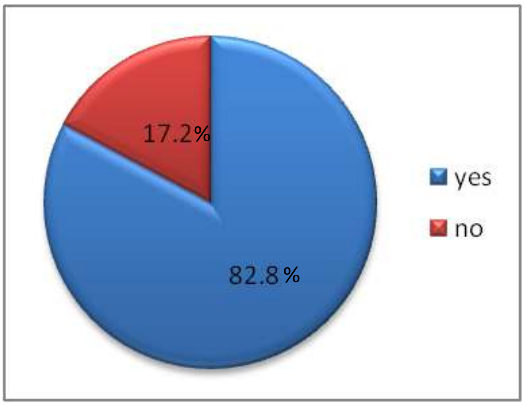

Figure 1. Proportion of respondents that hearing about climate change.

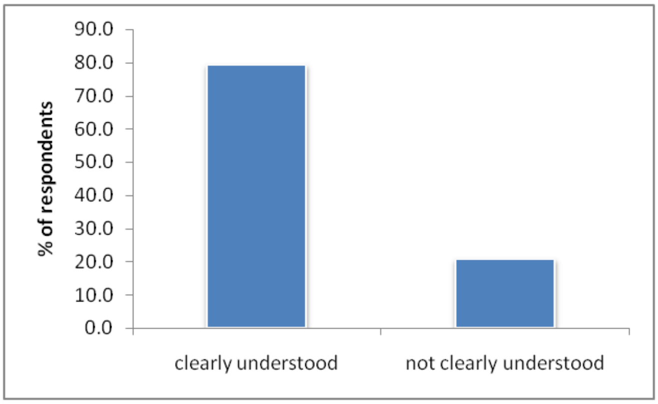

Figure 2. Understanding of the respondents about climate change

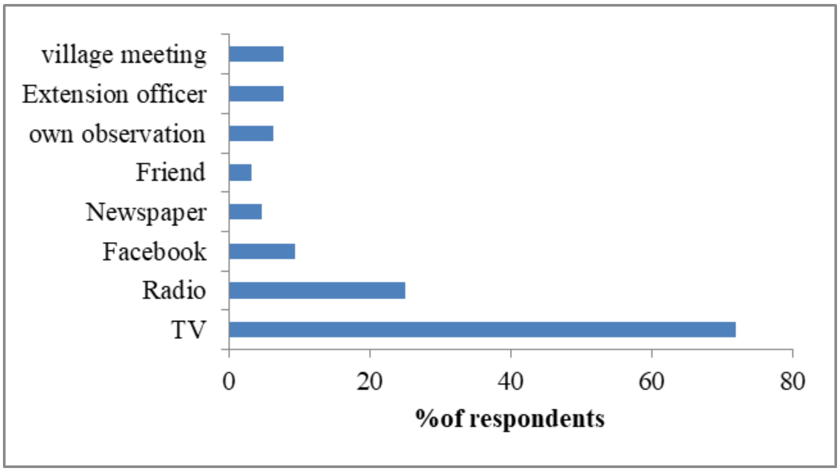

Figure3. Sources of climate change information

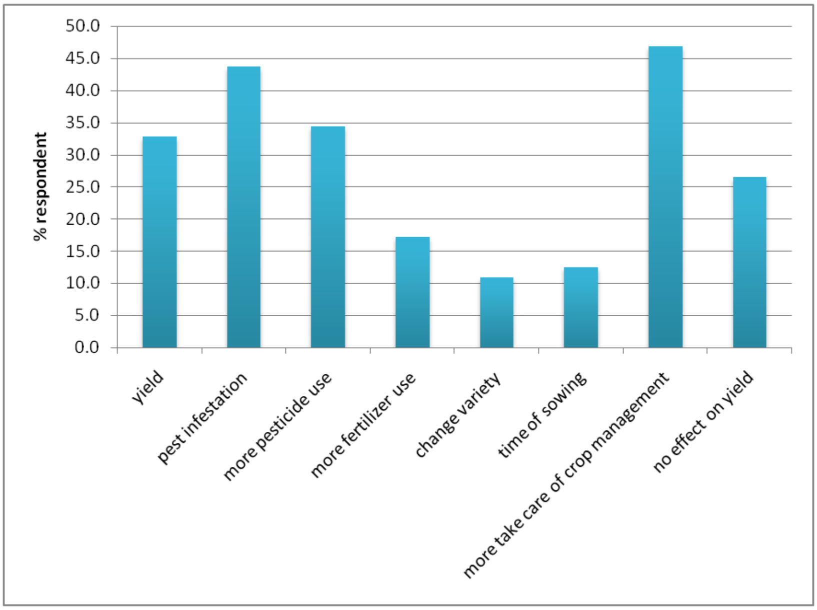

Figure 4. Proportion of respondents that notice on the impact of climate change

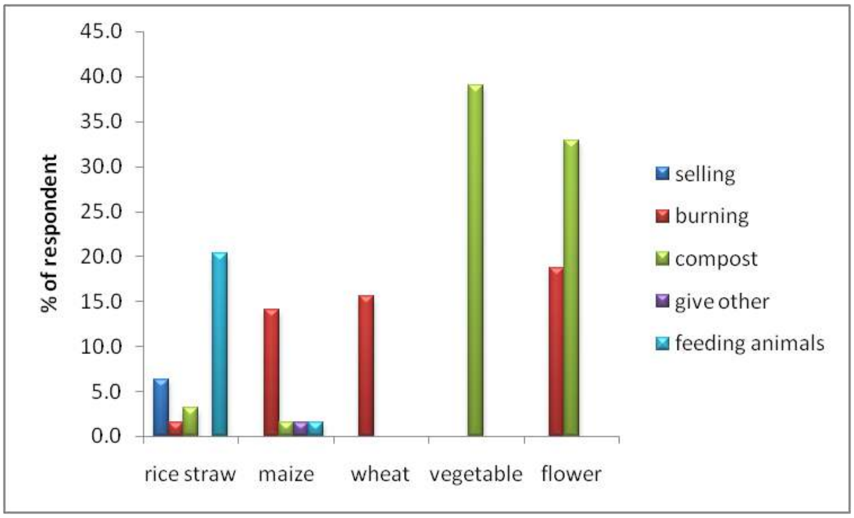

Figure 5. Proportion of respondents that showing the different crop residues management

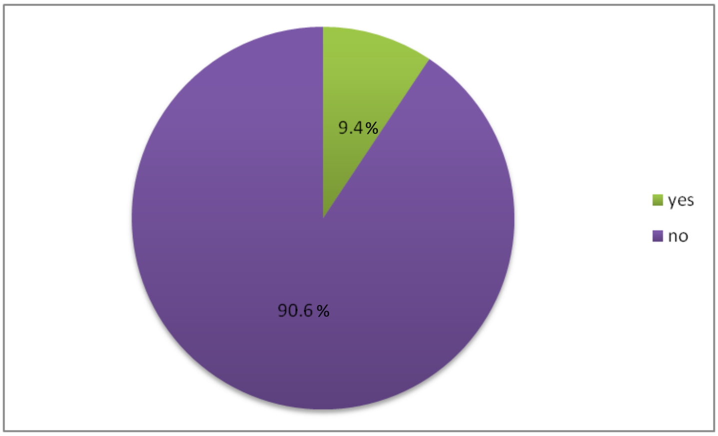

Figure 6. Proportion of respondents' perception about CSA

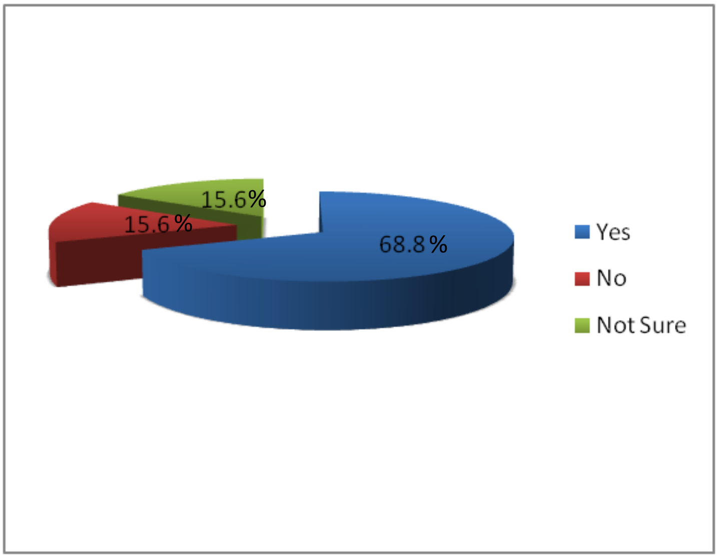

Figure 7. Proportion of respondents willing to practice CSA

mean the farmers have clearly understood about the climate change. The study showed that not all of the respondents who have heard about climate change clearly understand about it, only 79.2 % were clearly known about climate change but the remaining were not clear about this (Figure 2).

In the study area, the respondents received the information of the weather and climate through different ways. The main source of information is TV, followed by radio, Facebook, extension officers, village meeting, newspaper, own observation, and friends (Figure 3). The study found that the important dissemination of climate change was TV.

Understanding of climate change effect

Respondents were asked to state whether they have noticed the impact of climate change in their field. Based on the survey, 46.9 % of respondents stated that they are taking more care of crop management because of the climate change effect. Moreover, 43.6 % of respondent reported that the pest infestation is more prominent problem in the current years and consequently they have to use more pesticide in their farm. Furthermore, 17.6% of the farmers said that they have used more amount of fertilizer than before. Some of respondents stated that they changed the time of sowing and variety. On the other hand, 26.6% of respondents said that nothing changes on the yield by the effect of climate change if they manage the field properly and do farming effectively.

Farmers' Current Agriculture Practices

The study found that farmers have adopted various agricultural practices mainly to increase crop production, improve household income, and enhance food security. Some of the farmers are implementing the practices like use of compost for improvement of soil fertility, burning for cleaning the farm and protecting the pests and diseases. Irrigation is the most common practices and used for long times and use of crop rotation as well. In the case of crop residue management in the survey, as shown in figure.5, 20.3% of respondents stated that rice straw was used as animal feeding, followed by selling (6.3%), compost (3.1%), burning (1.6%). Moreover, the study found that 14.1% of respondents have burned the residues of maize and 15.6% of respondents have burned the residues of wheat as well. Furthermore, the residues of vegetables are used o make compost by 39.1% of farmers. Similarly, the flowers byproducts are also used to make compost by 32.8% of respondents.

However, 18.8% of respondents have burned the byproducts of flowers.

Understanding of CSA

The respondents were asked to state whether they have heard about CSA. The result showed that only 9.4% of respondents have heard about CSA from TV and the remaining 90.6 % of respondents have not heard about it (Figure 5). Aside from that, the farmers who heard about CSA were not sure that they know it clearly. They mentioned about CSA is only selecting the suitable crops and variety according to the season.

Based on the discussion with farmers about CSA, the farmers were asked to mention whether they have willingness to practice CSA or not. The results pointed out that 68.8 % of farmers want to practice and the remaining do not want to implement it (Figure 7). The reasons for adopting CSA are to increase income and yield, to get new technologies, and to do their farming systematically aiming to receive more benefit. The farmers who do not want to practice the CSA gave the reasons such as they want to do normal and they want to see the success story of others first. Some farmers stated that they are hiring land from others to cultivate so that they don't want to invest in new technologies for climate change adaptation.

In addition, it was found that there are no training and workshop conducted in the past on climate change and CSA in the study areas.

Conclusion

This study has indicated that most of the respondents are known about the climate change, they have awareness of climate change impact, and want to overcome the adverse effect of climate change by systematic implementation of agricultural practices. Most of the farmers did not know about CSA practices although they have been practicing some CSA practices without knowing. It is also found that the major media to receive information for the farmers is TV. To improve farmers' knowledge and upgrade the current agricultural systems, it is important to make capacity building and knowledge sharing workshop/trainings and to conduct demonstration programs on CSA.

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Methane emission from different rice fields as affected by Water Management

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Abstract

Rice is an essential crop in Myanmar. Methane (CH_4) emission from rice fields are believed to contribute to the greenhouse effect. The objectives of this study were: (1) to investigate the effect of methane emission from different rice fields and (2) to develop an effective environmental friendly water management technology. Field experiments were conducted in Water Utilization Research Section, Department of Agricultural Research (DAR) at Yezin, Naypyitaw, Myanmar. In the research study, closed chamber method was used. By employing transparent chamber, methane gas was sampled from three paddy fields with different irrigation methods. The methane gas samples were collected at the rice fields and analyzed the concentrations by Gas Chromatography (GC plus). Three rice fields with water saving irrigation method effectively reduced 16-20% of methane emission compare to the flooding irrigation method. Alternate wetting and drying could save irrigation water by 25-30 % without significant yield loss as compared to farmer practices. Among the different rice varieties, methane emission from Sinthukha rice field was higher than Theehtatyin and Shwethweyin because of their crop duration. Increasing trend of methane emission was observed from each paddy field from the tillering stage till flowering stage of paddy. There was no interaction effect on plant height, tillers per hill, SPAD meter reading, biomass weight, panicle length, yield and yield components and water use efficiency between water regimes and rice varieties. The results demonstrated that methane emission rate from non-flooded with the water saving irrigation method was found relatively low compared to the flooded field.

Keywords; methane emission, water management, grain yield

Introduction

Rice fields are the major contributors to the increasing atmospheric methane (CH_4) concentration, because of the general upward trend of the area under rice production to meet the food demand of the increasing world population. (Dlugokencky et al., 1994)

Yan et al., (2009) mentioned that paddy fields are a major source of agricultural methane emission, contributing about 20-40 Tg CH_4 year^{-1} and thus accounting for nearly

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20% of anthropogenic global methane emissions.

Global warming was one of the several challenges for humanity in this Century, CO2 and CH4 are the most important GHGs, which contribute 76 and 16 % to the anthropogenic GHG effect, respectively. (IPCC 2014)

Water management has been recognized as one of the most important practices that affect methane emission from paddy field. Conventional irrigation of rice field requires the consumption of large amount of water. The development of efficient irrigation water management practices such as water saving irrigation method may reduce methane emission from paddy fields.

Moreover, due to the scarcity of freshwater resources available for irrigated agriculture and escalating food demand around the world in the future, it will be necessary to produce more food with minimum water usage.

Besides, Butterbach-Bahl et al., (1997) studied that lower emission levels for the improved high yielding varieties compared to the traditional cultivars which exhibited profuse vegetative growth link with the enhancement of GHG emissions. In addition, there is a need to verify about methane emission from different rice field as affected by water management.

The objectives of this study were: (1) to investigate the effect of water management on methane emissions from different rice fields and (2) to develop an effective environmentally friendly water management technology.

Materials and methods

Soil and treatments

In 2017–2018 wet season, the experiment was established on a sandy loam soil in Water Utilization Research Section at Department of Agri-

Table 1. Effect of water regimes and rice varieties on plant height, tillers/hill and SPAD meter reading

Variety	Plant height (cm)			Tillers/hill			SPAD meter reading		
	AWD	CF	Mean	AWD	CF	Mean	AWD	CF	Mean
Shwethweyin	105.25	104.50	**104.88**	18.00	16.25	**17.13**	40.38	38.98	**39.68**
Theehtatyin	124.19	124.38	**124.29**	9.75	11.00	**10.38**	32.63	30.75	**31.69**
Sinthukha	147.49	143.38	**145.44**	10.69	11.69	**11.19**	35.48	32.23	**33.85**
Mean	**125.6**	**124.1**	**-**	**12.81**	**13.98**	**-**	**36.16**	**33.98**	**-**
F-test	**Water regime**		**ns**			**ns**			**ns**
	Variety		**1 %**			**1 %**			**1 %**
	WR * V		**ns**			**ns**			**ns**
CV %	**Water regime**		**2.55**			**13.23**			**11.43**
	Variety		**3.3**			**16.1**			**8.2**
LSD 0.05	**Water regime**		**-**			**-**			**-**
	Variety		**3.52**			**1.78**			**2.48**
	WR * V		**-**			**-**			**-**

cultural Research (DAR), which is located at Yezin, Nay Pyi Taw, Myanmar (19˚ 38' N, 96˚ 50 'E) . The soil properties from (0-15 cm depth) of the experimental site were: pH (7.37), organic matter (1.51 %), available N (21.8 mg/ kg), available P (20.0mg/kg) , available K (95.3 mg/kg) and EC (0.95 dS/m).Two water treatments, namely continuous flooding and alternate wetting and drying (AWD) were used as main plot factor and types of variety Shwethweyin, Theehtatyin and Sinthukha were used as the sub plots. Experimental design was split plot design with three replications.

Install close chamber

The close chamber with glass were placed with a distance of 5 m at random in each treatment. Eighteen glass chambers were designed to collect the methane gas in each treatment and each chamber was equipped with one thermometer and a small fan. Before the gas sampling was started, temperature of air was recorded using the thermometer placed in the chamber. The temperature recorded throughout the experiment was used for methane flux calculation. Methane in the chamber was collected by micro liter syringe once a week in the mid-morning and put in the 50 ml glass bottle which was cleaned without air.

Measurement of methane emission and calculation

Methane gas samplings were prepared in 50 ml glass bottle and the methane concentration was measured with a Gas Chromatography (GC 2010 plus series) from Japan.

According to IPCC 2014 Guide line, the methane flux was calculated based on linear changes in methane concentration during the sampling period, as the following equation,

Table 2. Effect of water regimes and rice varieties on biomass weight, panicles/hill and panicle length

Variety	Biomass weight (g)			Panicles/hill			Panicle length (cm)		
	AWD	CF	Mean	AWD	CF	Mean	AWD	CF	Mean
Shwethweyin	64.21	61.33	**62.77**	17.92	17.50	**17.71**	23.48	24.42	**23.95**
Theehtatyin	64.82	58.00	**61.41**	8.25	10.50	**9.37**	26.19	25.95	**26.07**
Sinthukha	82.99	75.72	**79.35**	9.75	12.17	**10.96**	25.29	23.99	**24.64**
Mean	**70.67**	**65.01**	-	**11.97**	**13.39**	-	**24.99**	**24.78**	-
F-test	**Water regime**		**ns**			**ns**			**ns**
	Variety		**5 %**			**1 %**			**1 %**
	WR * V		**ns**			**ns**			**ns**
CV %	**Water Regime**		**17.7**			**12.2**			**2.4**
	Variety		**16.7**			**16.3**			**4.3**
LSD 0.05	**Water Regime**		**-**			**-**			**-**
	Variety		**7.32**			**2.12**			**1.09**
	WR * V		**-**			**-**			**-**

Table 3. Effect of water regimes and rice varieties on 1000 grain weight, filled grain % and harvest index

Variety	1000 Grain weight (g)			Filled grain %			Harvest index		
	AWD	CF	Mean	AWD	CF	Mean	AWD	CF	Mean
Shwethweyin	17.17	18.37	17.77	70.02	71.87	70.95	0.54	0.59	0.57
Theehtatyin	19.20	19.33	19.27	57.65	55.40	56.53	0.39	0.40	0.40
Sinthukha	18.30	17.97	18.14	66.48	61.57	64.03	0.43	0.39	0.41
Mean	**18.22**	**18.56**	-	**64.72**	**62.94**	-	**0.45**	**0.46**	-
F-test	**Water regime**		**ns**			**5 %**			**ns**
	Variety		**5 %**			**1 %**			**1 %**
	WR * V		**ns**			**ns**			**ns**
CV %	**Water regime**		**5.4**			**6.4**			**9.3**
	Variety		**4.6**			**10.5**			**9.4**
LSD 0.05	**Water regime**		**-**			**5.55**			**-**
	Variety		**0.88**			**7.12**			**0.04**
	WR * V		**-**			**-**			**-**

Flux $CH_4 = \Delta c/\Delta t \times V/A \times \rho \times 273/(273+T)$

Where $\Delta c/\Delta t$ is the concentration change over time (ppm CH_4), V is chamber volume (m3), A is chamber area (m2), ρ is gas density (0.717 kg m3 for CH_4) and T is the mean air temperature inside the chamber (˚C).

Field management

Irrigation management

The amount of water applied was controlled and recorded using a volume meter. Water depth was measured using a field water tube. During one week before and after peak at the flowering stage, Alternate Wetting and Drying (AWD6) means the standard AWD and re-irrigated again when water level reach under 6 inches from the soil surface) were suspended and water depth was maintained 3-5 cm. The plots were re–irrigate when water level reaches 6-inch depth in the soil. 10 days before harvest, no irrigation water was applied in all the experimental plots to enable the rice plants to mature and soil to harden for harvesting.

Fertilization

Fertilizer was applied at the rate of 112 lb/ac Urea, 56 lb/ac T super and 56 lb/ac Muriate of potash. Nitrogen from Urea was applied three times in equal splits, Phosphorus from Triple super phosphate and Potassium from Muriate of potash were applied in two equal splits, and fertilizer was applied by side dressing in the rows.

Weed control

Weeds were controlled by manual weeding as required to keep the field clean.

Table 4. Effect of water regimes and rice varieties on yield, total water use, water use efficiency

Variety	Yield (t/ha)			Total water use (mm)			Water use efficiency (g/l)		
	CF	AWD	Mean	CF	AWD	Mean	CF	AWD	Mean
Shwethweyin	6.52	7.05	6.78	719.00	519.00	619.00	0.72	1.11	0.92
Theehtatyin	4.30	5.46	4.88	930.20	730.20	830.20	0.43	0.62	0.52
Sinthukha	5.80	5.83	5.81	1322.20	1022.20	1172.20	0.42	0.55	0.48
Mean	**5.54**	**6.11**	-	**990.47**	**757.133**	-	**0.52**	**0.76**	-
F-test	**Water regime**		**ns**			**-**			**5 %**
	Variety		**5 %**			**-**			**1 %**
	WR * V		**ns**			**-**			**ns**
CV %	**Water regime**		**15.8**			**-**			**16.9**
	Variety		**20.6**			**-**			**21.5**
LSD 0.05	**Water regime**		**-**			**-**			**0.22**
	Variety		**1.59**			**-**			**0.18**
	WR * V		**-**			**-**			

Table 5. Effect of different water regimes and rice varieties upon the methane emission

Variety	Flux of CH_4 (mg CH_4 $m^{-2}h^{-1}$)			Flux of CH_4 (mg CH_4 $m^{-2}h^{-1}$) (one acre)		
	CF	AWD	Mean	CF	AWD	Mean
Shwethweyin	0.131	0.092	0.112	530.14	372.31	**451.22**
Theehtatyin	0.147	0.095	0.121	594.89	384.45	**489.67**
Sinthukha	0.188	0.153	0.186	760.81	619.17	**689.99**
Mean	**0.155**	**0.113**	**-**	**628.61**	**458.64**	**-**

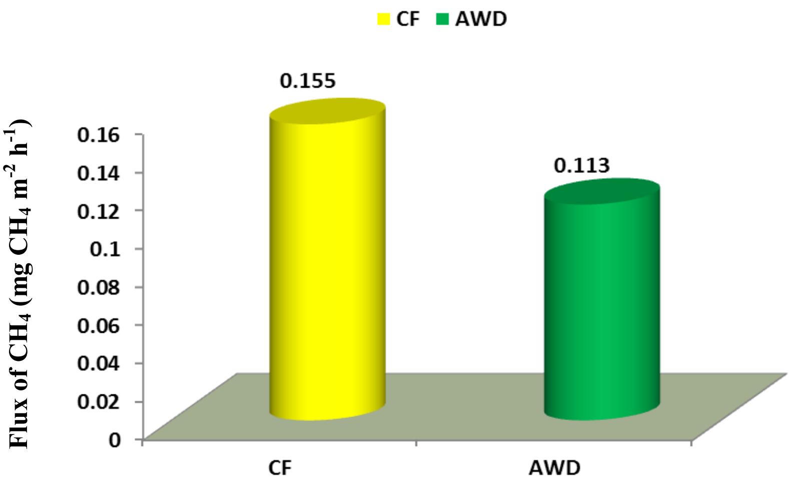

Figure 1. Methane flux of different water regimes

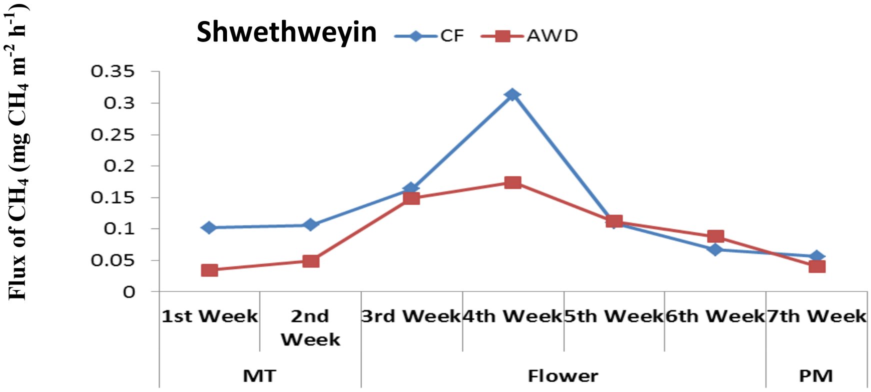

Figure 2. Observed and simulated CH_4 emission at growth stage of Shwethweyin

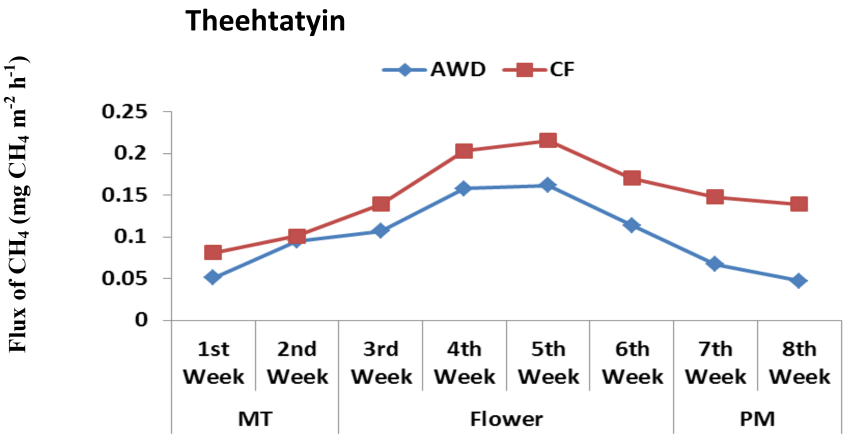

Figure 3. Observed and simulated CH_4 emission at growth stage of Theehtatyin

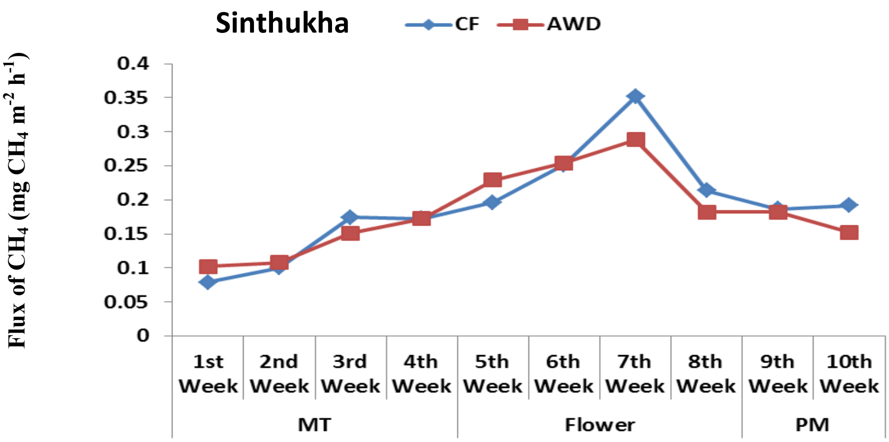

Figure 4. Observed and simulated CH_4 emission at growth stage of Sinthukha

Crop protection

The experiment was monitored daily for pest and disease incidence. Cypermethrin was applied twice for the control of Brown plant hopper, Green leaf hopper, Leaf folder and White fly during early stage.

Harvesting

Harvesting was done when 80-85 % of the grains in the panicle were brown or straw colored. Rice plants were cut at the ground surface. All grains were threshed and sun dried for two to three days, weighed and the moisture content determined with a moisture meter.

Plant sampling

In 2017—2018 wet season, the data on yield and yield component characters were collected at three random positions in each plot using a 2m x 3m frame. Some of parameters such as yield and yield components characters, plant height, SPAD meter reading, biomass weight, harvest index, total water use and water use efficiency were collected.

Statistical analysis of data

Crop Stat (Version 7.2) was used for statistical analysis and treatment means were compared by using Least Significant Difference (LSD) test at 5 % level of significance (Gomez and Gomez, 1984).

Results and discussion

In 2017—2018 wet season, plant height, tillers per hill and SPAD meter reading were not influenced by water regimes but highly significant influenced by rice varieties at physiological maturity stage. There was no interaction effect of plant height, tillers per hill and SPAD meter reading between water regimes and rice varieties. Among the varieties, Sinthukha had the highest plant height followed by Theehtatyin and Shwethweyin (Table 1). This was also observed by Kumar (2000) when he said that rice varieties were different significantly in terms of growth.

There was no interaction effect on biomass weight, panicle per hill and panicle length between water regimes and rice varieties. Biomass weight was significantly different in rice varieties but not different in water regimes. And also, panicles per hill and panicle length were highly significantly different in rice varieties. Among the tested varieties, Theehtatyin was the highest panicle length (26.07 cm) which is due to genetic variation (Table 2).

Based on the result, yield component characters of 1000 grain weight, and harvest index were not significantly different in water regimes except fill grain % but significantly different in rice varieties. Table 3 showed that significantly higher percentage of filled grains was produced by Shwethweyin with a mean of 70.95 % than Sinthukha and Theehtatyin with mean of 64.03% and 56.53% respectively. The low percent filled grain can be attributed to the prevailing climatic condition such as high temperature and low relative humidity, both of which cause spikelet sterility. According to Yoshida (1981), one more of temperature exceeding 35 ˚C at anthesis can cause high percentage of sterility.

Grain of Theethatyin, with an average weight of 19.27 g per thousand grain was found to be significantly heavier than the grains of the other varieties. Yoshida (1981) has said that 1000 grain weight is a stable varietal characteristic. The differences in grain weight obtained in this study reflect varietal difference.

Independent influence of variety showed that the harvest index of Shwethweyin with a mean of 0.57 was significantly higher than that of the other varieties. Bouman et al., (2005) mentioned that the high harvest index compensated for the short growth duration of the varieties that increased their yield. There was no interaction effect of these parameters between water regimes and different rice varieties. (Table 3)

Grain yield was significantly influenced by rice varieties but not influenced by water regimes. Within the tested varieties, Shwethweyin obtained the highest yields with an average of 6.78 t/ha. There was no interaction effect between water regimes and rice varieties on grain yield.

Among the water treatments, AWD irrigation method could save 25-30% water than farmer practices. Total water use was the highest in Sinthukha variety and the lowest in Shwethweyin variety. There was no interaction effect between water regimes and varieties on water use efficiency. Water use efficiency was significantly different in different varieties and water regimes (Table 4). All pairs of variety means were significantly different with water productivities following the trend Shwethweyin>Theehtatyin>Sinthukha (I am not sure the way of writing is correct. Water Productivity is significantly influenced by variety ranged from 0.92 to 0.48 (g/l).

In this study, during the gas sampling, three paddy fields with water saving irrigation method has effectively reduced 16-20% of methane emission compared to the flooding irrigation paddy fields Fig 1. Similarly, the implementation of water saving irrigation method decreased methane emission rate successfully (Lo.et al., 2016). Among the different rice varieties, methane emission from Sinthukha rice field was higher than Theehtatyin and Shwethweyin because of their longer life (crop duration) periods (Table 5).

Shwethweyin emitted methane starting from transplanting to harvesting stage, peaking at three weeks after transplanting up to the flowering stage (Fig 2). Result showed that a significant CH_4 emission rate was at flowering stage in Theehtatyin (Fig 3). For CH_4 emission from Sinthukha rice varieties, a significant rate was at seventh week after transplanting (Fig 4). The peak of fluxes might be attributed to vigorous growth of rice roots, high air temperature and the interface of soil and water (Wassmann et al., 2000).

Conclusion

Rice cultivars/ varieties are biological means of mitigating GHG emissions from rice cultivation system. Intermitted irrigation is effective in mitigating CH_4 flux in rice crops when climatic conditions enable water absence during cultivation. The conventional irrigation method of rice field could contribute to methane emission significantly. Result showed that, amount of methane emission from long life rice genotype was higher than short life genotypes. Alternate Wetting and Drying system required less water and had higher water use efficiency than farmer practices and saved water and reduced methane emission. It can be concluded that the research on sustainable rice cultivation should be given attention in Myanmar to enhance continuous generation of knowledge and an understanding of the potential methods that can contribute to intensity of rice cultivation and reduce GHG emission.

Recommendation

Further verification study should be done to consider the followings, (1) need to investigate the methane emission from different rice fields as affected by water management (2) need to conduct on different crop establishment methods and cropping systems to investigate methane emission (3) need to investigate the combination impacts of different soil types and fertilizer application forCH_4, CO_2 and N_2O emission to recommend the potential Green House Gas mitigation strategies

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Evaluation of different rates of organic manure and water management practices on methane emission from rice production

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Abstract

To find out water management and organic manures practices to obtain minimum methane emission, the pot experiments were conducted in Si Taing Kan village tract during the summer and rainy season in 2017. Split plot design with three replications was used. Two water management practices and four cow-dung manure rates were allocated in main and sub factor arrangement. IR 50 was planted with twenty-one day-old seedlings. The higher methane emission was recorded in continuous flooding (CF) as compared to alternate wetting and drying (AWD) method.

In summer season, the soil temperature was significantly correlated with methane emission, and the methane production was found in the temperature range of 22.7 – 34.1°C. In this experiment, the methane production was largely correlated with soil redox potential. The methane production was found from 201 - 345 mV. The surface water pH was not significantly correlated with methane emission. Instead, the soil pH was significantly correlated with methane emission. The methanogenesis occurred in the neutralized condition. Higher methane emission was recorded from OM3 and lower methane emission from OM0 in both water management practices. Therefore, according to these findings in field condition, higher manure gave higher methane emission. In alternate wetting and drying, the methane production was restricted in the aerated soil condition although higher amount of cow-dung manure was added. In rainy season, the soil temperature, soil redox potential and surface water pH were not significantly correlated with methane emission. However, the methane production was significantly correlated with soil pH. Higher methane production was recorded from the range of 7.22–7.97 of soil pH. The methane emission was also significantly affected by water management practices. Higher methane emission was recorded from CF over AWD. Higher methane emission was found in OM3 followed by OM1, OM2, and OM0 in summer season and in OM3 followed by OM0, OM1, OM2 in rainy season. In the field condition, the methane emission was affected by soil temperature, soil redox potential, and soil pH.

Keywords: rice, organic manure, water management, methane emission

Introduction

Rice (*Oryza sativa*) is the most important agricultural staple food for more than half of the

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world's population and is grown in 114 countries over a total area of around 153 million ha, which is 11% of the world's arable land (FAO 2011). Rice production must increase by 40% by the end of 2030 to meet rising demand from a growing world population (FAO 2009).

Estimates of global methane emissions from paddy soils range from 31 to 112 Tg yr^{-1}, accounting for up to 19% of total emissions, while 11% of global agricultural N_2O emissions come from rice fields (US-EPA 2006; IPCC 2007). There is an urgent need to reduce GHG emissions to the atmosphere to mitigate the adverse impacts of climate change (Islam et al. 2017). Therefore, appropriate rice production practices will need to be identified and promoted which could lead to increased rice yield and decreased GHG emissions.

The burgeoning population and increasing rice demand in the future have induced tremendous concerns on the stimulation of GHG emissions (Van Beek et al., 2010; Zhang et al., 2011). Therefore, developing technologies and practices to overcome GHG emissions is inevitable for sustainable and productive rice-based systems. In rice fields, the emission of GHGs mainly depends on crop management practices, but changes in management regime also offer possibilities for mitigation. Often a practice may affect more than one gas, by different mechanisms, sometimes antagonistically, so that the net benefits depend on the integrated effects of that practice on all gases (Schils et al., 2005).

Methane is the dominant GHG emitted from paddy fields in terms of global warming potential (GWP). It is an end product of organic matter decomposition under anaerobic soil conditions (Conrad, 2002; Linquist et al., 2012). Therefore, the two strategies most often proposed to reduce CH_4 emissions are: to limit the period of soil submergence (i.e. draining the field) and reduce carbon inputs (through residue management). Several field studies have shown that the drainage of wetland rice once or several times during the growing season effectively reduces CH_4 emissions (Wassmann et al., 1993; Yagi et al., 1997; Lu et al., 2000; Towprayoon et al., 2005; Itoh et al., 2011).

With respect to residue management, according to the International Rice Research Institute (IRRI), about 620 million tons of rice straw are produced annually in Asia alone and this quantity is increasing every year (IRRI, 2016). Additional reported benefits include the reduction of ineffective tillers, the removal of toxic substances and the prevention of root rot, leading to increased yields and reduced water use (Zou et al., 2005; Itoh et al., 2011). The objectives of this study were to evaluate the performance of rice plant as affected by different rates of organic manure and water management practices and thereby to find out the suitable rate of organic manure and water management practice on methane emission.

Materials and methods

The field experiment was conducted at farmer's field in Si Taing Kan village tract during the summer and rainy season, 2017. The experimental plots were arranged in split plot design with three replications. The water management practices: continuous flooding (CF) and alternate wetting and drying (AWD) were used as main factor. Sub factor was application of different rates of organic manure. The cow-dung manure was assigned to four levels: OM0 (no cow-dung), OM1 (half of recommended cow-dung manure), OM2 (recommended cow-dung manure) and OM3 (one and half of recommended cow-dung manure). The recommended cow-dung manure is 5 t ha^{-1} (4 cart load ac^{-1}). The experimental soil and cow-dung manure were analyzed at Water Science Section, Water Utilization and Agricultural Engineering Division, Department of Agricultural Research (DAR) (Appendix I). The meteorological data for the study period (February to October) are shown in Appendix II.

Treatment application

The calculated cow-dung manure according to treatments (OM0 = no cow-dung, OM1 = half of recommended cow-dung (2.5 tons ha^{-1}), OM2 = recommended cow-dung (5 tons ha^{-1}) and OM3 = one and half of recommended cow-dung (7.5 tons ha^{-1}) were applied at seven days before transplanting. The recommended cow-dung manure is 5 t ha^{-1} (4 cart load ac^{-1}). Each pot received the recommended fertilizer at the rates of 86.8 kg N ha^{-1}, 30.2 kg P2O5 ha^{-1}, 18.9 kg K2O ha^{-1}. Urea, T-super and Potash were used as nutrient element sources. Urea was applied as three equal splits at active tillering, panicle initiation and heading growth stages. T-super was applied only as basal at one day before transplanting and potash fertilizer was used for two equal splits at basal and panicle initiation.

Field water tubes were installed in the AWD plots at a depth of 15 cm below the soil surface in between the seedlings and base just after transplanting. For AWD pots, whenever there was no water in the field tube, irrigation water was applied until 5 cm depth above the soil surface. The irritation interval ranged from 4 to 9 days and the amount ranged from 7 to 13 liters depending on the different rates of cow-dung manure in AWD plots. Withdrawal of water was started one week before the harvest period in all water treated plots.

Data collection

Soil parameters

Surface water pH was recorded by using pH meter (HI8314, Hanna, Japan). Redox potential was taken by ORP meter (HI8314 Hanna, Japan) with probes. Soil temperature was collected with waterproof digital thermometer (CT-300WP, Tokyo, Japan). These parameters were recorded along with gas sampling time. Soil (15 g) was taken from soil surface of each pot for soil pH analysis. Soil pH was analyzed at Department of Agriculture, Madaya using pH meter in 25:1 ratio of deionized water and soil.

Gas sampling and calculation

Just after transplanting, the base was put to the gas sample plant to avoid the disturbance of the environmental conditions around the rice plants during chamber deployment. The base was equipped with a water seal to ensure gas-tight closure. The base remained embedded in the soil throughout the rice growing period. The two-binded chamber of total capacity of 77 L (93 cm height) was used for collecting gas sample. The mouth of closed chamber had diameter of 41 cm. Therefore, the diameter of chamber base is wide to 40 cm with 3 cm wide-water seal. The chamber was painted with white color to prevent the absorption of temperature. To thoroughly mix the gases in the chamber, the chamber was equipped with a small fan of 12-volt DC connected with three 9 -volts dry cells. For CH_4 calculation, temperature was recorded with a digital thermometer (TT-508 Tanita, Tokyo, Japan). For compensation of air pressures between increased temperature and gas sampling, an air buffer bag (1-L Tedlar bag) was attached to chamber. The silicon rubber tube together with the soft vinyl tube (In dia 3mm x out dia 5 mm) attached with double three-way stop corks was inserted air tight to a hole on chamber. The gas sample was taken with airtight 50 ml syringe by inserting it to the three way stop cock. The 50 ml syringe was stroke 5 times for air cleaning before collecting of gas sample. The air inside the chamber was thoroughly mixed by flushing the syringe three times before collection of the gas samples. The gas sample was drawn to the 50 ml volume of syringe through the three way cock from chamber and then transferred to 15 ml vacuum glass vial which were evacuated after adjusting the pressure to the 40 ml volume of syringe.

Methane (CH_4) concentration was analyzed with a gas chromatograph (GC 2014, Shimadzu Corporation, Kyoto, Japan) equipped with a flame ionization detector (FID). The amount of CH4 flux was calculated by using the following equation;

$$Q = (V/A) \times (\Delta c/\Delta t) \times (M/22.4) \times (273/K)$$

Where, Q = the flux of CH_4 gas (mg m^{-2} min^{-1}), V = the volume of chamber (m^3), A = the base area of chamber (m^2), ($\Delta c/\Delta t$) = the increase or decrease rate gas concentration (mg m^{-3}) per unit time (min), M = the molar weight of the gas, K = Kelvin temperature of air temperature inside the chamber

Total emissions were calculated by multiplying the daily gas flux at each measurement for the time interval and summing up the values for the growing period.

Statistical analysis

The data were analyzed by using Statistix (version 8.0). Mean comparisons were done by Least Significant Difference (LSD) at 5% level.

Results and discussion

Soil parameters during the summer season, 2017

Soil temperature: Variation of soil temperature during the rice growing season has been illustrated in Figure 3.1. In the first sampling (8 DAT), the soil temperature was about 28°C and then slightly increased at 14 DAT. After that, it dramatically decreased at 24 DAT, and then increased at 34 DAT. Then it slightly leveled off for about 5 times until 74 DAT. From that, it sharply increased at 84 DAT and a little

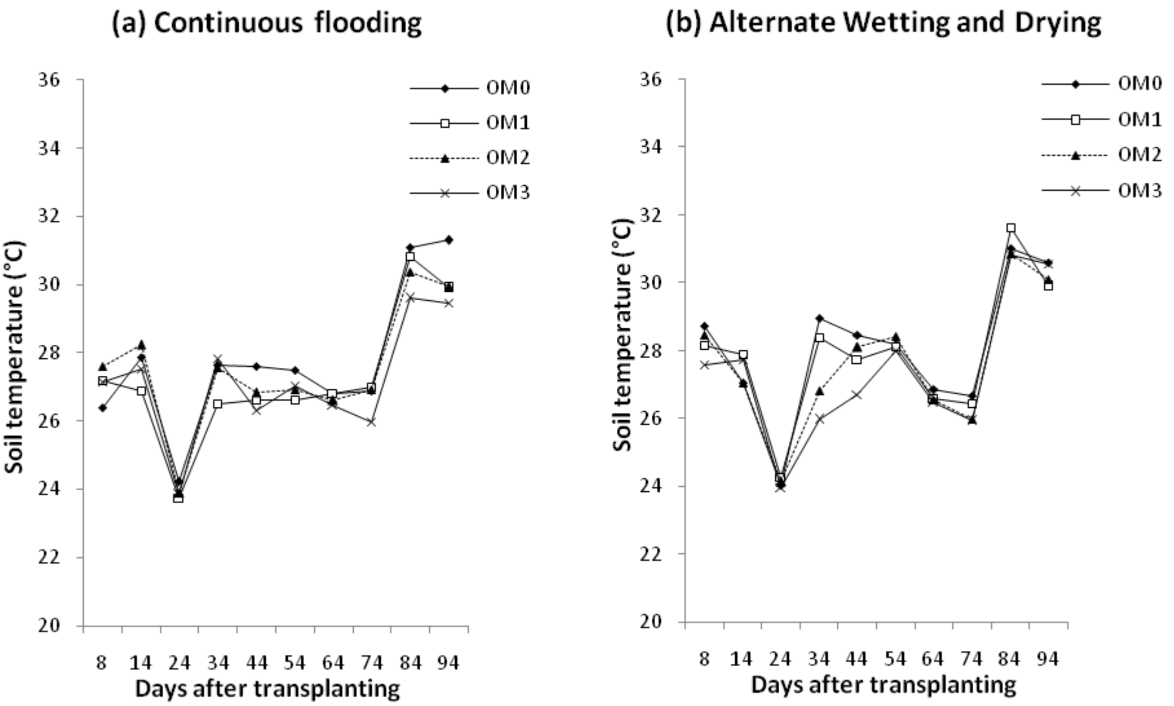

Figure 1. Variation in soil temperature (a) continuous flooding and (b) alternate wetting and drying during the summer season, 2017

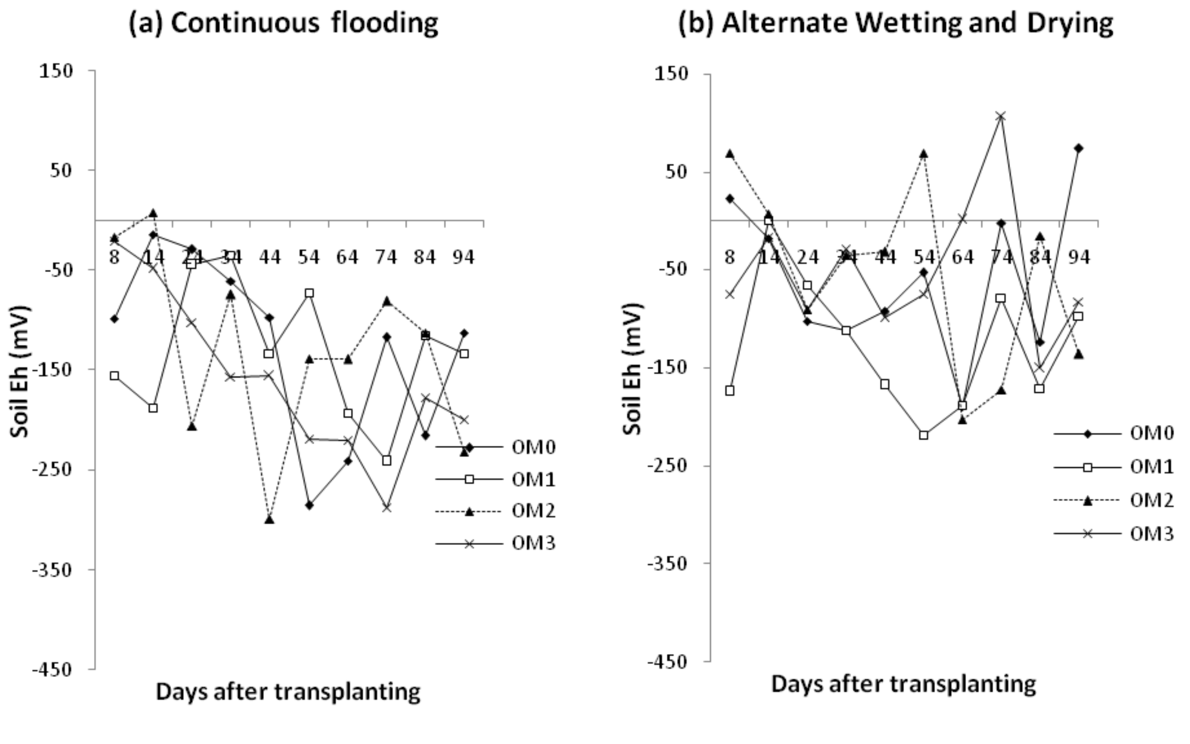

Figure 2. Variation in soil redox potential (Eh) (a) continuous flooding and (b) alternate wetting and drying during the summer season, 2017

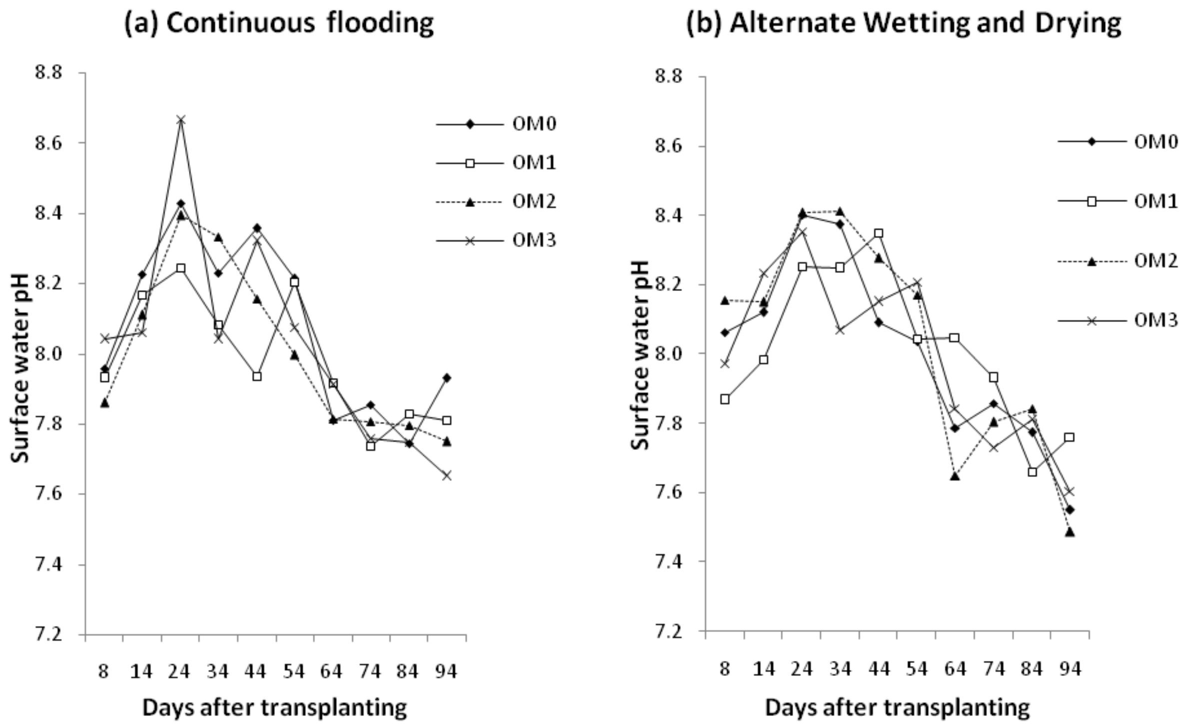

Figure 3. Variation in surface water pH (a) continuous flooding and (b) alternate wetting and drying during the summer season, 2017

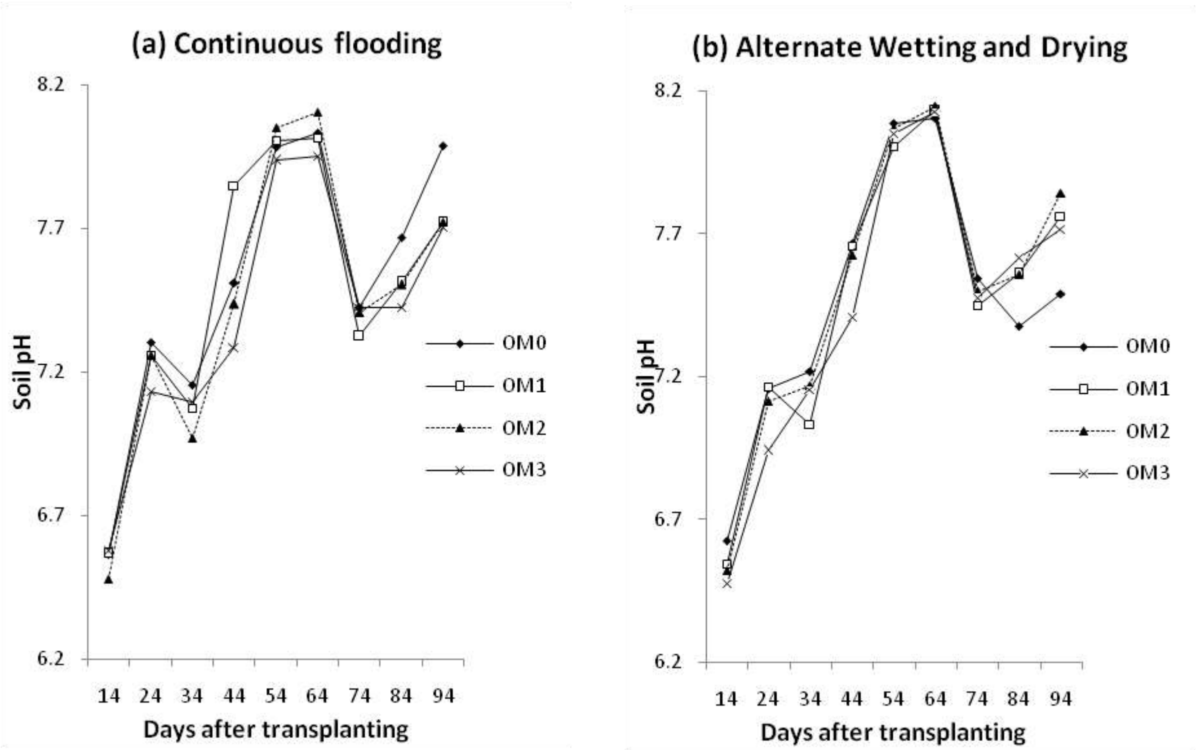

Figure 4. Variation in soil pH (a) continuous flooding and (b) alternate wetting and drying during the summer season, 2017

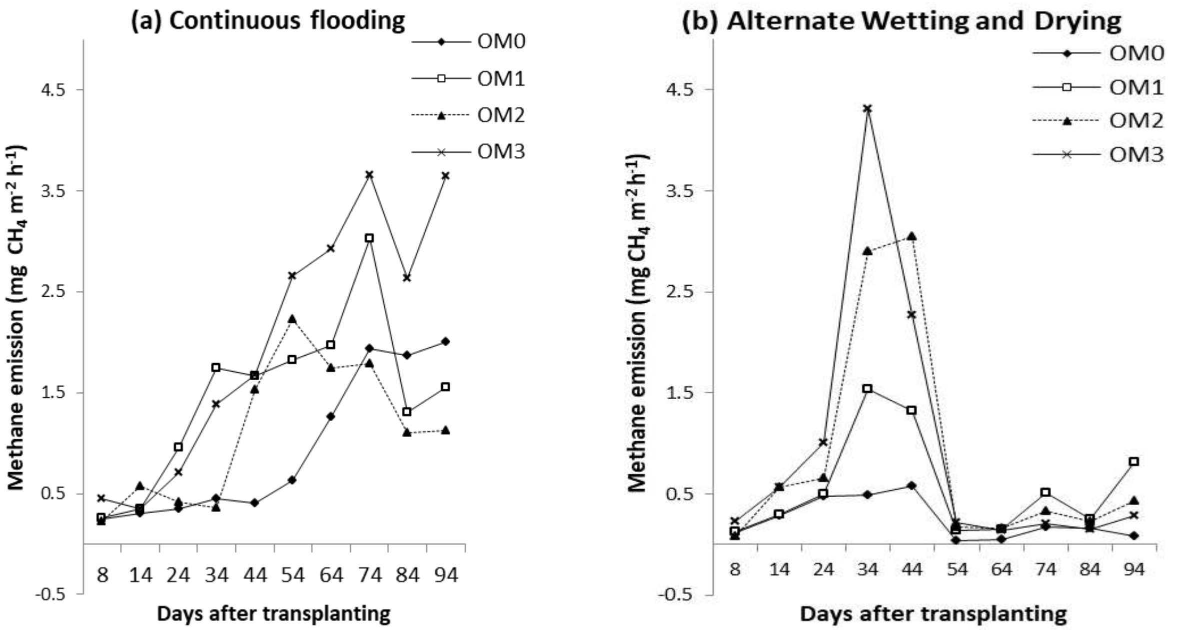

Figure 5. Methane variation of rice (a) continuous flooding and (b) alternate wetting and drying during the summer season, 2017

decreased at the last time sampling (94 DAT). The soil temperature decreased at 24 DAT (maximum tiller stage). This may be affected by soil environmental factors (chemical changes of soil). The high methane emission was observed at 74 and 94 DAT. The temperature ranged from 25.96°C to 27.00°C at 74 DAT, and from 29.47°C to 31.30°C at 94 DAT. The highest soil temperature was recorded from OM0 and the low soil temperature was observed in OM3.

In AWD, the same trend was observed. The peak high methane emission was observed at 34 DAT (in the range of soil temperature, 25.97°C - 28.97°C) and 44 DAT (in the range of soil temperature, 26.70°C – 28.47°C). The highest soil temperature was observed in OM0 and the low soil temperature was resulted from OM3.

The soil temperature ranged from 23.73°C to 31.3°C in continuous flooding and from 23.97°C to 31.63°C in AWD. According to results, the optimum soil temperature for methane production (25.97°C -29.47°C) was observed in continuous flooding and (25.97°C - 26.70°C) in AWD water regime and high methane emission was recorded from OM3 and low methane emission from OM0. From this study, it can also be concluded that soil temperature was influenced not only by water and manure management but also soil physical and chemical properties.

Soil redox potential: Variation of soil redox potential during the rice growing season is stated in Figure 3.2. The different trends were observed for each treatment. It varied throughout the growing season depending on the cow-dung manure management and growth stages. The high methane emission was observed at 74 and 94 DAT. The soil redox potential ranged from -287.00 to -80.67 at 74 DAT, and from -231.33 to -112.67 at 94 DAT. The lowest soil redox potential was recorded from OM3 at 74 DAT and from OM2 at 94 DAT. The soil redox potential depends on the chemical parameters, microbial activity and temperature characteristics of soil (Stein et al. 2007).

In AWD, similarly the different trend of each treatment was observed. But in this AWD water regime, the high positive potential value (oxidation condition) was resulted. The peak level methane emission was observed at 34 DAT (in the range of soil redox potential, -111.67 to - 29.00) and 44 DAT (in the range of soil redox potential, -168.00 to -32.00). The low soil redox potential was observed in OM1 at 34 and 44 DAT.

The soil redox potential ranged from -298.67 to 8.00 in continuous flooding and from -218.67 to 107.67 in AWD. According to results, the high methane production was found in the range of Eh (-287.00 to -231.33) in continuous flooding and in the range of -29.00 to -32.00 in AWD water regime. The high methane emission was recorded from OM3 and low methane emission from OM0. From this study, it can also be concluded that the methane production was found in the high soil redox potential in alternate wetting and drying. Zoltan (2008) has stated that fluctuation in Eh have abiotic as well as biotic origin, and differences in water regime is one of the most important abiotic factors for Eh variations across different ecotopes.

Surface water pH: The variation of surface water pH during the rice growing season has been shown in Figure 3.3. In continuous flooding, the surface water pH was observed the higher values in the early growth stages than later growth stages. It may be due to the decomposition of organic manures. Generally the surface water pH was not influenced by water and organic manure application in the field study. It is more or less consistent in the flooded condition. The surface water pH ranged from 7.65 to 8.67. The highest surface pH level was recorded from OM0 and the low pH was observed in OM3 and OM1.

In AWD, the same trend of surface water pH was observed. The surface water pH ranged from 7.48 to 8.41. The highest surface pH was recorded from OM1 and OM2. The lowest level of surface pH was observed in OM1.

In this study, the surface water pH did not significantly affect on methane emission and it was not affected by water and manure management. The surface water pH did not change significantly due to cattle manure application (Oo et al. 2016).

Soil pH: The variation of soil pH during the rice growing season was observed in Figure 3.4. The start-up decreased soil pH value was found. This may be due to the effect of cold temperature (Appendix II). But in the succeeding sampling, the increased soil pH trend was recorded until 64 DAT. And then the soil pH was slightly decreased at 74 DAT (in the leaf senescence). From that, it slightly increased in the harvesting period because of soil microbial

Table 1. Mean effects of water and cow-dung manure applied on cumulative methane emission of rice during the summer season, 2017

Treatment	Cumulative methane emission (kg CH_4 ha^{-1})
Water	
CF	30.28 a
AWD	15.01 b
LSD $_{0.05}$	5.62
Manure	
OM_0 (0 t ha^{-1})	12.97 b
OM_1(2.5 t ha^{-1})	22.84 ab
OM_2(5 t ha^{-1})	21.89 ab
OM_3(7.5 t ha^{-1})	32.89 a
LSD $_{0.05}$	18.59
Pr>F	
Water	0.0072
Manure	0.1966
Water x Manure	0.7161
CV_a (%)	14.14
CV_b (%)	65.26

Means followed by the same letter are not significantly different at 5% LSD.

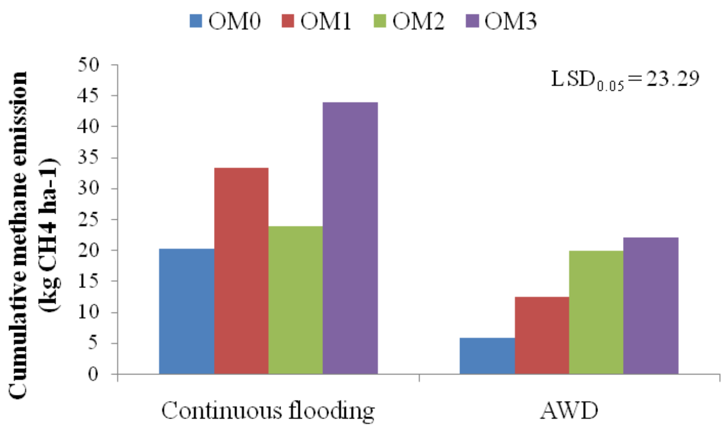

Figure 6. Mean values of cumulative methane emission of rice as affected by water and cow-dung manure applied during the summer season, 2017

Table 2. Relationship between methane emission and soil parameters during the summer season, 2017

	ST	EH	SWPH	SPH
CH_4	-0.6593**	-0.6695**	-0.0458^{ns}	-0.5665**

CH_4 – Cumulative methane emission (kg ha^{-1}), ST – Average soil temperature (°C)EH – Average soil redox potential (mV), SWPH – Average surface water pH SPH – Average soil pH

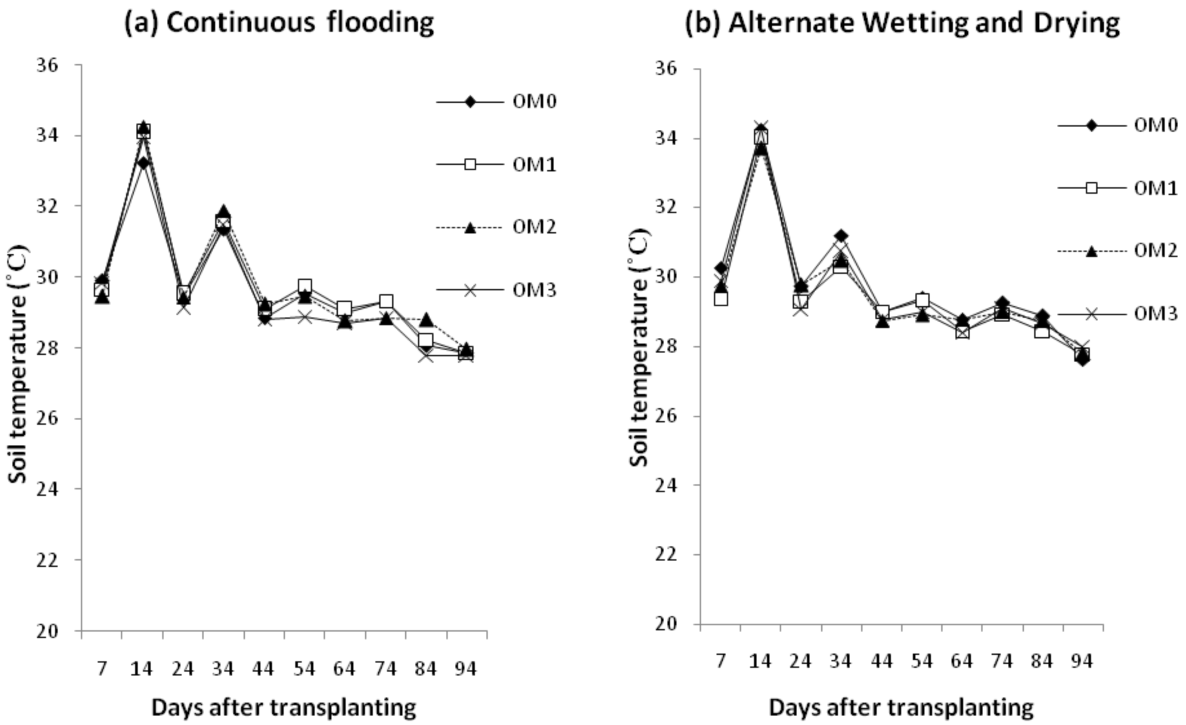

Figure 7. Variation in soil temperature (a) continuous flooding and (b) alternate wetting and drying during the rainy season, 2017

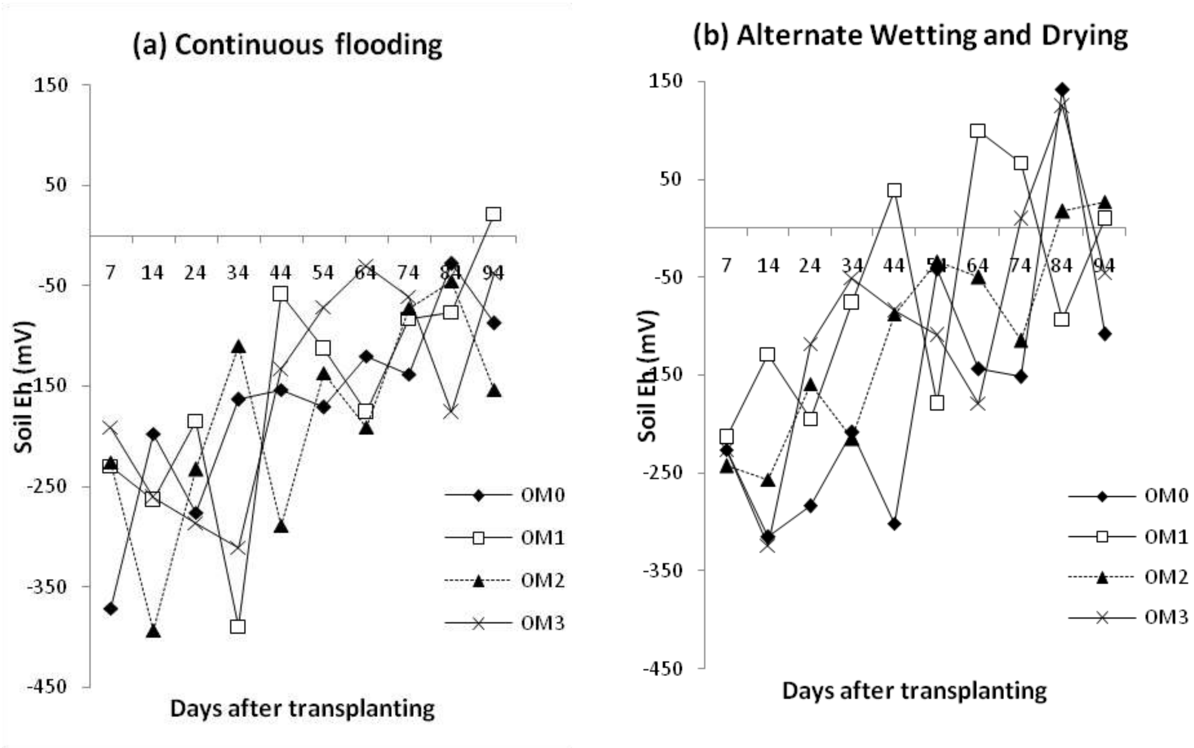

Figure 8. Variation in soil redox potential (Eh) (a) continuous flooding and (b) alternate wetting and drying during the rainy season, 2017

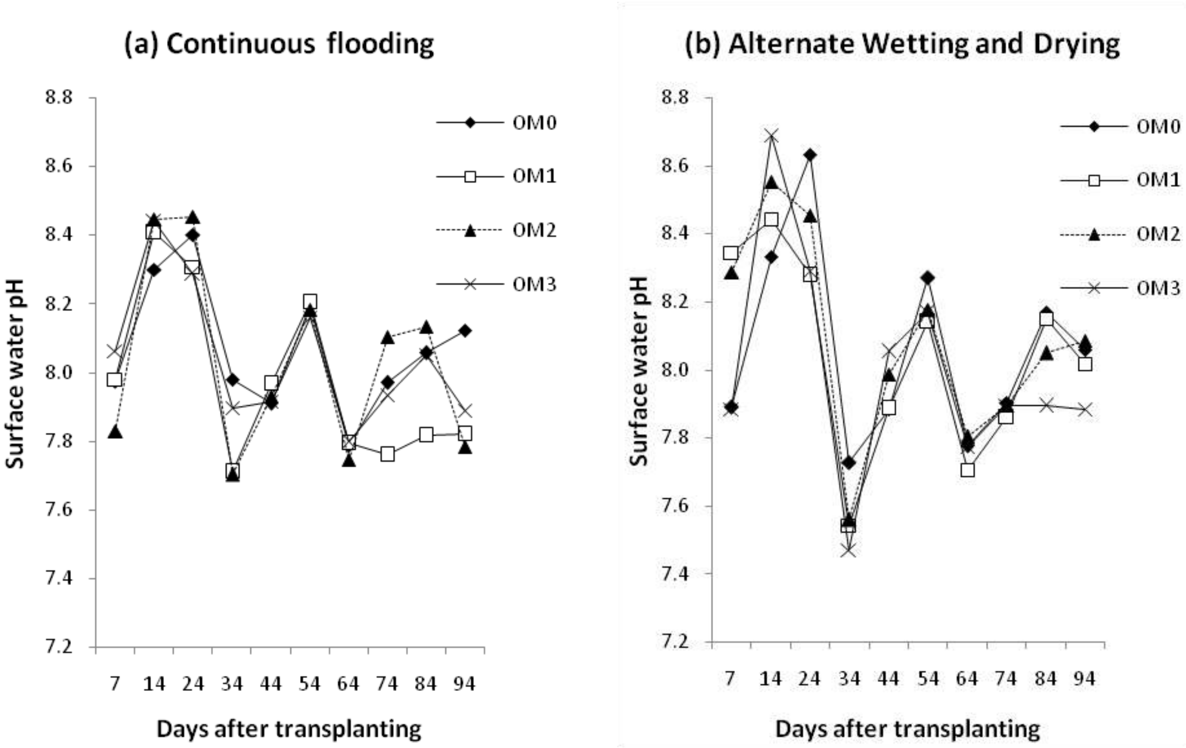

Figure 9. Variation in surface water pH (a) continuous flooding and (b) alternate wetting and drying during the rainy season, 2017

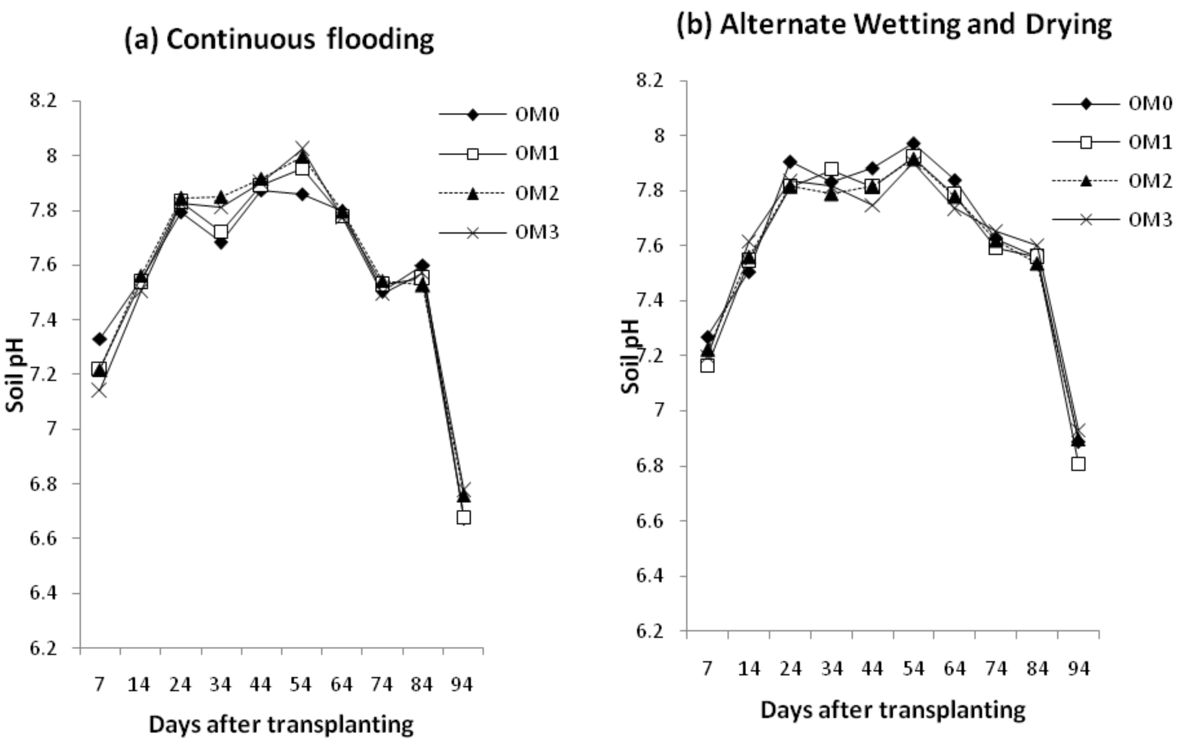

Figure 10. Variation in soil pH (a) continuous flooding and (b) alternate wetting and drying during the rainy season, 2017

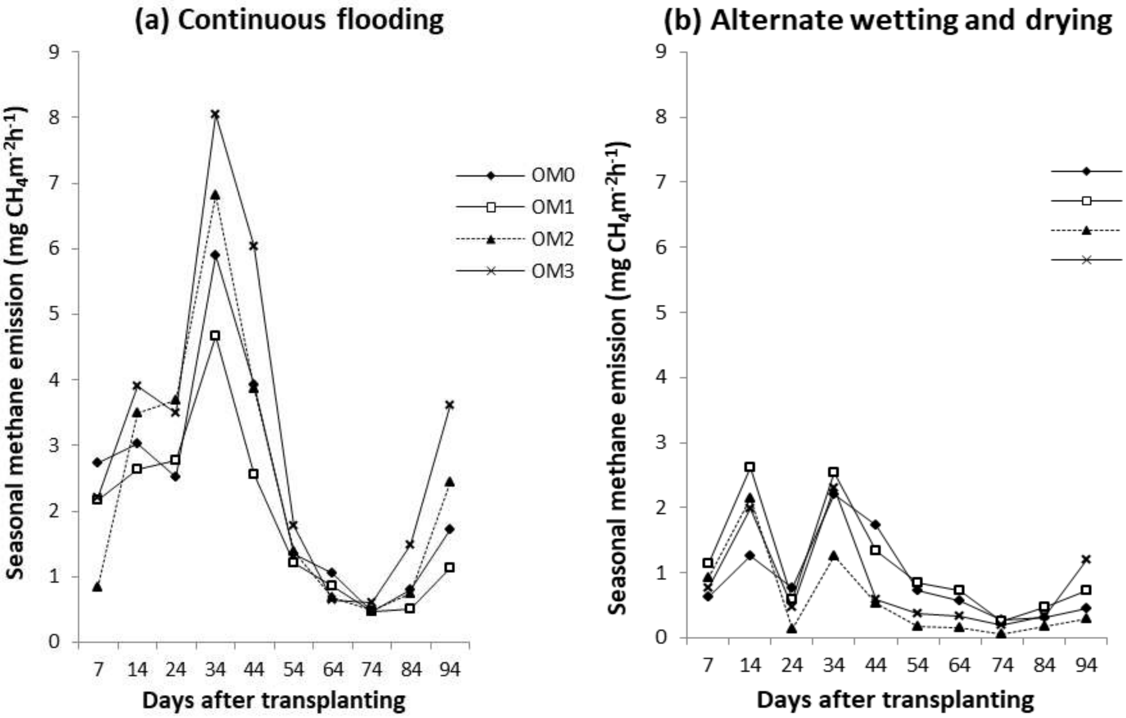

Figure 11. Methane variation of rice (a) continuous flooding and (b) alternate wetting and drying during the rainy season, 2017

Table 3. Mean effects of water and cow-dung manure applied on cumulative methane emission of rice during the rainy season, 2017

Treatment	Cumulative methane emission (kg CH_4 ha^{-1})
Water	
CF	55.68 a
AWD	19.39 a
$LSD_{0.05}$	41.028
Manure	
OM_0 (0 t ha^{-1})	37.07 a
OM_1(2.5 t ha^{-1})	34.45 a
OM_2(5 t ha^{-1})	33.92 a
OM_3(7.5 t ha^{-1})	44.71 a
$LSD_{0.05}$	21.862
Pr>F	
Water	0.0626
Manure	0.6945
Water x Manure	0.4115
CV_a (%)	62.23
CV_b (%)	46.30

Means followed by the same letter are not significantly different at 5% LSD.

Table 4: Relationship between methane emission and soil parameters during the rainy season, 2017

	ST	EH	SWPH	SPH
CH_4	-0.1667 ^{ns}	-0.1446 ^{ns}	-0.0957 ^{ns}	-0.441*

CH_4 – Cumulative methane emission (kg ha^{-1}), ST – Average soil temperature (°C)EH – Average soil redox potential (mV), SWPH – Average surface water pH SPH – Average soil pH

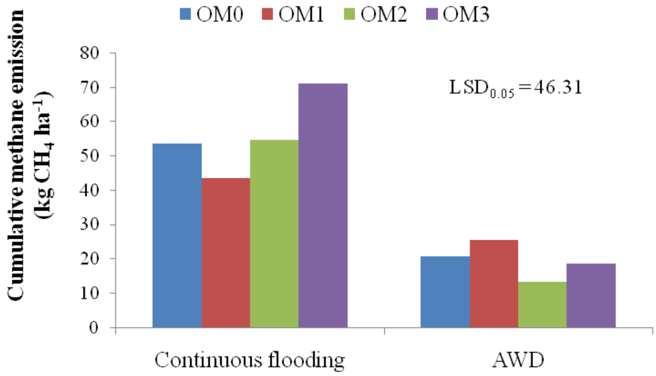

Figure 12. Mean values of cumulative methane emission of rice as affected by water and cowdung manure applied during the rainyseason, 2017

changes. High methane emission was observed at 74 and 94 DAT. The soil pH ranged from 7.32 to 7.43 at 74 DAT, and from 7.70 to 7.99 at 94 DAT. The highest level of soil pH was recorded from OM3 at 74 DAT and from OM0 at 94 DAT. Zoltan (2008) has reported that longer saturated conditions higher amount of soil organic matter resulted slightly alkaline conditions.

In AWD, similarly the same trend was observed. The peak level of methane emission was observed at 34 DAT (in the range of soil pH, 7.03 to 7.22) and 44 DAT (in the range of soil pH, 7.41 to 7.67). The highest soil pH was resulted from OM0 at 34 DAT and in OM1 at 44 DAT. High methane emission was recorded from OM3 in both water regimes. The soil pH ranged from 6.56 to 8.05 in continuous flooding and from 6.48 to 8.14 in AWD. According to results, the high methane production was found in the range of soil pH (7.42 to 7.70) in continuous flooding and in the range of 7.15 to 7.63 in AWD water regime. According to the results in this study, soil pH was significantly affected by water and manure. Zoltan (2008) has stated that fluctuation in soil pH have abiotic as well as biotic origin, and differences in water regime is one of the most important abiotic factors for soil pH variations across different ecotopes.

Methane emission during the summer season, 2017

Methane variation of rice during the growing season is illustrated in Figure 3.5. The different emission pattern of the treatments was observed. High variation was found among the treated plots. Spatial variation of CH_4 emission from rice fields is regulated by a variety of agronomic and environmental factors, as well as the complex interactions of the whole system involving the rice plants, soil and atmosphere (Jean and Pierre 2001; Wang and Li 2002). In continuous flooding, the methane emission gradually increased from the first gas sampling until harvest. High methane emission was found starting from 34 DAT until harvest. This is due to the microbial decomposition of cow-dung manure and supports the substrates for methanogen. Therefore, the high methane emission was observed in OM3 at most DAT except 14, 24, 34 DAT. The low methane emission was observed in OM1 at 14, 24, 44, 54, 64 DAT and in OM2 at 8, 34, 74, 84, 94.

In alternate wetting and drying, in the early stage, the low methane emission was found and rapidly increased to the highest at panicle initiation (PI) stage, and then promptly decreased to small amount until harvest. This might be due to the decomposition and their effect on soil properties in the presence of oxygen because the time intervals between dry and wet conditions appear to be too short to facilitate the shift from aerobic to anaerobic soil conditions (Wassmann et al., 2000). The highest methane emission was observed in OM3, and the lowest methane emission was recorded from OM0 at all DAT except 8, 84 DAT.

Methane emission of rice was significantly affected by water regime (Pr > F 0.0072) (Table 3.1). The high methane emission was obtained in continuous flooding (30.28 kg CH_4 ha^{-1}) as compared to AWD (15.01 kg CH_4 ha^{-1}). The results showed that methane emission was not significantly affected by different cow-dung manure rates (Pr > F 0.1966) (Table 3.1). The high methane emission (32.89 kg CH_4 ha^{-1}) was observed in OM3, and the minimum methane emission (12.97 kg CH_4 ha^{-1}) was recorded from OM0.

In the analysis of variance (ANOVA), there was no significant interaction between the factors tested. The result of ANOVA showed that the effect of different cow-dung manure rates on methane emission was not depended on the effect of water regimes. Mean values of methane emission ranged from 5.73 to 43.82 kg CH_4 ha^{-1} (Figure 3.6). The higher methane emission was observed in continuous flooding water regime. The high methane emission was recorded from continuous flooding with 7.5 t ha^{-1} cow-dung manure rate. The minimum methane emission was observed in AWD water regime with no cow-dung manure. Jain et al. (2004) reviewed that water regime of soil is important for gas exchange between soil and atmosphere and has a direct impact on the processes involved in CH_4 emission. In AWD, the highest methane emission from OM0 is due to the intrinsic CH4 production from inherent soil organic matter. Milkha et al., (2001) has mentioned that the role of soils in determining CH_4 production can be broken up into two functions, i.e. (a) intrinsic CH^4 production from inherent soil organic matter and (b) response to amended material which varies widely among different soils.

Relationship between methane emission and soil parameters during the summer season

Relationship between methane emission and soil parameters in field experiment during the summer season, 2017 was described in Table

3.2. The methane emission was significantly negative correlated with soil temperature, soil redox potential and soil pH (Pr > F 0.01). However, it was not significantly correlated with surface water pH in this study.

Soil parameters during the rainy season, 2017

Soil temperature: Variation of soil temperature during the rice growing season has been shown in Figure 3.7. In the early growth stages, the soil temperature fluctuated until 44 DAT because of soil chemical changes affected by organic matter decomposition, and from that it decreased gradually to harvest. It was found a little bit stabled in the later growth stages. The highest soil temperature was recorded from OM2 and the low soil temperature was observed in OM3.

In AWD, the same trend was observed. The highest soil temperature was observed in OM0 and the low soil temperature was resulted from OM1. The soil temperature ranged from 27.80°C to 34.27°C in continuous flooding and from 27.63°C to 34.27°C in AWD. In this study, the soil temperature did not significantly affect on methane emission and it was significantly not affected by water and cow-dung manure management.

Soil redox potential: The variation of soil redox potential during the rice growing season has been described in Figure 3.8. The different trends of each treatment were observed. It varied throughout the growing season depending on the cow-dung manure management and growth stages. The decreased soil redox potential was observed in the early growth stage as compared to later growth stage. In most soils, rapid initial decrease of Eh after flooding is caused by rapid decomposition rates of organic substrates and the low buffer capacity of nitrates and Manganese oxides (Neue et al., 1995). The lowest soil redox potential was recorded from OM2 and the highest soil redox potential was observed in OM3.

In AWD, similarly the different trend of each treatment was observed. But in this AWD water regime, high positive potential value (oxidation condition) was resulted. The lowest soil redox potential was observed in OM0 and the high soil redox potential was observed in OM1. The high methane emission was recorded from OM1 and OM0. This study is supported with the finding of Cicerone et al., (1983), Yagi and Minami (1990), Lindau et al., (1991), and Denier (1996) who have reported that CH4 emissions have been recorded at much higher Eh values in field studies. The soil redox potential ranged from -393.00 to 22.00 in continuous flooding and from -324.00 to 141.33 in AWD. According to results, the high methane production was found in the range of Eh -389.67 to -58.67 in continuous flooding and in the range of -324.00 to -50.67 in AWD water regime. The high methane emission was recorded from OM3 and low methane emission from OM2. In this study, the methane production was found in the high soil redox potential in both water regimes.

Surface water pH: The variation of surface water pH during the rice growing season has been shown in Figure 3.9. In continuous flooding, the start-up decreased surface water pH was observed and increased in the active tillering stage and decreased at panicle initiation again depending on the chemical changes of soil by organic matter decomposition. From that, the surface water pH fluctuated in the later growth stage. The surface water pH ranged from 7.71 to 8.45. Generally, the surface water pH was not influenced by water and organic manure application in the field study. Therefore, the highest surface pH was recorded from OM2 and the low surface pH was also observed from OM2.

In AWD, the same trend of surface water pH was observed. The surface water pH ranged from 7.47 to 8.63. The highest surface pH was recorded from OM0. The lowest surface pH was observed in OM3.

In this study, the surface water pH did not significantly affect on methane emission.

Soil pH: The variation of soil pH during the rice growing season has been presented in Figure 3.10. At the start-up decreased soil pH value was found. But in the succeeding sampling, the increased soil pH trend was recorded until 54 DAT. From that, the soil pH sharply decreased until harvest. This effect may be due to the soil microbial activity in the presence of organic substrates. The high methane emission was observed at 34 and 44 DAT. The soil pH ranged from 7.68 to 7.85 at 34 DAT, and from 7.87 to 7.92 at 44 DAT. The highest soil pH was recorded from OM2 and the lowest soil pH from OM0.

In AWD, similarly the same trend was observed. The peak high methane emission was observed at 14 DAT (in the range of soil pH 7.51 to 7.62) and 34 DAT (in the range of soil pH 7.79 to 7.88). The highest soil pH was resulted from OM0 and the low soil pH was observed in OM1.

The soil pH ranged from 6.67 to 8.02 in continuous flooding and from 6.80 to 7.97 in AWD. The highest methane emission was recorded from OM3 in continuous flooding and from OM1 in AWD. According to results, high methane production was found in the range of soil pH (7.68 to 7.92) in continuous flooding and in the range of 7.51 to 7.91 in AWD water regime. In this study, the soil pH significantly affected on methane emission and it was significantly affected by water and manure rates.

Methane emission during the rainy season, 2017

Variation of methane emission of rice has been shown in Figure 3.11. In continuous flooding, in the early growth stage, the slightly increased methane emission was observed because of intrinsic methane production potential of soil. And then it was sharply increased near the middle growth stage due to favorable decomposition rate of residue and cow-dung manure. However, it suddenly decreased in later growth stage until near harvest because of depletion of organic substrates for methanogens. At harvest time, it can be found slightly increase of methane emission. This could be due to the supporting of substrates by decaying of tillers. The highest methane emission was recorded from OM3 at all DAT except at 7, 24, 64 DAT. The lowest methane emission was observed in OM1.

In AWD water regime, the methane was found little increased in the early growth stage, but it was decreased in the later growth stages. This might be due to the reduced substrates and mineralization process on soil methanogenesis because of aeration effect in the early stage, and depletion of substrates in the later growth stage. At most DAT except 24, 44, 74 and 94, the high methane emission was resulted from OM1 and the low methane emission was observed in OM2 at all DAT except 7, 14 DAT.

The cumulative methane emission of rice during the growing season has been described in Table 3.3. The significant difference of cumulative methane emission was found among the water treatments at (Pr > F 0.0626). The higher emission (55.68 kg CH_4 ha^{-1}) was recorded from CF as compared to AWD (19.39 kg CH_4 ha^{-1}). Lo et al., (2016) observed that the methane emission from flooded paddy field was 74% higher than non-flooded paddy field. The methane emission was not significantly affected by different cow-dung manure rates (Pr > F 0.6945). The high methane emission (44.71 kg CH_4 ha^{-1}) was found in OM3 and the low methane emission (33.92 kg CH_4 ha^{-1}) was observed in OM2. Khosa et al., (2010) has reported that the methane emission from rice field depends on the flooding status of the soil, crop variety and addition of organic materials and the incorporation of humified organic matter could minimize methane emission form rice fields with co-benefits of increased soil fertility and crop productivity.

In the analysis of variance (ANOVA), no significant interaction on cumulative methane emission was observed between the factors tested. The mean values of cumulative methane emission depended on water regimes and cow-dung manure rates (Figure 3.12). The significantly high methane emission was observed in continuous flooding water regime. The maximum methane emission was resulted from OM3 in continuous flooding. The minimum methane emission was observed in OM2 under AWD water regime. Zou et al., (2005) reported that decomposition of organic materials offers the predominant source of methanogenic substrates, particularly in the early stage of rice development, and crop residue-induced CH_4 was dependent on the water regime in rice paddies, continuous flooding in rice paddies with organic application would extremely intensify the radiative forcing. Promoting aerobic degradation of organic matter in the fields can decrease CH_4 emission from rice paddy fields (Yagi et al., 1997).

Relationship between methane emission and soil parameters during the rainy season

Relationship between methane emission and soil parameters in field experiment during rainy season, 2017 has been presented in Table 3.4. Methane emission was not significantly correlated with soil parameters (soil temperature, soil redox potential, surface water pH) but it was significantly negative correlated with soil pH (Pr > F 0.05) in this study.

Conclusion

The methane emission was significantly higher in CF than AWD. In summer season experiment, the soil temperature was significantly correlated with methane emission, and the methane production was found in the range of 22.7–34.1°C. In this finding, the specific range (26.41-27.71°C) of soil temperature was observed convenient for methane production. Beyond this range, the methane production was suppressed. The methane production was largely correlated with soil redox potential, however, it was not significantly correlated with surface water pH. The soil pH was significantly correlated with methane emission. The methanogenesis occurred in the neutralized condition. In CF, the higher methane emission was recorded from 74 DAT with the range of 7.32 – 7.42 and in AWD, the higher methane emission was observed from 34 DAT with the range of 7.03 – 7.21.

In rainy season, the soil temperature, soil redox potential and surface water pH were not significantly correlated with methane emission because the methane production was influenced not only by soil factors but also by environmental factors (i.e. temperature, rainfall). The environmental condition fluctuated more in rainy season than in summer season (Figure 4.1 and 5.1). However, the methane production was significantly correlated with soil pH. The higher methane production was recorded from the soil pH range of 7.22 – 7.97. The higher methane emission was found in OM1 and the lower emission from OM2. This might be due to the effect of soil chemical and physical changes with crop residues and cow-dung manure addition with the inherent soil organic matter in the presence of oxygen.

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Effect of cutting position in cut stem transplant method, climate resilient practices implemented in Deepwater area in Bago region

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Abstract

Thanapin Township located in Bago Region is situated beside the Bago-Sittaung canal and flooding occurs frequently due to inundated water from Sittaung river. Only local rice varieties can be grown in these areas. The rice plant elongates as the water level rises and lodged after water recede. In such case, the farmers in this area followed "the cut stem transplant method" i.e. cutting the elongated stem and transplanting. Although the yield is realized to be higher than direct seeding method, there may be some cutting position effect on the yield. Therefore, experiment was conducted to: 1) examine the plant growth of transplanting with stem cutting and 2) clarify different cutting effect on the growth of deep water rice. Experiment was implemented in Ywa Houng village, Thanatpin Township where some of the farmers followed cut stem transplant method. Five treatments were tested in Randomized Complete Block Design with 4 replications. Although the stem are cut and transplanted, plant growth parameters such as plant height, tiller number, number of roots per tiller and number of roots per hill were not statistically different from non-cut treatment (control). The effect of cutting position was observed and stem cutting at 15 cm above the soil/ground produced the highest yield although it is not statistically different from control, cut at un-elongated internode and cut at 30 cm above the soil. Among the yield components, yield is related with number of panicles per meter square rather than the number of grains per panicle. Therefore, to obtain the high yield of cut stem transplant method in deep water area in Thanatpin, it should be emphasized to increase the number of panicle per meter square.

Keywords: cut stem transplanting, cutting position, deep water rice, panicle number per m^2, yield

Introduction

Climate and weather pattern are changing currently due to the global warming. Green house effects mostly caused by human activities lead to more evaporation and precipitation making some places wetter and some dryer. The ocean and glaciers are warmed and causing ice melts

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leading to rise in sea level. Temperature will rise to 2.5 to 100C over the next century, precipitation pattern will change, more drought and heat weaves and hurricane will become more intense and sea level will rise 1-4 feet by 2100 (Shaftel et al. 2018). Therefore, flooding is expected to increase in the future. To protect flooding damage to the cultivated field, construction of flood protection measures or growing flood tolerant varieties or flood resilient cultural practices should be done.

There are many conventional rice crop establishment methods in which direct seeded and transplanted rice are the most commonly used methods in the world. Dry seeding is fairly common in deepwater rice. Sometimes, transplanting or double transplanting is practiced (De Datta 1981). Double and triple transplanting is locally practiced in flooded area of Indonesia (Noorsyamsi et al. 1984), Vietnum (Puckridge 1988) and India (Singh et al. 2004) depending on land situation and weather condition. Likewise there is locally used method which is adapted to flooded condition in Myanmar.

Flooding is frequently occurred in delta and coastal area. Thanatpin Township located in the Bago Region is situated beside the Bago-Sittaung canal which used to reduce inundated water from Bago river to Sittaung river. However, if Sittaung river is flooded due to heavy rain, Thanatpin is suffered from flooding damage especially in the months of June, July and August. Cultivated varieties in these areas are selected to grow only photoperiod sensitive deep water rice varieties (Raitzer et al. 2015). Deep water rice responses to flooding by stem elongation, which occurs chiefly by internode elongation together with a lengthening of the terminal leaf blade and sheath (Alim et al. 1962). However, the plant will lodge after water recedes. If the rice plants are lodged, the elongated stem is cut and transplanted without roots. It is practiced in some of deep- water rice field in Thanatpin Township, Bago Region in Myanmar. This method is the feasible way to resist from flood damage. Conventionally used practice is transplanting with intact seedlings (seedlings with roots). However, transplanting of rice plant without root is rather strange although it is currently followed by some farmers cultivated in Thanaptin Township. Because, root is important to uptake water and nutrient to the plant. Recent finding revealed that root pruning affect the rice growth and development. Root pruning of all roots in lowland rice at 6 leaf age affect growth and development of tiller buds (Yamamoto 1989). In cutting of roots in hybrid rice at different length at 25- and 40-days seedlings age, the larger the root cutting, the more inhibit of root growth and effect the development of rice seedlings was observed (Li et al. 2018). In contrast, root cutting treatment on high yielding rice at 40-45 days after sowing did not retard the plant growth if roots were cut after shooting of tiller buds from the main culm (Tanabe 1982). Therefore, it is necessary to investigate whether root cutting affect the growth and yield of deepwater rice.

In addition, there might have some effect of cutting position of the elongated stem of deep-water rice. Decapitation of different bud in the shoot responses differently in Ipomoea nil (Chern et al. 1993), Pisum sativum (Balla et al. 2016) and Eucalyptus globules (Wilson 2015). Moreover, Dun et al. (2006) interpreted that buds located at different nodes show various response to decapitation and the location of the bud on the stem influences its outgrowth potential. Hence, there might have some effect of stem cutting and different cutting position effect on the growth and yield. Therefore, the objectives of this experiment are: 1) to examine the plant growth of transplanting with stem cutting and2) to clarify different cutting effect on growth of deepwater rice.

Materials and methods

Experiment site

Experiment was conducted at Ywa Houng village, Thanatpin township, Bago Region which is suited 17o12'42"N, 96o18'11"E and 9 m above sea level. It was done in 2017 wet season.

Experimental design

Experimental design is Randomized Complete Block (RCB) design with 4 replications. There were five treatments as follows.

T1 intact seedling (control)

T2 cut at unelongated internode

T3 cut at 15 cm above the soil

T4 cut at 30 cm above the soil

Table 1. Mean plant height (cm) during plant growth

No.	Treatment	20DAT		50DAT		80DAT	
1	T1	99.45	ab	115.05	a	128.5	c
2	T2	87.1	c	119.65	a	136.5	b
3	T3	101.5	ab	122.1	a	142.5	a
4	T4	107.05	a	119.45	a	142.1	ab
5	T5	95.25	bc	123.2	a	143.8	a
	C.V.	6.42		5.29		2.72	

Table 2. Mean number of tillers per hill producing during plant growth

No.	Treatment	20DAT		50DAT		80DAT	
1	T1	2.8	abc	11.6	a	14.95	a
2	T2	3.0	ab	11.9	a	11.85	b
3	T3	2.7	bc	12.3	a	11.6	b
4	T4	2.4	c	11.4	a	11.65	b
5	T5	3.1	a	12.6	a	11.25	b
	C.V.	9.4		11.26		12.62	

Table 3 Mean plant height (cm) for each treatment at harvest

No.	Treatment	Plant height (cm)
1	T_1	123.71 b
2	T_2	126.12 ab
3	T_3	126.42 ab
4	T_4	131.17 a
5	T_5	127.96 ab
	C.V.	3.68

Means followed by the same letters are not significantly different at LSD 5% level

Table 4. Mean number of tillers produced from each node

Treatment	Tillers on node						
	1	2	3	4	5	6	7
T1	3.5	4.5	2	2.33	1.7	1.7	
T2	3	2.25	2	2	2.7	1.5	1
T3	3.25	3.25	2	1.75	1	1	
T4	3	2.5	1.5	2.5	1.3	1	
T5	4	3.75	1.75	1.5	1.5	1	
mean	3.35	3.25	1.85	2.02	1.6	1.2	1
SD	0.42	0.92	0.22	0.41	0.6	0.3	
CV	12.5	28.3	12.1	20.3	38	26	

Table 5. Mean comparison of root characteristics at harvest

Treatment	Average root/ tillers	Root no./ hill	Root dry weight/ hill (g)	Shoot dry weight/hill (g)	Root/ shoot
T1	17.50 a	257.25 a	0.983 a	59.66 a	0.017 a
T2	21.51 a	251.33 a	0.933 a	52.45 a	0.019 a
T3	20.57 a	239.17 a	0.983 a	57.54 a	0.017 a
T4	18.69 a	213.42 a	0.925 a	54.56 a	0.017 a
T5	20.58 a	251.67 a	1.1 a	50.29 a	0.022 a
C.V.	28.91	23.93	31.12	17.42	33.22
LSD	8.81	89.42	0.47	14.70	0.01

Means followed by the same letters are not significantly different at LSD 5% level

Table 6. Mean comparison of yield and yield component parameters at harvest in Pawsan

No.	Treat-ments	Hill/m^2		Num-ber of pani-cles /		Number of grains/ panicle		Number of pani-cles/m^2		Grains/ m^2		Filled grain(%)		100 grain weight (g)		Y yield/ hill (g)		yield / m^2 (g)	
1	T1	13.8	b a	15.0	a	92.5	a	206.3	a	18416	a	54.23	a	3.50	a	26.11	a	339.5	ab
2	T2	15.8	b a	13.6	a	85.8	a	212.0	a	18279	a	52.23	a	3.45	ab	20.80	ab	324.7	ab
3	T3	16.0	b	13.6	a	96.4	a	217.6	a	20812	a	54.61	a	3.47	a	24.50	ab	391.4	a
4	T4	17.0	a a	12.6	a	91.0	a	211.0	a	19246	a	53.94	a	3.41	ab	21.18	ab	361.1	ab
5	T5	16.3	b	12.6	a	88.3	a	202.5	a	17852	a	52.3	a	3.21	b	18.22	b	296.7	b
	C.V.	12.1		15.4		11.8		19.3		18		11.25		4.85		21.08		15.7	
	LSD	2.9		3.2		16.5		62.4		5253		9.3		0.25		7.21		83.0	

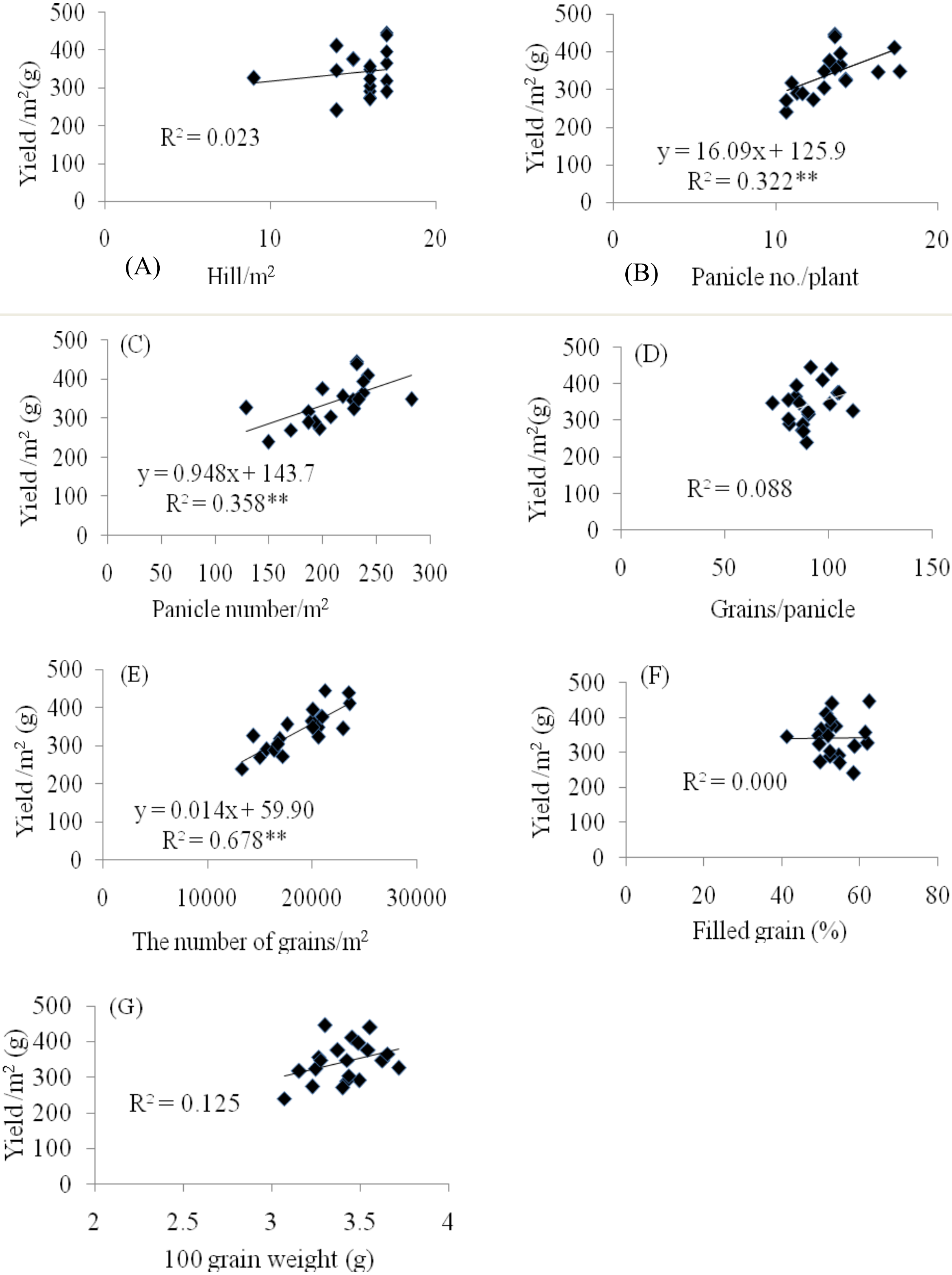

Figure 1. Relationship between yield/m^2 and number of hills/m^2 (A), number of panicle / plant (B), number of panicle /m^2 (C), grains/m^2 (D), filled grain (%) (E) and 100 grain weight (F).

T5 cut at 45 cm above the soil

Cultural practices

The ungerminated seeds of Pawsan, photoperiod sensitive cultivar flowering at mid of November, was collected from the farmer and dry seeded to the nursery field at the beginning of May 2017 with the seed rate of 170 kg/ha (3.3 basket/ac). No fertilizer was applied during the nursery period. When the seedlings were 130 days old, the seedlings were cut as the treatment and transplanted with the spacing of 25cm × 25cm at the rate of one seedling per hill. The size of each plot is 2m x 2m and sixty four hills were transplanted in each plot.

To favor rooting, at least one node per cutting was required as the root comes out from the node. The plant height at transplant is not too high and the node number was insufficient to cut because the experimental nursery is situated in the shallow water area. Therefore, to transplant T1, T2 and T3, the seedlings were taken from the experimental nursery while the cutting for T4 and T5 were collected from farmer's field situated in deeper water area. Transplanting was done by placing the basal node about 30 cm immersed to the puddle soil for all treatment. Water level at transplanting is 25cm in the field. Besides, there was the top dressing application of urea fertilizer for 2 times; 52kg/ha (46lb/ac) at 18 days after transplanting and 77 kg/ha (55lb/ac) again at 80 days after transplanting. No insecticide or herbicide was applied during cultivation period. The plants were harvested on third week of December, 2017 when the rice was fully ripened.

Data collection

Plant growth were recorded at 20 days after transplanting (DAT), 50DAT and 80DAT by sampling 5 plants which was taken diagonally across the plot. At harvest, the number of hills/ plot and tiller numbers /hill in each plot were counted and 3 hills from each plot were sampled to measure the growth and yield component characteristics. To realize the weight yield of each plot, 1m^2 plots were harvested at the middle of each plot.

Statistical analysis

Collected data were analyzed by using excel and statistix version 8.0 and mean separation was done with least significant distance (LSD) at 5% level.

Results

During the plant growth period, plant height (cm) and the number of tillers were recorded. Increase of plant height measured at 20DAT, 50DAT and 80DAT which is presented in Table 1. The highest plant (cm) at 20DAT was observed in T4 (107.05) followed by T3 (101.5), T1 (99.45), T5 (95.25) and T2 (87.1) accordingly. Nevertheless, no significant differences of plant height were observed in 50DAT. On the other hand, difference in plant height (cm) was observed again at 80DAT in which T5 (143.8) achieved the highest plant height, although not significant difference with T3 (142.5) and T4 (142.1) except T2 (136.5) and T1 (128.5).

Besides recording of the plant height (cm) during cultivation, tiller number was also counted to know the plant growth performance (Table 2). The highest number of tillers at 20DAT was found at T5 (3.1) followed by T2 (3.0), T1 (2.8), T3 (2.7) and the least by T4 (2.4) respectively. Conversely, tiller number checked at 50DAT was not significantly different each other. However, the highest tiller number was acquired in T5 (12.6). When recording again at 80DAT, all of the treatment were not significantly different each other except T1 (14.95) which achieved the highest number of tillers.

Besides the plant height and tiller number during plant growth period, other parameters such as plant height and yield component data were recorded after harvest. Plant height (cm) examined at harvest is shown in Table 3. The highest plant height (cm) was recorded in T4 (131.17) subsequently followed by T5 (127.96), T3 (126.42), T2 (126.12) and T1 (123.71) respectively.

The number of tillers produced from each node is shown in Table 4. In this table, treatment T2, T3, T4 and T5 were not different in producing tillers from each node as control (T1). In addition, the number of tillers produced from each node were similar in all treatments in the order of node 1> node2>node3>node4 and so on.

Concerning the root characters such as root number per tiller, root number per m^2, root dry weight (g), shoot dry weight (g) and root shoot ratio are not statistically different (Table 5).

Yield and yield component data were recorded at harvest (Table 6). Regarding hill/m^2, the highest number of hill/m^2 was recorded in T4 (17.0) subsequently followed by T5 (16.25), T3 (16.0), T2 (15.8) and T1 (13.8). There were no statistically differences in number of panicles per plant, grains/panicle and filled grain (%). Moreover, hundred grains weight of T5 (3.21) was the least and statistically different from T1 (3.5) and T3 (3.47) whereas it was not different from T4 (3.41) and T2 (3.45) respectively. Concerning yield/hill (g), the highest yield was observed in T1 (26.11) successively followed by T3 (24.5), T4 (21.18), T2 (20.8) and the least by T5 (18.22).

Number of panicles perm^2, grains/m^2 and filled grain/m^2 were not statistically differences between stem cut treatment and control. Regarding the yield/m^2 (g), the highest was observed in T3 (391.42) followed by T4 (361.08), T1 (339.49), T2 (324.66) and T5 (296.72) consequently.

The relationship between yield and other yield component characters is shown in Fig.1. Yield/m^2 is highly significantly related with number of panicles /plant (R2= 0.322**), number of panicles m^2 (R2= 0.358**), grain/m^2 (R2= 0.678**) while it is not related with number of hills/m^2 (R2= 0.023), filled grain (%) (R2=0.000) and 100 grain weight (R2= 0.125).

Discussion

Internodes elongation owing to flooded water was observed in the literature. Deep-water rice and floating rice tried to escape from flooding stress by vigorous growth of its internode. Due to elongated stem, the plants are lodged after water recede. In this experiment, the elongated stem are cut and transplanted without root. Rooting from elongated internode in deep-water rice and the important of nodal rooting was observed in the literature (Chang et al. 1965; Nitta et al. 1998; Nitta et al. 1999). Lorbiecke and Sauter (1991) reported that adventitious roots are born in the node and it produced all characteristic produced in primary and lateral roots. Sophonsakulkaew et al. (1977) conducted in the screening for elongation ability of deep-water rice by transplanting the cutting of the top part of the plant (the second node from the top). Therefore, it is obvious that stem cutting from the elongated stem of deep-water rice can be used for plant propagation. Propagation by using stem cuttings in rice is recognized and rooting is observed in this experiment. Although the stem is cut and transplanted, the shoot and roots characters are not different from control (Table 5). Therefore, the result approved that new plant can produced from stem cutting of Pawsan variety. In addition, plant height (Table 1) was increased until 80DAT, the number of tillers was only increased unto 50DAT and remains the same or decreased in tillers from 50DAT to 80DAT. This tillering pattern is comparable to other reports. Chang et al. 1965 and Badshah et al. 2014 reported that tiller number increase until maximum tillering stage and after that it decline and some of the tillers die. That reduction is due to the competition of assimilates between tillers and mother culm (Biswas and Salokhe 2005).

At harvest, the plant height is not different from control and even higher plant height is produced in T4 (Table 3). The trend of tillers produced from each node in stem cut treatment (T2, T3, T4 and T5) is very similar to control T1 (Table 4) in which the first and second node is the largest tiller producing node. This finding was agreed to the report of Akita (1976) that the two lowest tillering nodes produced the tillers number much larger than those produced from upper nodes. Lowest nodal tillers are important and contribute to increasing yield (Gendua et al. 2009). Tillers emerged from lower node was earlier than those produced from middle or upper node (Ming et al. 2012).

In comparing the yield per m^2 of each treatment, the treatment T3 produced the highest yield among treatments even though which is not statistically different from other treatments except T5. Besides, T5 bears the least yield among treatments although it is not statistically different from T1 (control). Therefore, it could be interpreted that transplanting with stem cutting cut at unelongated internode, 15 cm above the soil surface, 30 cm above the soil surface and 45 cm above the soil surface are not different with control (non cut seedlings). Different cutting effect was observed in literature. In cutting the stem of pineapple into basal, middle and upper part as mature, semi mature and immature cutting, the highest weight of shoot per cutting was observed in semi mature cutting (Ranawana and Eeswara 2008). Moreover, in decapitation of Ipomoea nil, the buds at the higher nodes (3 to 6) bear greater length than the buds at the lower nodes (1 and 2).

However, the youngest bud produced from node 6 was smaller at the beginning; it exhibited vigorous growth during four days after decapitation. Therefore, there exist position effects on lateral bud outgrowth in Ipomoea nil (Chern et al. 1993). Furthermore, decapitation of two-nodal-bud in Pisum sativum, growth rate of the lower and upper axillary buds growth was initiated at the same rate. Whereas, lower buds development begins to slow at 3 days after decapitation while upper buds continued growth and became evidently dominant (Balla et al. 2016). Moreover, propagation by stem cutting of Garcinia kola (Heckel), cutting above node 3 formed 3 shoot per stump while the other cutting node produced only 2 shoot per stump. Besides that, cutting above node 1 and 2 generate longest length of leaf while cutting above node 1 bears the greatest stem diameter (Kouakou et al. 2016). Buds located at different nodes show various response to decapitation and it confirms the fact that the location of the bud on the stem influences its outgrowth potential (Dun et al. 2006). Comparable to those finding, different cutting effect was observed in this experiment. Transplanting with stem cutting cut at 15 cm above the soil favors the highest yield among the stem cut treatment and even slightly higher yield than control.

When observing the relation between yield and yield related characters, yield/m^2 is highly and significantly related with panicle number/m^2, total grain per m^2 and total filled grain per m^2. Similar finding was observed by (Rajeswari and Nadarajan 2004). Total number of spikelet is influenced mostly by the number of panicle/hill rather than the number of spikelet/panicle and hill/m^2 in this experiment. That finding was similar to the finding of (Gravois and Helms 1991; Miller 1991). In addition, De Datta (1981) and Sidhu et al. (2014) evaluated that rice yield is mostly determined by the number of panicle per m^2. Reduced tillering is the constraint for higher yield in medium-deep water condition (Mahapatra and Reddy 1982). In addition, Yoshida (1981) interpreted that the yield increased with the increasing spikelet number/m^2 than filled spikelet percentage and 1000 grain weight. However, at some location and weather condition, filled spikelet (%) is more affect to the yield than the number of spikelet number/m^2. Hence, the author suggests that both of spikelet number per m^2 and filled spikelet (%) should be examined to check the causes of yield variation.

Conclusion

Elongated stems of 130 days old seedlings of Pawsan can be cut and transplanted. Seedlings from the stem cutting at unelongated internode, 15 cm above the soil, 30 cm above the soil and 45 cm above the soil can produce roots and shoots comparable to transplanting with normal seedlings. During plant growth period, plant height and tillers produced from the stem cutting treatment (T2, T3, T4 and T5) facilitate similar trend to the development of normal seedlings. Furthermore, tillers produced from each node in stem cutting treatments bears the same trends as produced in normal seedlings.

Different stem cutting effect was examined in this experiment. Transplanting with stem cutting cut at 15 cm above the soil generate the highest yield while stem cutting cut at 45 cm above the soil surface bears the lowest yield. Moreover, it is observed that the yield is highly correlated with panicle/m^2 rather than the number of spikelet/panicle and hill/m^2.

Suggestion

According to the result, the number of panicle bearing tillers should be improved to increase the yield of Pawsan practiced to transplant with stem cutting in Thanatpin, Bago region. Although the stem cutting cut at 15cm above the soil bears the highest yield, further identification should be done to confirm the yield of different stem cutting treatments.

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Screening magic *Indica* population for their cold stress tolerance at the seedling stage

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Abstract

Tolerance to cold stress were investigated using 444 MAGIC Indica lines through GBS involving 27041 SNPs. This study was conducted in the walk-in growth chamber at International Rice Research Institute (IRRI) to screen MAGIC Indica under cold stress condition at the seedling stage and to map the Quantitative Trait Loci (QTL) for cold stress tolerance. Three significant QTLs of S1-39508393 on chromosome 1, S12_6755981 on chromosome 12 and S6_6716446 on chromosome 6 which are linked to cold tolerance could be explored in rice varietal improvement to develop cold tolerance and in marker assisted selection for cold tolerance. Five cold tolerant lines: MIB-3553, MIB-3606, MIB-4354, MIB-4546 and MIB-4642 could be utilized in well-strategies of plant breeding program to develop cold stress tolerant advanced lines. The tolerant lines investigated in this study should be tested further to have strong finding for its use in cold tolerant rice variety improvement.

Keywords: MAGIC Indica, cold stress, single marker analysis, interval mapping, GWAS

Introduction

Natural hazards such as heavy rain and floods, intense heat and drought, cyclones and storm surges are common occurrences in Myanmar these days (NAPA, 2012). The constraints to rice production in CDZ in Myanmar include climatic-related factors as discussed in Chapter I, but also lack of infrastructure and inputs such as reliable use of rice varieties, fertilizer, as well as irrigation system and inaccessibility to markets. Also, less rainy days and increased intensity of rainfall events reduce the amount of water available for crop growth, given increased runoff and drainage (Challinor et al., 2004). Changes in both the mean and the variability of temperature will also affect crop yield. Adaptation to these changes is possible: a change of crop variety can mitigate the impact of extremes (Challinor et al.,2005).

To develop rice cultivars tolerant to low temperatures at critical growth stages is therefore an important breeding objective for these regions. A wide range of variation in cold tolerance at various growth stages has been observed in rice. The Indica rice subspecies, asso-

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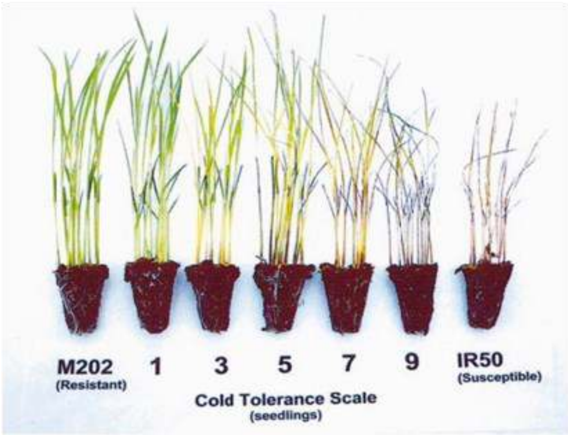
ciated with tropical environments, is more sensitive to low temperature than the tolerant japonica subspecies which is divided into tropical and temperate groups. So far, the genetic mechanism of the trait has not been well clarified due to its quantitative inherence and it has been difficult to improve the level of cold tolerance in rice through breeding programs. With the development of diverse DNA markers and the construction of high density linkage maps for many plant species like rice, QTL (quantitative trait loci) analysis has become a powerful tool for the genetic dissection of quantitative traits (Tanksley, 1993). By this approach, several QTL conferring cold tolerance at seed germination, vegetative and reproductive growth stages have been identified (Saito et al., 2001). Similar to many other stress-related traits, cold tolerance is developmentally regulated and growth stage-specific. The cold tolerance at one development stage is therefore not necessarily correlated with the tolerance at other stages

Materials and Methods

Plant Materials - MAGIC Indica population was developed by using eight Indica founder lines, which carry QTLs conferring tolerance of biotic and abiotic stresses. The first stage followed a half-diallele mating system by inter-mating the eight founder lines and 28 bi-parental crosses were made. The resulting 28 F1s were inter-crossed to derive 4-way crosses for which 70 such 4-way crosses (out of 210 possible crosses) were made. The 70 crosses were selected in such a manner that no parent was represented more than once in the 4-way cross. Also only one of the possible 4-way combinations was selected (e.g., one of ABCD or ACBD or BCAD etc.). The last stage involved intercrossing of the 70 4-way crosses to derive 8-way crosses. Only 35 out of 105 such possible 8-way crosses were made keeping in mind that no parent was represented more than once. From each of the 35 8-way crosses ~60 seeds were advanced by selfing (Bandillo et al.,2013).

SCALE (for seedlings)	
1	Seedlings dark green
3	Seedlings light green
5	Seedlings yellow
7	Seedlings brown
9	Seedlings dead



Four hundred and fourty-four genotypes including MAGIC Indica populations, and six checks were used in this study. The seeds were sourced from the International Rice Gene bank Collection, International Rice Research Institute (IRRI), Philippines. The experiment was conducted at the International Rice Research Institute (IRRI), in the Philippines in August 2016.

Growing Conditions - The screening was

Figure 2. Phenotyping for cold stress tolerance of MAGIC *Indica* for standard evaluation score (SES) at seedling stage

done in the walk-in growth chamber. The seeds were germinated followed by planting on Styrofoam using modified Yoshida's nutrient solution (Singh et al.,2010) in screen house at the IRRI. Augmented RCB design was used. There were totally 30 blocks, and 24 lines including tolerant check (M 202) and susceptible check (IR 50) in each block. All the seedlings at a three-leaf stage were transferred into a temperature-controlled walk-in growth chamber set at 16/12°C with 14/10 hrs settings. The chamber was set to 75% relative humidity and light intensity of 800 m mol $m^{-2}s^{-1}$. After 10 days of cold treatment, plants were scored as alive or dead. Visible symptoms such as yellowing of leaves, stunted growth, partially dead leaves and completely dead plants are used to assess the cold damage. According to SES scoring system (IRRI, 2014), the seedlings were observed differences in vigor along with subtle changes in leaf color. The criteria for scoring at the early seedling stage are shown in the following table:

Figure 1. Cold-tolerance scale used in scoring seedlings treated at 16/12°C day/ night temperature regime for cold stress tolerance (Andaya and Mackill, 2003)

Statistical Analysis

Population structure - Analysis of population structure among MAGIC Indica population was performed using Principal Component Analysis (PCA) by R programming in order to examine whether there is population structure in the tested population or not.

Genotyping - For genotyping, a high resolution approach was needed to take advantage of the highly recombined population. Single nucleotide polymorphism (SNP) markers are the most abundant types of DNA markers and are the marker of choice due to the availability of extensive rice genome sequences and the de-

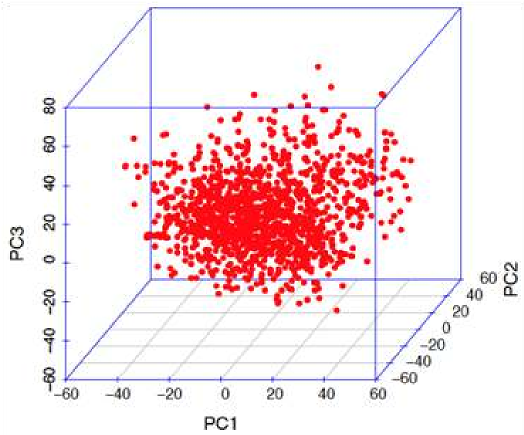


Figure 3. Principal Component Analysis (PCA) of MAGIC Indica population

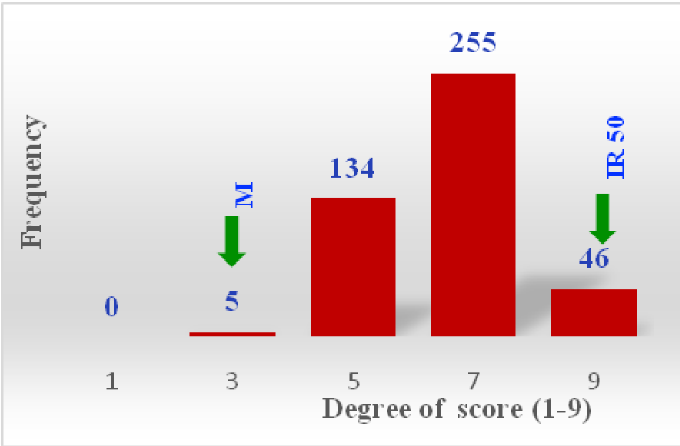


Figure 4. Phenotypic variation of cold stress tolerance for MAGIC Indica Population

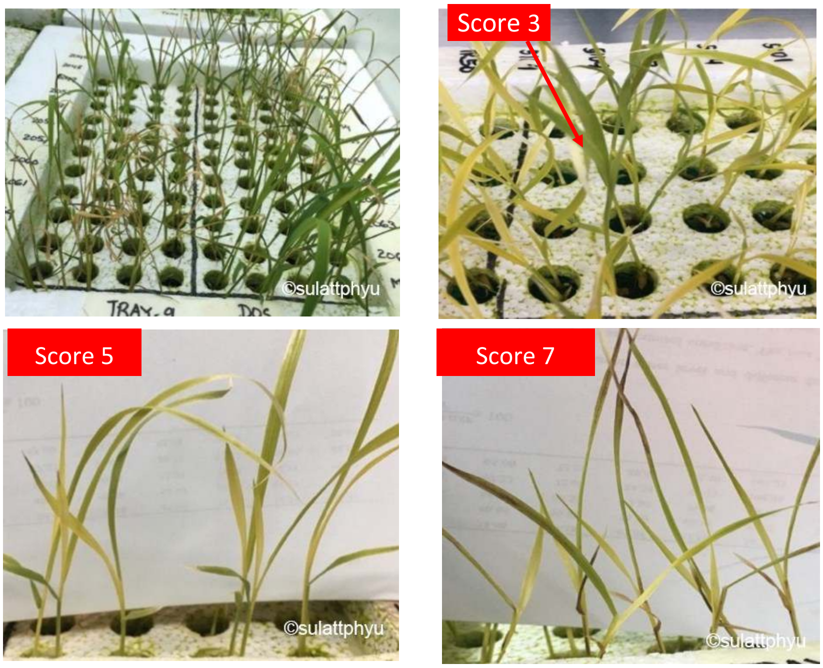


Figure 5. Different scoring of seedlings showing the response to cold stress in MAGIC Indica population

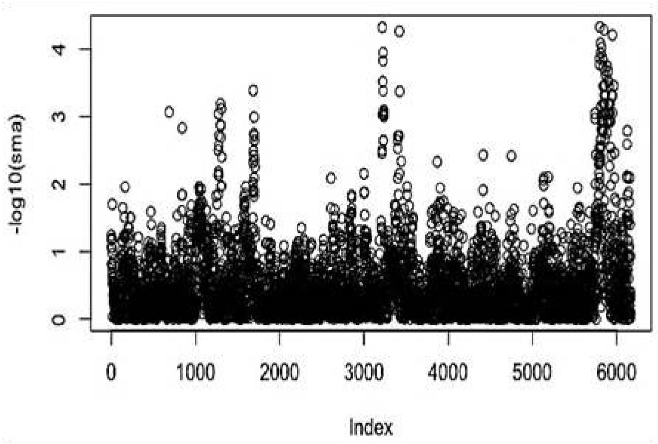


Figure 6. Single marker analysis of MAGIC Indica population for cold tolerance. Index value: Chr 1 (1-762), Chr 2 (763-1510), Chr 3 (1511-2064), Chr 4 (2065-2661), Chr 5 (2662-3067), Chr 6 (3068-3540), Chr 7 (3541-4019), Chr 8 (4020-4468), Chr 9 (4469-4798), Chr 10 (4799-5189), Chr 11 (5190-5689) and Chr 12 (5690-6616)

Table 1. Results of interval mapping associated with cold tolerance in MAGIC Indica at seedling stage.

CHRO#	Position	Left marker	Right marker	P-vaule (a)	Phenotypic variation (R^2)
1	82.78	S1_20705831	S2_22175518	0.00492	3.1
2	88.4	S2_22142097	S6_23231889	0.00877	3.23
3	38.66	S3_9856465	S6_23231889	4.76E-05	3.8
12	36	S12_9075718	S12_9209708	0.0984	4.58

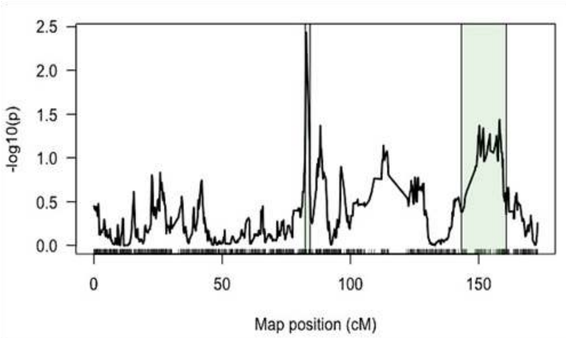


Figure 7. Interval mapping for markers for cold tolerance detected on chromosome 1 among all MAGIC Indica population

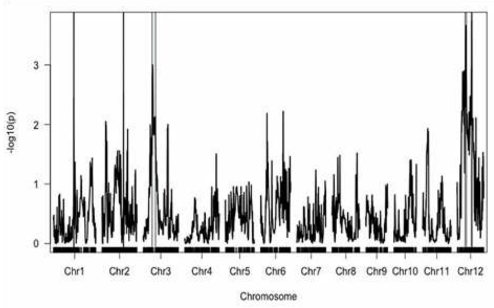


Figure 8. The –log10 profile on chromosome with significant QTL detecting cold tolerance of MAGIC Indica population

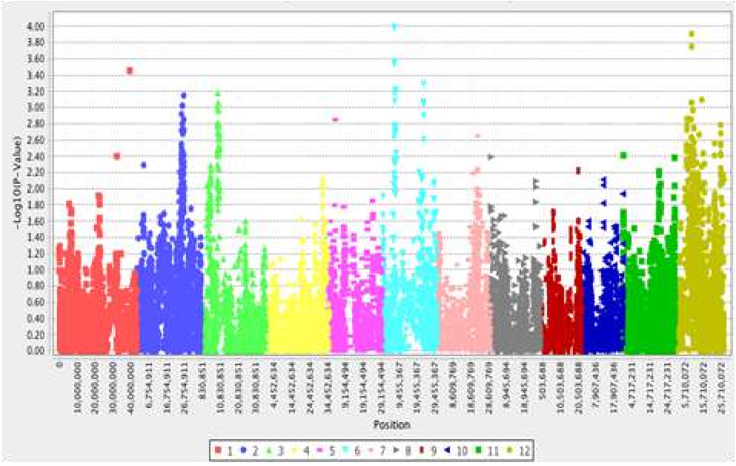


Figure 9. Manhattan plot (MLM) showing GWAS for cold tolerance in MAGIC Indica population

Table 2. Some of the significant SNP markers of cold tolerance trait in MAGIC Indica population.

SNP	CHROMOSOME	POSITION (cM)	P-VALUE(a)	MARKER R^2 (%)
S6_6698403	6	6698403	1.02E-04	3.50
S6_6701738	6	6701738	1.02E-04	3.50
S6_6701762	6	6701762	1.02E-04	3.50
S6_6703357	6	6703357	1.02E-04	3.50
S6_6703943	6	6703943	1.02E-04	3.50
S12_9180482	12	9180482	1.23E-04	3.42
S12_9182794	12	9182794	1.78E-04	3.26
S6_6686862	6	6686862	2.70E-04	3.07
S6_6716446	6	6716446	2.89E-04	3.04
S6_6716477	6	6716477	2.89E-04	3.04
S1_39508393	1	39508393	3.53E-04	2.96
S6_23200830	6	23200830	5.10E-04	2.79
S6_7644636	6	7644636	6.14E-04	2.71
S6_7644634	6	7644634	6.14E-04	2.71
S6_7119093	6	7119093	6.59E-04	2.68
S6_7135091	6	7135091	6.59E-04	2.68
S6_7135175	6	7135175	6.59E-04	2.68
S6_7135382	6	7135382	6.59E-04	2.68
S6_7119111	6	7119111	6.59E-04	2.68
S6_7135135	6	7135135	6.59E-04	2.68

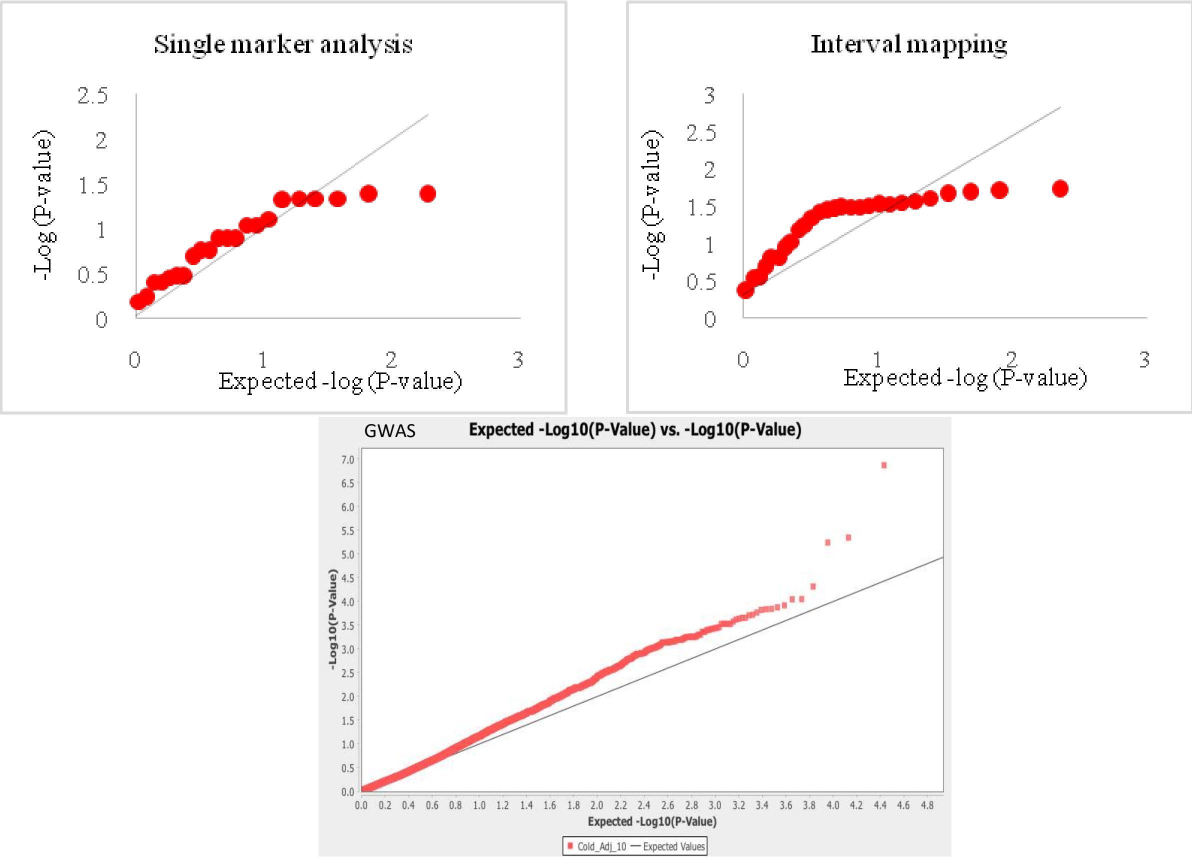


Figure 10. QQ-plots showing for SMA, IM and GWAS for cold tolerance in MAGIC Indica population

Table 3. Summary of QTLs detected for cold tolerance in single marker analysis (SMA), interval mapping (IM) and genome wide association (GWAS).

SMA		**IM**			**GWAS**		
Chro #	Significant Markers	Chro #	P-Value (a)	Flanking Markers	Chro #	P-Value (a)	No. Of Strong QTLs
6, 12	S6_6716446	1	0.0049	S1_20705831, S1_22175518	1	3.53E-04	11 (P<0.5E-04)
		2	0.0088	S2_22142097, S2_23231889	6	1.02E-04	
	S12_6755981	3	4.76E-05	S3_19856465, S3_23231889	12	1.23E-04	
		12	0.0984	S12_15006612, S12_15039531			

velopment of low cost SNP genotyping approaches. Recently, genotyping by sequencing (GBS) has been used as an efficient method to provide high resolution SNP genotyping through restriction digestion and multiplexed sequencing (Elshire et al.,2011). To test the efficacy of using GBS for high-resolution mapping of the MAGIC populations, the Indica subset and the founders were genotyped using a 96-plex ApeKI GBS protocol. This GBS technology provided 27041 polymorphic SNP marker sites across all 12 chromosomes with a call rate >70% and a minor allele frequency > 0.05.

Single marker analysis (SMA) and Interval mapping (IM) - The predicted mean of salinity scoring data of MAGIC Indica population was analyzed with 6616 SNP markers using R/mpMap for both SMA and IM. The traditional method to detect a QTL in the vicinity of a marker is studying single-genetic markers one at a time.

SMA and IM were performed with GBS data and phenotypic data for salinity tolerance at seedling stage in the MAGIC Indica population by using R/mpMap software based on RStudio (version 3.3.2, 2016). R/mpMap has been developed as a comprehensive suite of functions for multi-parent designs in close consultation with plant breeders and geneticists (Huang and George, 22011). It is able to handle the complexities associated with multi-parent inbred lines crosses.

Genome-wide association (GWAS) - The salinity tolerance scoring of 440 MAGIC Indica populations were carried out for GWAS to detect QTLs. GWAS was done by using a TASSEL software Henderson, 1976; Bradbury et al., 2007) with 27041 SNP markers of 440 Genotype By Sequencing (GBS) data Trait Analysis by aSSociation, Evolution, and Linkage (TASSEL version 5.2.35, 2017) program released by Bradbury et al. (2007) was used to perform a Genome-Wide Association Study (GWAS) using the phenotypic and genotypic data on the subset of 440 MAGIC Indica lines.

Results

Population structure of MAGIC Indica population

The presence of population structure often can lead to false positive discoveries. This population structure is not adequately accounted for in the analysis of marker-trait association. Before genomic evaluation, it is necessary to investigate the presence or the evidence of population structure. Principal component analysis (PCA) was recently suggested as a fast and effective way to diagnose population structure (Zhu and Yu, 2009). The PCA method summarizes variation observed across all markers into a number of underlying component variables to adjust for population structure. The PCA method makes it computationally feasible to handle a large number of markers and correct for subtle population stratification. The population structure of MAGIC Indica population was determined using PCA. The result showed that MAGIC Indica population has the negligible structure to conduct QTL Mapping and GWAS (Figure 3). Therefore, it is feasible to run QTL mapping and GWAS on this population.

Phenotypic variation among MAGIC Indica population in response to cold stress

Cold stress tolerance was evaluated using a controlled growth chamber in a phytotron facility. The tolerant check M 202 showed strong cold stress tolerance without seedling mortality although susceptible check IR 50 observed 100 % seedling mortality. The frequency distribution of the 444 MAGIC Indica (Figure 4) shows slight skewness to the susceptible types. The average degree of cold stress tolerance was 6.15 for all MAGIC Indica population. Five cold tolerant lines are MIB-3553, MIB-3606, MIB-4354, MIB-4546 and MIB-464 .

Single marker analysis (SMA) - Single marker analysis is a relatively simple method of QTL analysis that can be conducted to detect associations between molecular markers and traits of interest. The primary interest in SMA is to determine whether a marker is linked to a QTL. The predicted means of cold stress tolerance data was analyzed for single marker analysis using 6616 SNP markers. The result was shown in Figure 4.5. There were a number of markers which were significantly linked to QTLs on chromosomes 6 and 12. The maximum –log10 (sma) was 4.32484 (S12_6755981) on chromosome 12 and 4.31911 (S6_6716446) on chromosome 6.

Interval mapping (IM) - Although SMA has the ability to detect the QTLs, it cannot locate the positions of the QTL and obtain an estimation of the QTL effects. IM is a great improvement relative to single marker analysis for mapping QTL, because IM directly estimates QTL locations. Table 1 showed the result of the Interval Mapping for cold stress tolerance trait.

Markers which were associated with the cold stress tolerance trait were found on chromosomes 1, 2, 3 and 12 (Table 1, Figure 7). The QTLs between left marker S1_20705831 and right marker S2_22175518 and between left marker S3_9856465 and right marker S6_23231889 were strongly associated with the cold stress tolerance trait (<0.005 P-value) on the chromosomes 1 and 3, respectively. The highest R2 value was found on chromosome 12 with a pair of flanking markers S12_15006612 and S12_15039531.

The map position of the interval mapping analysis was plotted as shown in Figure 7. The detected QTLs were positioned at 82.78 cM, 88.4 cM and 38.66 cM on chromosome 1, chromosome 2 and chromosome 3, respectively. The large QTLs shown with the green part in the plot was also detected QTL region with very small P-value which were far from each other.

Genome wide association (GWAS) - GWAS peaks were located on chromosomes 6 and 12 at P-value 1.02E-04 and 1.23E-04, respectively (Table 4.2, Figure 4.8). Association between 230 marker loci and cold tolerance were determined by the MLM analysis which had P -value lower than 0.001. Eleven markers were tightly linked with the QTL (P-value < 0.0005) for cold tolerance trait in MAGIC Indica population. They were S6_6698403, S6_6701738, S6_6701762, S6_6703357, S6_6703943, S12_9180482, S12_9182794, S6_6686862, S6_6716446, S6_6716477 and S1_39508393 in chromosomes 1, 6 and 12.

In QQ plots, the Y-axis is the observed number and magnitude of observed P-value (-10 log) which displays associations between SNPs and cold tolerance and the X-axis is the expected P-value under the null hypothesis (there is no association between SNPs and cold tolerance). In Figure 10, QQ plots showing for SMA and IM found Type-II error (false negative, i.e., a QTL is not detected) and most of SNPs deviated from the expected distribution. In contrast with QQ plots showing for GWAS, most of the SNPs were close to the expected distribution and only a few SNPs found Type-I error (false positive, i.e., a QTL is indicated at a location where actually no QTL is present).

Discussion

Most of the previous studies on cold tolerance in rice were carried out under natural conditions which were easily affected by other environmental factors (Dilday, 1990; Glaszmann et al.,1990; Mackill and Lei, 1997). The intensity of cold treatment (level of low temperature and duration of exposure) is of particular importance for the effective evaluation of cold tolerance of the plants. In this study, scoring at seedling stage was used as an identification index for evaluation for cold tolerance using seedlings grown in the artificial chamber. The temperature was maintained at 16/12 °C for 10 days, and the relative humidity was 75%, then the temperature was adjusted from 12 to 16 by 1°C slowly up or down, and the appearance of the seedlings was recorded as SES scoring system. In this study, several QTLs associated with cold tolerance in rice were identified under a controlled-environment condition. It has been reported that cold tolerance at the germination stage of rice is a dominant trait with high heritability (Jin, 1990). Screening for cold tolerance at the germination and seedling stages could facilitate evaluation of rice lines/ varieties to cold tolerance.

In this study, the QTLs detected for cold tolerance on chromosomes 6 and 12 in SMA, on chromosomes 1, 2, 3 and 12 in IM and on chromosomes 1, 6 and 12 in GWAS ($P < 0.0005$). But significant markers were found in chromosome 6 in SMA and GWAS. Two significant QTLs of S12_6755981 and S6_6716446 linked to the cold tolerance were found to be located on chromosomes 6 and 12 in SMA and GWAS. IM was not consistent with the other SMA and GWAS. The possible reason was that there was limited seeds of MAGIC Indica population and only Augmented RCB design could be used without replication in this study. For better result of QTL analysis, there should be more replication.

However, Lou et al. (2007) observed S1-39508393 (qCTs-1-c) for cold tolerance in 193 doubled haploid (DH) lines by using composite interval mapping. The same QTLs was also detected in this study with the P-value of 3.53E-04 in GWAS. The same chromosome was also reported by Zhao et al. 2009 for the seedling stage cold tolerance in rice RILs (Recombinant Inbred Lines). Andaya and Mackill (2003) also suggested that survival percentage of seedlings under anaerobic condition in the RILs using M202 and IR 50 as parents found major QTLs on chromosome 12.

By comparing QQ plots of SMA, IM and GWAS, Type-II error is probably more serious since it will lead to the loss of chance for discovering real QTLs for the effective QTL mapping. Among three different QTL mapping methods, QQ-plots for SMA and IM showed type II error in most of the SNPs meaning there is no QTL although it actually is present. QQ-plot showing for GWAS observed that there is type I error in some of SNPs indicating that there is a segregating QTL whereas in reality there is not present. In this study, most of SNPs deviated from the expected distribution in SMA and IM showing Type-II error. However, in QQ plots of GWAS, most of the SNPs were close to the expected distribution and only a few SNPs found Type-I error. It can be suggested that GWAS is the appropriate method to discover QTLs for cold tolerance.

Conclusion

Most of the identified QTLs are distributed on all chromosomes of rice as revealed in the previous papers. However, it is difficult to utilize these QTLs in cold tolerance breeding program because most of the QTLs are associated with undesirable traits like spikelet sterility and epistasis effect. Most of the previous papers reported only detected QTLs with no information on breeding application. Based on the QQ plots of SMA, IM and GWAS, the best appropriated method is GWAS to discover QTLs for the association with the cold tolerance.

According to the result of cold stress study, the QTLs for the detection of cold tolerance were found in chromosomes 6 and 12. Three significant QTLs of S1-39508393 on chromosome 1, S12_6755981 on chromosome 12 and S6_6716446 on chromosome 6 which are linked to cold tolerance could be explored in rice varietal improvement to develop cold tolerance and in marker assisted selection for cold tolerance. The tolerant lines investigated in this study should be tested to have strong finding for its use in cold tolerant rice variety improvement.

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Root characteristics of rice (*Oryza sativa* L.) associated with tolerance to complete flooding in greenhouse condition

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Abstract

Rice root growth is a remarkably variable in terms of root architecture, growth patterns, and environmental adaptation to complete flooding. The following are significant observations to the cultivars after the flooding. The greatest root reduction was noted in Swarna-Sub1 and the least was noted in FR13A. The shoot length of Swarna-Sub1 showed no changes while shoot length of IR42 greatly increased after complete flooding. FR13A and Swarna-Sub1 cultivars had higher survival rate and the greater shoot elongation of IR42 results in the lowest rate of survival measured at 21 days after de-flooding. Being tolerant to complete flooding, FR13A had the highest increase in total aerenchyma percentage, and percentage of root porosity (root cross section C-4.5cm from root tip) after complete flooding. Total aerenchyma was positively correlated with the percentage of aerenchyma and the percentage of root porosity under complete flooding. Total aerenchyma in root cross section B was also positively and significantly correlated with plant survival.

Keywords – flooding tolerance and sensitive rice cultivars, root parameters, aerenchyma formation, root porosity

Introduction

Rice (*Oryza sativa*) is one of the most important staple food crops for more than half of the world's population (IRRI, 2006). It influences the livelihood of billions of people, as well as the economy of the country. In 2010, it was estimated that 88% of global rice was grown in Asia, 31% of which are from Southeast Asia alone (FAOSTAT, 2012). Agriculture is a major source of livelihood in Southeast Asia where about 115 million hectares of land are committed to the production of rice, maize, oil palm, rubber, and coconut (ADB, 2009). Approximately 557 millions of resource-poor farmers in Southeast Asia depend on rice for their life and culture (Manzanilla et al., 2011).

Various biotic and abiotic stresses cause yield reduction, especially in less favorable areas. Flooding brought about by typhoons and floods is one of the major reasons for production losses. About 80 kg/ha of annual average yield loss

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is caused by flooding stress (Dey and Upadhaya, 1996). Flooding is a common constraint all over the rainfed rice cultivated areas in South Asia, Southeast Asia, and in Africa.

The quantitative nature of root characteristic is complicated. Deep root system has been positively correlated with plant height in rice. Rice root growth and development under flooding showed that wet seeded rice had about 1.5 times as much as total root length in the transplanted rice. The greater the total root length, the deeper the maximum root depth. The peak and then decline in total growth of root length shortly after panicle initiation is most likely related to increased competition for assimilates by the developing panicles (IRRI, 1991).

Multiple anatomical and morphological adaptations develop in the root system. Aerenchyma is the general term for tissue with large intercellular spaces (Esau, 1997). The formation of aerenchyma in roots is associated with adaptation to hypoxia condition caused by flooding. Aerenchyma development is more favorable in flooded soil when the roots are examined and compared anatomically. Rice is adapted to flooded soil conditions because of its well-developed aerenchyma system that facilitates oxygen diffusion and prevents anoxia in roots (Mackill et al., 2010). Typically, the proportion of root porosity in different species is strongly correlated with the frequency of flooding in their natural habitat (Smirnoff and Crawford, 1983, as cited in Grimoldi et al., 2005). Porosity can differ based on root types. There are various approaches to determine and measure root porosity. The plant with highly developed root porosity provides better oxygen transport that contributes to their survival under flooding.

Most studies on traits necessary for adaptation to flooded conditions in rice focused on shoot traits, with very little investigations on root characteristics that could enhance tolerance to partial or complete flooding. Root morphological and anatomical traits that ensure continued root aeration, growth and function under flooded conditions are important tolerance mechanisms. These traits could either be constitutive in cultivars adapted to specific flood-prone environment, or induced upon stress. The experiment studied root and shoot growth, root anatomical features (aerenchyma formation and porosity), plant survival, and relationships between root characteristics and plant survival in tolerant and sensitive rice cultivars associated with tolerance to complete flooding under greenhouse conditions.

Materials and methods

The study was conducted in greenhouses and in the Plant Physiology Laboratory at the Crop and Environmental Science Division (CESD), and the Plant Molecular Biology Laboratory (PMBL) at the International Rice Research Institute (IRRI), Los Baños, Philippines.

Plant materials and experimental setup

The Experiment was conducted using six rice cultivars contrasting in tolerance to different types of flooding (Table 1). Seeds (~ 40-50) of each cultivar were pre-germinated for two (2) days in Petri plates lined with two layers of moistened paper towel. After two days, 25 pre-germinated seeds were transferred in a tray (32cm x 24 cm x 10.5 cm) containing the growth medium. The medium was divided into six rows where seeds of the six rice cultivars were randomly sown per tray. There were six trays per replication. Each replicate was placed in a concrete tank inside the greenhouse. The rice cultivars were grown in trays using a randomized complete block design (RCBD) with three replications and were subjected to complete flooding typical of flash flood at the vegetative stage and a control (non-flooded) under greenhouse conditions.

Table 1. Flooding tolerance and sensitive cultivars using in this study

CULTIVARS	CHARACTER TRAITS
IR42	Sensitive to flooding
Swarna	Sensitive to flooding
Swarna-Sub1	Tolerant to complete flooding (vegetative stage)
FR13A	Tolerant to complete flooding (vegetative stage)
IRRI 154	Tolerant to stagnant flooding
Madhukar	Tolerant to stagnant flooding

Growth medium

The growth medium consisted of soil mixed with sand in a 2:1 ratio. Six kilograms of this mixture was placed in each tray. After which, the fertilizer was added and mixed thoroughly with the growth medium in each tray. The fertilizer consisted of 1 gram of ammonium sulfate as N source, 0.5 grams of Solophos as P source, and 0.5 grams of muriate of potash as K source.

Treatment application and maintenance

After three weeks (i.e., 21 days after pre-germination), the seedlings were treated with complete flooding inside the concrete tank at 1-m (100 cm) depth of water under greenhouse condition. Additional trays of IR42 were also setup to check root shoot junction. The treatment setups were maintained for 14 days; i.e., 100 cm water level for complete flooding treatment and daily watering for the control (non-flooded) under greenhouse condition. Water temperature, oxygen level, and pH of floodwater at 25cm, 50 cm, and 100 cm water depths

Table 2. Average environmental parameters taken for two weeks in the concrete tanks at various water depths under green house condition.

PARAMETERS	DEPTH OF FLOODING					
	25 cm		50 cm		100cm(water surface)	
	AM	PM	AM	PM	AM	PM
	0800-0900h	1300-1400h	0800-0900h	1300-1400h	0800-0900h	1300-1400h
Water temperature (˚C)	31	32	31	32	31	32
Dissolved oxygen mg/L	5.63	6.54	5.60	6.48	5.66	6.51
Light intensity (µmol m^{-2} s^{-1})	204.74	226.65	211.53	238.04	266.65.	273.03
pH	7.77	7.80	7.75	7.82	7.79	7.81

were measured using a dual temperature and O_2 / pH meter (ORION Model 230A, Beverly, MA), while incident light was measured by a light meter (LI- COR 250, Lincoln, NE).

Termination of Experiment and Data Gathered

At termination of the experiment, i.e., after 14 days, water was drained in all set-ups. At this time, IR42, a cultivar sensitive to flooding had become soft at the root–shoot junction. For the data collection, three trays were used before and after complete flooding and the other three trays were used for the measurement of the percentage of plant survival. Rice seedlings were allowed to recover for 21 days after flooding and then percentage of plant survival was recorded.

Parameters such as Length/depth of root penetration (cm), Number of nodal roots, Root dry weight (g), Shoot length (cm), Stem dry weight (g), and Leaf dry weight (g) of tolerant and sensitive cultivars subjected to flooding and non-flooded conditions were observed, recorded, and analyzed, determined using a SHIMADZU top loading balance.

observed, recorded, and analyzed, determined using a SHIMADZU top loading balance.

Leaf –Shoot weight ratio (LSWR) – Using the leaf and stem dry weights, leaf –shoot weight ratio was calculated using the following formula:

Leaf –Shoot weight ratio = Leaf dry weight/ Total shoot dry weight

Root - Shoot weight ratio – Using the dry weights of roots and shoots, the root-shoot ratio was calculated as follows:

Root - Shoot weight ratio = Root dry weight/ (Leaf dry weight + Stem dry weight)

Measurement of Aerenchyma

Roots were obtained from three plants per replicate per treatment per cultivar and placed in corresponding 50 ml Falcon tubes. The tubes

Table 3. Average root length (cm) of six rice cultivars after 14 days of complete flooding under greenhouse condition. Treatment application was done 35 DAS.

CULTIVARS	ROOT LENGTH (cm)		
	Control (non-flooded)	Complete flooding	% of the control
IR42 (S)	18.84	12.73 bc	67.55**
Swarna (S)	18.89	12.00 c	63.28*
Swarna-Sub1 (T- CF)	20.13	11.69 c	58.70**
FR13A(T-CF)	19.51	14.02ab	72.83*
IRRI 154 (T-SF)	20.71	12.16 c	58.99**
Madhukar (T-SF)	21.18	15.04 a	70.87**

Means followed by the same letter are not significantly different at 5% level by t-test.

Table 4. Average number of nodal roots of the six rice cultivars after 14 days of complete flooding under greenhouse condition. Treatment application was done 35 DAS.

CULTIVARS	NUMBER OF NODAL ROOTS		
	Control (non-flooded)	Complete flooding	% of the control
IR42 (S)	26.31 b	16.62 a	63.18**
Swarna (S)	23.20 b	11.56 b	49.74***
Swarna-Sub1 (T- CF)	24.78 b	12.89 b	52.40***
FR13A (T-CF)	27.67 b	16.93 a	62.27**
IRRI 154 (T-SF)	37.18 a	16.22 a	44.38**
Madhukar (T-SF)	32.91 a	17.24 a	52.44***

Means followed by the same letter are not significantly different at 5% level by t-test.

Table 5. Average root dry weight (g) of six rice cultivars after 14 days of complete flooding under greenhouse condition. Treatment application was done 35 DAS.

CULTIVARS	ROOT DRY WEIGHT(g)		
	Control (non- flooded)	Complete flooding	% of the control
IR42 (S)	0.43 b	0.38 cd	89.84 ab ^{ns}
Swarna (S)	0.40 b	0.30 de	76.30 ab^{ns}
Swarna-Sub1 (T- CF)	0.47 b	0.27 e	58.05 ab^{ns}
FR13A (T-CF)	0.88 a	0.59 b	68.19 ab *
IRRI 154 (T-SF)	0.73 a	0.42 c	57.41 b **
Madhukar (T-SF)	0.88 a	0.79 a	91.94 a^{ns}

Means followed by the same letter are not significantly different at 5% level by t-test.

Table 6. Root shoot weight ratio of six rice cultivars after 14 days of complete flooding under green-house condition. Treatment application was done 35 DAS.

CULTIVAR	ROOT SHOOT WEIGHT RATIO		
	Control (non-flooded)	Complete flooding	% of the control
IR42 (S)	0.22	0.82b	379.98 b ***
Swarna (S)	0.17	0.83b	494.99 ab ***
Swarna -Sub1(T-CF)	0.20	0.75b	379.46 b **
FR13A (T-CF)	0.19	0.76b	401.12 b **
IRRI 154(T-SF)	0.22	0.83b	376.47 b **
Madhukar(T-SF)	0.21	1.25a	616.98 a ***

Means followed by the same letter are not significantly different at 5% level by t-test.

was measured by using an analysis program (GIMP 2.8.14). Percent root aerenchyma was measured based on the formula by Burton et al., 2012:

Root Aerenchyma (%) = Total aerenchyma in the cortex/(Total root cross sectional area – stele area) ×100

Measurement of root porosity

Root porosity was determined based on the method of Visser and Bogemann, (2003).

Root Porosity (%)= (Area of air space/Total root cross sectional area) × 100

Statistical analysis

The experiment was conducted using a split plot design with three replications. Treatments (water levels) are assigned as main plot and cultivars as sub plot. Data on root growth changes, plant growth changes, total number of aerenchyma, % aerenchyma and % root porosity were subjected to analysis of variance (ANOVA) using STAR 2.0.1 statistical program software (IRRI, 2013). Differences in root characters of tolerant and sensitive rice cultivars under flooding and their interactions were assessed using the Student's t-test. Associations between parameters were examined using Pearson's linear correlation coefficient.

Results and discussion

Daily environmental parameters were determined in the concrete tanks at various water depths under greenhouse condition for two weeks between 0800-0900 h and 1300-1400 h (Table 2). The average daily wind speed in the greenhouse was 423.97 ms^{-1} in morning and 326.82 ms^{-1} in afternoon.

Root growth (cm)

The root growth in terms of length of all six rice cultivars were reduced under complete flooding in comparison with the control (Table 3). Among cultivars, the shortest root length (in a column) was observed in Swarna-sub1, while Madhukar showed the least reduction. However, its root length was not significantly longer than FR13A (Table 3). Both Swarna-Sub1 and FR13A were tolerant to complete flooding but their root lengths were different due to genetic variation of these two cultivars. Root growth of traits of all six rice cultivars under non-flooded condition (control) was not significantly different.

Changes (% of the control value) in root growth (in a row) of the six rice cultivars were found significantly low after complete flooding (Table 3). For instance, the greatest root reduction after flooding was noted in Swarna-Sub1, while the lowest reduction in root growth was observed in FR13A confirming its tolerance to complete flooding. The highest reduction in root growth of Swarna-Sub1 as explained by Singh et al. (2011) indicated that the SUB1 QTL in Swarna-Sub1 does not influence root growth under complete flooding. Aguilar et al. (2008) reported that the length of roots was significantly reduced across cultivars under waterlogging condition, supporting the present

Table 7. Plant survival (%) of the six rice cultivars 21 days after de-flooding under greenhouse condition. Measurements were taken 56 DAS.

CULTIVARS	PLANT SURVIVAL (%)		
	Before complete flooding	After de-flooding	% of the control
IR42 (S)	88.89	9.33 d	10.72 b ***
Swarna(S)	82.22	21.33cd	24.76 b **
Swarna -Sub1(T-CF)	94.22	65.33 ab	69.34 a ***
FR13A(T-CF)	92.89	77.33 a	83.08 a^{ns}
IRRI 154(T-SF)	95.11	47.11 bc	49.85 ab ***
Madhukar(T-SF)	92.44	14.67 d	15.49 b ***

Means followed by the same letter are not significantly different at 5% level by t-test.

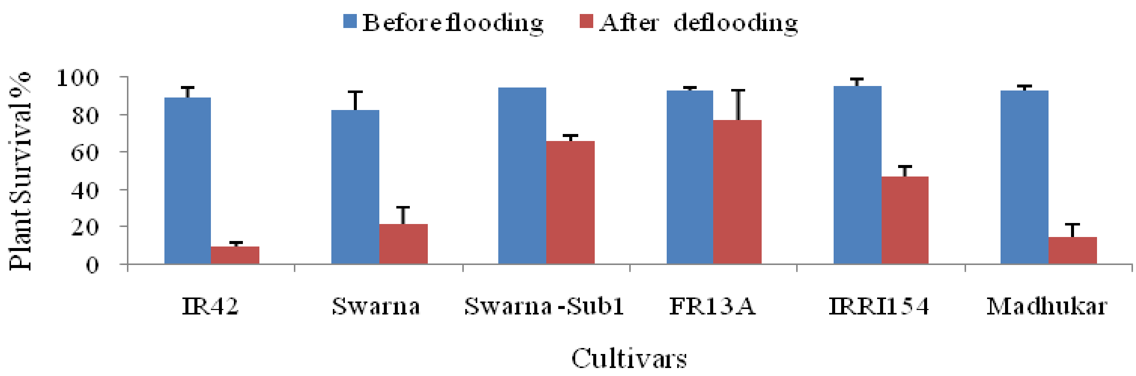

Figure 1. Plant survival (%) of the six rice cultivars after 21 days of de-flooding under greenhouse condition. Vertical bars represents the standard error bar.

Table 8. Average shoot length (cm) of six rice cultivars after 14 days of complete flooding under greenhouse condition. Treatment application was done 35 DAS.

CULTIVARS	SHOOT LENGTH (cm)		
	Control (non-flooded)	complete flooding	% of the control
IR42 (S)	49.73 c	75.38 b	151.6 9a **
Swarna (S)	47.09 c	64.69 cd	137.87 ab **
Swarna Sub1 (T- CF)	47.71 c	45.96 e	96.48 c^{ns}
FR13A (T-CF)	73.04 b	67.51 c	92.45 c *
IRRI154 (T-SF)	51.38 c	62.82 d	122.60 b **
Madhukar (T-SF)	82.18 a	114.78 a	140.12 ab ***

Means followed by the same letter are not significantly different at 5% level by t-test.

Table 9. Average stems dry weight (g) of six rice cultivars 14 days after flooding under greenhouse condition. Treatment application was done 35 DAS.

CULTIVARS	STEM DRY WEIGHT(g)		
	Control (non-flooded)	Complete flooding	% of the control
IR42 (S)	0.94 d	0.37 b	40.06 a**
Swarna (S)	1.23d	0.28 c	22.58 ***
Swarna Sub1 (T- CF)	1.22 d	0.28 c	23.23 ***
FR13A (T-CF)	2.89 a	0.65 a	22.75 ***
IRRI154 (T-SF)	1.77c	0.40 b	22.95 **
Madhukar (T-SF)	2.34 b	0.45 b	19.23 ***

Means followed by the same letter are not significantly different at 5% level by t-test.

Table 10. Average leaf dry weight (g) of six rice cultivars after 14 days of complete flooding under

CULTIVARS	LEAF DRY WEIGHT(g)		
	Control (non -flooded)	Complete flooding	% of the control
IR42 (S)	1.03 c	0.10 cd	9.25***
Swarna (S)	1.08 c	0.08cd	7.57***
Swarna Sub1 (T- CF)	1.12 c	0.08 d	6.94***
FR13A (T- CF)	1.75 ab	0.14 b	8.04***
IRRI154 (T- SF)	1.58 b	0.11 c	6.73***
Madhukar (T-SF)	1.97 a	0.19 a	9.97***

Means followed by the same letter are not significantly different at 5% level by t-test.

Table 11. Leaf –Shoot weight ratio of six rice cultivars 14 days after flooding under greenhouse condition. Treatment application was done 35 DAS.

CULTIVARS	LEAF- SHOOT WEIGHT RATIO		
	Control (non-flooded)	Complete flooding	% of the control
IR42 (S)	0.52a	0.21	40.14 b ***
Swarna (S)	0.47a	0.23	48.67 ab ***
Swarna -Sub1(T-CF)	0.48a	0.21	44.94 b ***
FR13A (T-CF)	0.38b	0.18	46.77 ab ***
IRRI154(T-SF)	0.47a	0.21	44.16 b ***
Madhukar(T-SF)	0.46a	0.30a	66.20 a **

Means followed by the same letter are not significantly different at 5% level by t-test.
In a row, *** = highly significant at $P < 0.001$, ** significant at $P < 0.01$, * significant at $P < 0.05$, ns = Not

were filled with 50 % ethanol such that the roots were fully submerged. Selected root tips per treatment per cultivar were cut into three portions of about 1.5 cm from the root tip (labeled A, B and C). Cross sections from each root portion were obtained by hand section. The root cross section was examined under a Zeiss LSM 510 confocal laser scanning microscope and an Olympus Camedia 4040 digital camera at 100x magnification. Aerenchyma

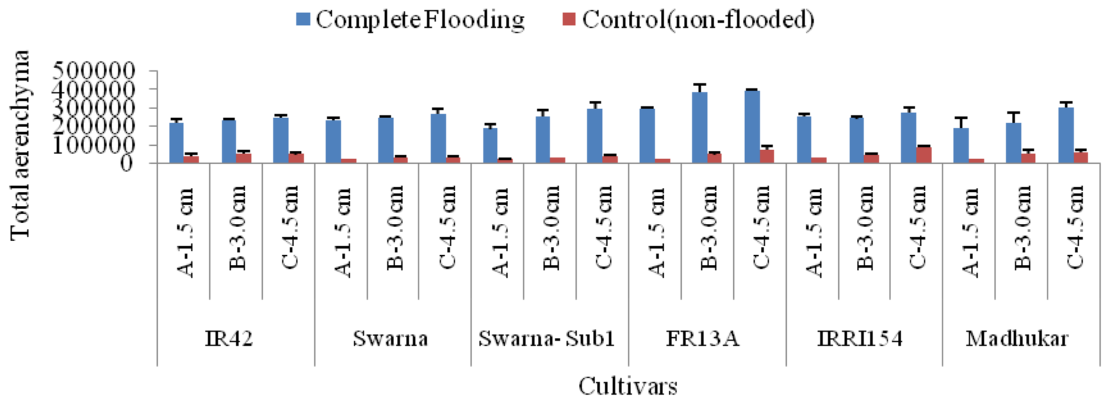

Figure 2. Total aerenchyma in root of the six rice cultivars 14 days after complete flooding at 100 cm water depth and control treatments under greenhouse condition. Vertical bars represent the standard error bar.

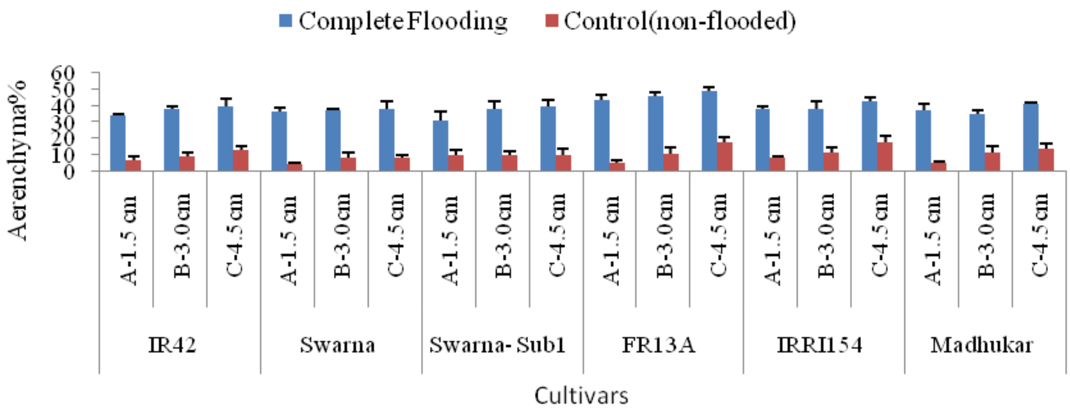

Figure 3. Percentage of aerenchyma in root of the six rice cultivars 14 days after complete flooding at 100 cm water depth and control treatments under greenhouse condition. Vertical bars represent the standard error bar.

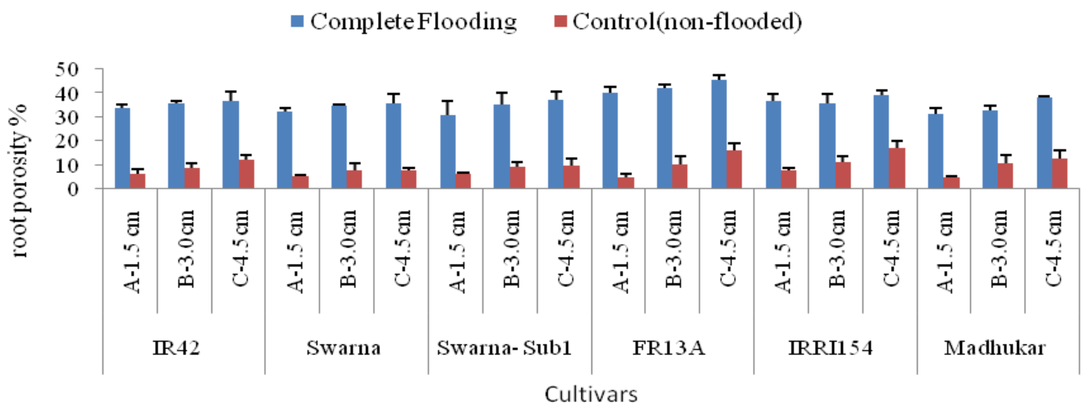

Figure 4. Percent porosity in root of the six rice cultivars 14 days after complete flooding at 100 cm water depth and control treatments under greenhouse condition. Vertical bars represent the standard error bar.

A, B and C are root cross sections at varying distances from the root tip: A= 1.5 cm, B= 3.0 cm, C= 4.5 cm from root tip

Table 12. Correlation coefficient between anatomical root characteristics and percentage of plant survival of the six rice cultivars at the vegetative stage 14 days after complete flooding under greenhouse condition.

ANATOMICAL ROOT CHARAC-TERS	TOTAL AERE-A	% AERE A	% PORO A	TOTAL AERE B	% AERE B	% PORO B	TOTAL AERE C	% AERE C	% PORO C	% SUR
TOTAL AERE-A	1.000	0.799***	0.665**	0.726***	0.657**	0.679**	0.341ns	0.380ns	0.399ns	0.324^{ns}
% AERE-A		1.000	0.677**	0.584*	0.622**	0.620**	0.340ns	0.528*	0.543*	0.283^{ns}
% PORO -A			1.000	0.616**	0.815***	0.829***	0.291ns	0.790***	0.796***	0.215^{ns}
TOTAL AERE-B				1.000	0.648**	0.691**	0.623**	0.597**	0.618*	0.519*
% AERE-B					1.000	0.990***	0.197^{ns}	0.645**	0.669**	0.338^{ns}
% PORO -B						1.000	0.177^{ns}	0.637**	0.659**	0.333^{ns}
TOTAL AERE-C							1.000	0.580*	0.592**	0.462^{ns}
% AERE-C								1.000	0.997**	0.274^{ns}
% PORO -C									1.000	0.298^{ns}
% SUR										1

*** = highly significant at $P < 0.001$ level, ** = significant at $P < 0.01$ level, * = significant at $P < 0.05$ level, ns= not significant
Where: AERE = aerenchyma, PORO= porosity and % SUR = percentage of plant survival
A, B and C are root cross sections at varying distances from the root tip: A= 1.5 cm, B= 3.0 cm, C= 4.5 cm from root tip

results. Root lengths as % of the control were not significantly different.

Number of nodal roots

The numbers of roots were highest in the order - Madhukar > FR13A >IRRI 154. Their root lengths, however, were not statistically different from each other under complete flooding (Table 4). In the control the highest number of nodal roots was noted in IRRI 154 and Madhukar, both are stagnant flooding tolerant cultivars. Number of roots as % of the control was significantly reduced in all six rice cultivars after complete flooding (Table 4). The least reduction in root growth was observed in IR42 cultivar. The results agreed with the previous study of Mishra and Salokhe (2008) who stated that initially, root growth was limited which was important for the development of greater number of nodal roots under hypoxic soil conditions.

Root dry weight (g)

The root dry weights of the six rice cultivars were significantly reduced after complete flooding (Table 5). The least reduction in root dry weight was observed in Madhukar at 0.79g. This corresponds to about 91.94% of the control value. The lowest root dry weight was noted in Swarna-Sub1 which also showed greatest reduction in root growth (Table 3). IR42, Swarna and Swarna-Sub1had the lowest dry weights, but are not statistically different from each other under non-flooded condition (Table 5). The results agreed with the earlier study of Kato and Okami (2011) both tolerant and sensitive rice cultivars gave almost similar root growth after complete flooding.

Root -Shoot biomass ratio

The root-shoot biomass ratio of the six rice cultivars increased significantly under complete flooding (Table 6). The root-shoot ratio of Madhukar was the highest among the cultivars under complete flooding while the other five cultivars did not differ significantly. This confirms that Madhukar is tolerant to flooding. On the other hand, the root shoot ratios of the six rice cultivars were not significantly affected under non-flooded condition. This result was in agreement with the findings of Dandeniya and Thies (2012) who observed that root shoot biomass ratio increase under continued flooding as compared with aerobic condition.

Plant survival (%)

Percent survival of the six rice cultivars was not significantly different before flooding under greenhouse condition. FR13A and Swarna-Sub1 showed the highest % plant survival 21 days after de-flooding, (Table 7). FR13A was tolerant to flooding at the vegetative stage. Previous studies identified four QTLs in FR13A that are associated with flooding tolerance beside the major QTL SUB1 (Nandi et al., 1997).

Swarna-Sub1 has high survival following complete flooding. This is because this genotype did not elongate during flooding, conserving energy for survival and recovery after deflooding. This result was in agreement with the early repot of Singh et al., 2011. These observations confirmed the result of previous studies showing that SUB1 is effective in conferring tolerance to transient flooding (Sarkar et al., 2009). The lowest survival was observed in the sensitive cultivar IR42 as shown in Figure 1. This result agreed with Das et al. (2005) who reported that flooding for 10 days resulted in high mortality of IR42.

Shoot length (cm)

The shoot length was significantly different among the six rice cultivars under complete flooding and control conditions. Madhukar showed the longest shoot under both control and complete flooding. The shoot length of Swarna-Sub1 showed no significant changes after complete flooding compare to non-flooded condition while shoot length of the sensitive cultivar IR42 and Madhukar was increased after flooding as shown in Table 8. The result agrees with the earlier report that inhibition of shoot growth caused anaerobic respiration under complete submergence (Ria and Murty, 1976).

Stem dry weight (g)

Stem dry weight of the six rice cultivars was significantly different under complete flooding. The stem dry weight of FR13A was the highest while Swarna and Swarna-Sub1 were lowest following complete flooding. FR13A showed the highest stem dry weight and IR 42 showed the lowest stem dry weight under non-flooded condition as shown in Table 9. The present study indicated that all tolerant and sensitive cultivars showed over 75% loss in stem dry weight compared with the control.

Leaf dry weight (g)

A highly significant difference was observed in leaf dry weight between the six rice cultivars following complete flooding. Madhukar had the highest and Swarna-Sub1 had the lowest in leaf dry weight under complete flooding condition. Leaf dry weight was also significantly different among six rice cultivars under non-flooded condition, being highest in Madhukar and lowest in IR42. As percentage of the control, leaf dry weight showed over 90% reductions following flooding as shown in Table 10. The result suggested that leaf dry weight of both tolerant and susceptible six rice cultivars were similarly affected by complete flooding.

Leaf-shoot weight ratio (LSWR)

The leaf-shoot weight ratios (LSWR) of the six rice cultivars under non flooded condition (control) did not differ except for FR13A which had the lowest leaf weight ratio. There was no significant difference in this character among the rice cultivars after complete flooding. However, the decrease in LSWR (as % of the control value) per cultivar after complete flooding was highly significant (Table 11).

Root aerenchyma formation

The total aerenchyma and percentage aerenchyma refers to area of the cortex occupied by aerenchyma cells. The highest increase of total aerenchyma in all three sections under complete flooding was found in FR13A, tolerant genotype to complete flooding at the vegetative stage. The highest total aerenchyma was noted in the C sections of the six rice cultivars under complete flooding (Figure 2). This indicates that more aerenchyma is observed in root sections farther away from the root tip as has been reported before (Armstrong et al., 1982, 1983).

Root aerenchyma percentage

Percentage aerenchyma in all three sections (A, B and C) increased in different rice cultivars after complete flooding. These characteristics were not significantly different between complete flooding and control condition. Aerenchyma in section C in most roots of the rice cultivars increased more than in sections A and B. FR13A showed the highest increase in % aerenchyma among the six rice cultivars (Fig. 3).

Root porosity percentage

Root porosity (%) was not significantly different between complete flooding and control. Root porosity of the three root sections of all six rice cultivars increased under complete flooding. FR13A showed the highest increase in % root porosity after flooding (Fig. 4). Therefore, the increased formations in total aerenchyma obviously result in the higher % aerenchyma and % root porosity after complete flooding. These results support the findings of Malik et al., (2003) who reported that increased porosity is due to the formation of aerenchyma along the entire root length. However, % aerenchyma and root porosity depend on the root cross sectional area of cultivars.

Correlation between root anatomical characters and percentage of plant survival

The relationships between root anatomical characteristics and plant survival of the six rice cultivars under complete flooding are presented in Table 12. In Anatomical root characteristics, except total aerenchyma in root section B, all of total aerenchyma, % aerenchyma and % root porosity in root section A and C were not significantly correlated with plant survival percent. Total aerenchyma in root section B was positively and significantly correlated with the percentage of aerenchyma and the percentage of root porosity in sections B and C, and also slightly correlated with the percentage of plant survival. This result suggests that greater aerenchyma formation provides to greater percentage of aerenchyma and percentage of root porosity under complete flooding. And finally, higher plant survival was strongly correlated with greater total aerenchyma in root section B.

Conclusion

The result clearly suggested that complete flooding restricts development of morphological and anatomical characteristics during the vegetative growth. The greatest reduction in root length, root dry weight, leaf dry weight, and leaf-shoot weight ratio was noted in Swarna-Sub1. However, the shoot length of Swarna-Sub1 did not change after complete flooding and its root-shoot ratio increased. Additionally, Swarna-Sub1 had high survival percentage under complete flooding as repeatedly reported before.

The lowest reduction in root growth, number of roots, and root dry weight of FR13A was observed after complete flooding. FR13A exhibited slight changes in shoot length and showed highest survival percentage. It can be concluded that FR13A was tolerant to complete flooding. On the other hand, IR42 showed significant changes in shoot length and its root-shoot junction become soft after complete flooding and indicative of plant mortality. Moreover IR42 showed the lowest survival and low recovery rate after de-flooding. This is because of its high sensitivity to complete flooding. The results proved that increased changes in root aerenchyma formation and root porosity occurred after complete flooding. FR13A had the highest increase in total aerenchyma, percentage of aerenchyma, and percentage of root porosity in root sections -C under complete flooding. Generally, the higher the total aerenchyma, and the greater the percentage of root porosity observed after complete flooding. However, the percentage of root porosity is decreased based on the influence by total cross sectional area of some cultivars. In this study, total aerenchyma is correlated with plant survival rate and it is suggested that the more aerenchyma observed in rice root, better will be the chances of plant survival of complete flooding.

Acknowledgement

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Appendix figure

(a) Complete Flooding (100 x magnification).

IR42 (A) IR42 (B) IR42 (C) Swarna (A) Swarna (B) Swarna (C)

(b)Non- Flooded (Control) (50x magnification).

IR42 (A) IR42 (B) IR42 (C) Swarna (A) Swarna (B) Swarna (C)

Figure 5. Aerenchyma formation in IR42 and Swarna roots (a) before flooding, (b) during complete flooding, and (c) non-flooded (control)

(a) Complete Flooding (100 x magnification)

Swarna-Sub1 (A) Swarna-Sub1 (B) Swarna-Sub1 (C) IRRI154 (A) IRRI154 (B) IRRI15 (C)

(b) Non- Flooded (Control) (50 x magnification).

Swarna-Sub1 (A) Swarna-Sub1 (B) Swarna-Sub1 (C) IRRI 154 (A) IRRI 154 (B) IRRI 154 (C)

Figure 6. Aerenchyma formation in Swarna-Sub1 and IRRI154 roots (a) before flooding, (b) during complete flooding, and (c) non-flooded (control)

(a)Complete Flooding (100 x magnification).

Madhukar (A) Madhukar (B) Madhukar (C) FR13A (A) FR13A (B) FR13A (C)

(b) Non-Flooded (Control)(50 x magnification).

Madhukar (A) Madhukar (B) Madhukar (C) FR13A (A) FR13A (B) FR13A (C)

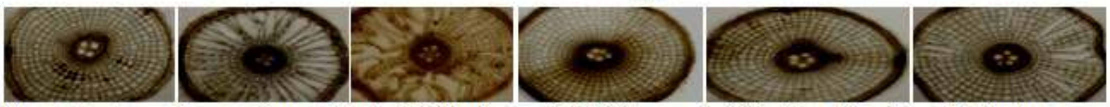

Figure 7. Aerenchyma formation in Madhukar and FR13A roots (a) before flooding, (b) during complete flooding, and (c) non-flooded (control)

A, B and C are root cross sections at varying distances from the root tip: A= 1.5 cm, B= 3.0 cm, C= 4.5 cm from root tip

Impact assessment on agricultural production and coping strategies to flood InKambalu township, Sagaing region

San San Myint[1] and Yu Yu Tun[1]

Abstract

In Myanmar, floods are the most frequent and devastating natural disasters that affect the livelihood of the people. Previously, flood was brought by Cyclone Komen mainly affected the rural areas of Myanmar where people rely heavily on agriculture to support their livelihoods. Therefore, this study was an attempt to know a short term impact of flood by comparing socioeconomic and agricultural production of flood affected sample farmers before and after flood and coping strategies adopted by sample farm households in Kambalu Township, Sagaing Region. Primary data were obtained from 135 flood affected farm households from six sample villages by using purposive random sampling method. Focus group discussions (FGD) and key informant (KI) interviews were also carried out to enrich the data from household survey. The sample farm households were categorized into three groups: seriously affected, moderately affected and less affected farmers according to their damaged crop areas due to flood. Descriptive analysis, paired sample t-test and Pearson Chi-square test were used to compare the data among the three different categories of flood affected sample farm households. It was observed that there were significantly different in the farm and livestock assets of harrows, ploughs and boats, chicken and cattle in seriously and moderately affected groups but slightly different in less affected group before and after flood. The flood extremely reduced yield of monsoon paddy, sugarcane and maize among three groups. The lower yield of crop production resulted lower farm income in all groups. Therefore, sample farm household groups faced with insufficient farm investment and they adopted commonly reducing household expenditure, borrowing money, selling household assets and livestock as their coping strategies. As a result, there is needed to create non-farm income activities and credit, improved agricultural technology, disaster awareness information and adaption's education program to overcome the negative impact of disaster.

Keywords: affected farm households, flood, agricultural production, coping strategies

Introduction

With the passage of time, the impacts of natural and man-made disasters continue to increase. Myanmar has experienced a number of natural disasters such as floods, cyclones, earthquakes and landslides that have caused serious damages in the recent years. The disaster affects not only the lives of the population but also production and productive assets

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especially in the rural area.

More recent disasters in Myanmar included the tsunami in 2004, severe landslides in the mountainous region in 2005 and Cyclone Mala in 2006 (Ponja, 2009). In 2008, Cyclone Nargis was the worst natural disaster in the history of Myanmar. It was also the most devastating cyclone to strike Asia. Moreover, as a country prone to heavy rainfall, floods occur regularly during the mid-monsoon period (June to August) in areas traversed by rivers or large streams (Mohamed, 2009). Therefore, on 30 July 2015, the floods that resulted from Cyclone Komen nearly in all over spreading across 12 states of Myanmar's out of 14 states and regions had a severe impact on rural livelihoods that rely on agricultural activities and food security according to a joint Government-United Nations report (UNICEF, 2015). The six most-affected regions/states were Ayeyawady, Bago, Sagaing, Magway, Rakhine and Chin. Among them, Ayeyawady is the most affected region in terms of destroyed crops with more than 100,000 ha of cultivated land washed away due to floods and a total loss of crops. Sagaing is the second most affected region with over 30,000 ha of cultivated land washed away, followed by Bago and Magway (FAO, 2015). In the lower part of Sagaing region included in Central Dry Zone of Myanmar, Kambalu Township was the worst affected Township in terms of destroyed crop's areas on cultivated land (DoA, 2016). The reason why Kambalu Township was selected as the study area is to understand socioeconomic and agricultural conditions of affected farm households before and after flood.

Data collection and data analysis

Both primary and secondary sources of data were used in this study. Field survey was carried out in October 2016, one year period after flood in 2015. The primary data were gathered by household interview, focus group discussions and key informant interview by using purposive random sampling method. A total sample of 135 flood affected farm households from six sample villages were interviewed by using structural questionnaire.

Descriptive statistics were used to identify socioeconomic and agricultural conditions before and after flood and coping strategies used by affected farm households. Four focus group

Table 1. Groups of the sample farm households according to different flood affected levels

Category	Village	Farm households
Group I (seriously affected - above 1.0 ha)	Pauk Sein Kone Zee Ka Nar Shaw Phyu Kone	55 (40.74%)
Group II (moderately affected - 0.4 ha to 1.0 ha)	Kya Khat Aingh Koe Taung Boet	55 (40.74%)
Group III (less affected - less than 0.4 ha)	Pay Kone (South)	25 (18.52%)
Total		135 (100.00%)

discussions and five key informant interviews were conducted to discuss the effects of flood experienced by affected farm households, local perspectives of agricultural livelihoods and what coping strategies they used to overcome the impact. Pearson Chi- square test and paired sample t-test were used to process sets of primary data with Microsoft excel and SPSS version 17 software.

Results and discussion

Background information of sample farm households in the study area

Kambalu Township in Sagaing region is one of the seriously affected areas of the flood in 2015 due to the heavy rains in Myanmar from the effect of Cyclone Komen. The sample farm households were collected from the sample village of Pauk Sein Kone, Zee Ka Nar, Shaw Phu Kone, Kya Khat Aingh, Koe Taun gBoet and Pay Kone (South) in Kambalu Township, Sagaing Region (Table 1).

Classification of sample farm households

The selected sample farm households were categorized based on their damaged cultivated crop area due to flood into three groups: seriously affected (group I)-farm households damaged cultivated crop area of above 1.0 ha; moderately affected (group II)-farm households damaged cultivated crop area of 0.4 ha to 1.0 ha and less affected (group III)-farm households damaged cultivated crop area of less than 0.4 ha. There were 55 sample farm households in each seriously and moderately affected group and 25 sample farm households in less affected group (Table 1).

Socioeconomic and agricultural conditions after flood

According to the focus group discussions of seriously and moderately affected groups, participants mentioned that monsoon paddy was the most seriously damaged crop and followed by sugarcane. Key informant and participants from less affected group also expressed that crop yield reduced to two third of last year where maize was the most affected crops and consequently crop income was significantly reduced.

(Age range 28-60 years, two males, six females, FGD, Shaw PhuKone Village - group I)

(Age range 49-77 years, eight males and one female, FGD, KoeTaungBoet Village -group II)

(43 years, male, KI interview, KyaKhatAingh Village _ group II)

(Age range 35-60 years, all males, FGD & 57 years old, female, KI interview Pay Kone Village - group III)

Discussions of farmers and key informants on the impact of flood

Participants from focus group discussion of seriously and moderately affected groups described that they encountered with many losses of farm and livestock assets and crop fields, pest and disease problems and insufficient of farm investment. Participants and key informant of seriously affected group discussed that the flood mainly damaged monsoon paddy and sugarcane fields and some cultivated areas was covered by sand. Therefore, they faced many difficulties; low yield, pest or disease infestation and seed scarcity. Participants and key informant of moderately affected group reported that monsoon paddy and sugarcane fields were damaged and therefore, yield reduced up to 50% as compared to before flood. Some affected farmers left the yield of monsoon paddy for home consumption. According to the descriptions of focus group discussion and key informant interviews, monsoon paddy and maize were the most serious crops for less affected farmers.

(Age range 28-60 years, two males, six females, FGD, Shaw PhuKone Village _ group I)

(46 and 42 years, two males, KI interviews, Zee Ka Nar and PaukSeinKone Villages _ group I)

(Age range 49-77 years, eight males and one female, FGD, KoeTaungBoet Village _ group II)

Table 2. Farm assets of three groups of sample farm households before and after flood in the study area

	Group I			Group II			Group III			Total		
Item (Number)	**Before**	**After**	**t-test**	**Before**	**After**	**t-test**	**Before**	**After**	**t-test**	**Before**	**After**	**t-test**
Harrow	1.82	1.44	3.518^{***}	1.29	1.15	2.213^{**}	1.68	1.68	-	1.58	1.36	4.055^{***}
Plough	1.76	1.40	3.833^{***}	1.27	1.13	2.213^{**}	1.64	1.64	-	1.54	1.33	4.295^{***}
Boat	0.53	0.47	1.765^{*}	0.11	0.11	-	-	-	-	0.26	0.24	1.745^{*}
Bullock cart	1.33	1.29	1.427^{ns}	1.00	1.00	-	1.12	1.12	-	1.16	1.14	1.420^{ns}
Sprayer	0.40	0.44	-1.427^{ns}	0.42	0.38	1.000^{ns}	0.52	0.52	-	0.43	0.43	0.000^{ns}
Water pump	0.51	0.51	-	0.24	0.22	0.375^{ns}	0.08	0.08	-	0.32	0.31	0.377ns
Tractor	0.20	0.22	-1.000^{ns}	0.05	0.07	1.000^{ns}	0.04	0.04	-	0.11	0.13	-1.420^{ns}
Well	0.64	0.62	1.000^{ns}	0.33	0.33	-	0.44	0.40	0.043^{ns}	0.47	0.46	1.420^{ns}

Note: ***, ** and * are significant at 1%, 5% and 10% level respectively and ns is not significant.

Table 3. Livestock assets of three groups of sample farm households before and after flood in the study area

	Group I			Group II			Group III			Total		
Item (Number)	**Before**	**After**	**t-test**	**Before**	**After**	**t-test**	**Before**	**After**	**t-test**	**Before**	**After**	**t-test**
Cattle	7.40	6.24	2.107^{**}	3.71	3.22	1.773^{*}	3.48	3.20	0.838^{ns}	5.17	4.44	2.797^{***}
Chicken	18.15	11.07	2.906^{***}	23.69	5.40	1.897^{*}	20.88	14.80	1.474^{ns}	20.91	9.45	2.777^{***}
Duck	0.20	0.47	-1.070^{ns}	-	-	-	-	-	-	0.08	0.19	1.069^{ns}
Pig	2.29	1.89	0.546^{ns}	2.20	1.44	1.262^{ns}	1.64	0.80	1.359^{ns}	2.13	1.50	1.568^{ns}
Sheep/goat	-	-	-	-	-	-	2.50	2.50	-	0.45	0.45	-

Note: *** and ** are significant at 1% and 5% level respectively and ns is not significant.

Table 4. Crop yield of sample farm household groups before and after flood

Item		Before (kg/ha)	After (kg/ha)	Yield reduction (%)	t-test
Group I	Monsoon paddy	2,605.00	1,138.59	56.29	11.176***
	Brown slab-sugar	2,362.00	598.00	74.68	6.804***
Group II	Monsoon paddy	3,114.00	1,197.00	61.56	10.454***
	Brown slab-sugar	2,209.00	642.00	70.94	2.627**
Group III	Monsoon paddy	2,346.99	1,681.06	28.37	3.495***
	Maize	2319.50	1355.89	41.54	3.074***
Total	Monsoon paddy	2,702.51	1294.62	52.10	12.072***
	Brown slab-sugar	2,165.98	624.98	71.15	6.396***
	Maize	2,599.95	938.69	63.90	3.187***

Note: ***, ** and * are significant at 1%, 5% level and 10% level respectively and ns is not significant.

Table 5. Average annual income of sample farm household groups before and after flood

Annual income/Year	Before (MMK)	% of total HH income	After (MMK)	% of total HH income	t-test
Group I (n=55)					
Farm income	4,092,670	90.88	1,712,544	77.19	9.246***
Non-farm income	526,546	9.12	541,582	22.81	-0.102ns
Total HH income	4,619,215	100.00	2,254,126	100.00	7.846***
Group II (n=55)					
Farm income	2,376,130	83.08	981,811	68.19	8.575***
Non-farm income	569,836	16.92	383,182	31.81	1.841*
Total HH income	2,945,967	100.00	1,364,993	100.00	7.427***
Group III (n=25)					
Farm income	2,713,464	91.68	1,750,120	87.49	3.789***
Non-farm income	190,600	8.32	169,112	12.51	0.968ns
Total HH income	2,904064	100.00	1,919,232	100.00	3.973***
Total (n=135)					
Farm income	3,137,930	88.00	1,421,796	75.44	11.159***
Non-farm income	503,452	12.00	408,072	24.56	1.269ns
Total HH income	3,641,382	100.00	1,829,860	100.00	12.261***

Note: *** is significant at 1% level. Here, total HH income is the annual income of all household members including farm income.

Farm assets of sample farm household groups before and after flood

During flooding, the average possession of farm assets such as harrow, plough and boat of all sample farm households were extremely decreased from 1.58, 1.54 and 0.26 to 1.36, 1.33 and 0.24 because some of their farm implements floated along the river or stream. Therefore, the paired sample t-test showed that there was significantly different at 1% level for harrow and plough and at 10% level for boat before and after flood. In terms of specific group, the farm assets such as harrow, plough and boat were significantly decreased from 1.82, 1.76 and 1.53 before flood to 1.44, 1.40 and 0.47 after flood in group I while harrow and plough of group II farm households were also drastically decreased from 1.29 and 1.27 before flood to 1.15 and 1.13 after flood. Therefore, paired sample t-test showed that there was significantly different at 1% level for the average farm assets losses (harrow and plough) in group I and 10% level difference for the average loss of boat as well as 5% level significant difference in the average damage harrow and plough of group II. In group III farm households, the average possession of their farm assets was the same before and after flood. However, it was found that the average possession of farm asset (eg. well) decreased slightly from 0.44 before flood to 0.40 after flood as it was covered by sand due to flood (Table 2).

Livestock assets of sample farm household groups before and after flood

The farm households in the study area used cattle for crop production activities while chicken, pig, duck and sheep also were raised for their extra family income. In all sample farm households, the average number of cattle significantly decreased from 5.17 before flood to 4.44 after flood as they were sold to cope their immediate basic needs due to flood. On the other hand, the average number of chickens was also substantially reduced from around 21 to 9 after flood as it had been killed by flooding. After flood, the average number of cattle and chicken was significantly reduced from approximately 7.40 and 18 to 6.24 and 11 in groups I farm households. Therefore, paired sample t-test showed that there was significantly different at 5% level for cattle and at 1% level for chicken before and after flood. As for group II, the average number of cattle and chicken was reduced from about4 and 24 before flood to 3 and 5 after flood. Therefore, the paired sample t-test showed that there was significantly different at 10% level for cattle and chicken of group II farm households. Moreover, the paired sample t-test showed that no significant difference was found in any livestock of group III farm households before and after flood as it had no seriously loss due to being less affected by flood. Therefore, it was observed that the average number of cattle, chicken and pig were slightly decreased from 3.48, 20.88 and 1.64 before flood into 3.20, 14.88 and 0.80 after flood but the average number of sheep was the same before and after flood in group III (Table 3).

Crop yield of sample farm household groups before and after flood

Most of the farmers in the study area mainly cultivated monsoon paddy in lowland as shown in Table 4. In upland, the main cultivated crops were sugarcane in group I and II and maize in group III farmers before and after flood.

According to the different categories of flood affected level, the average yield of monsoon paddy was highly decreased from over 2,600 kg/ha to about 1,139 kg/ha occupying 56% of yield reduction due to flood in group I farm households. Therefore, paired sample t-test showed that there were significant different at 1% level for the average yield of monsoon paddy before and after flood. Additionally, the average yield of brown slab-sugar was extraordinarily declined from 2,362 kg/ha to 598 kg/ha because the sugarcane fields were deteriorated due to overflow for a long time. As a result, the sample farmers faced with 75% yield reduction of brown slab-sugar as compared to the normal year. Paired sample t-test showed that there was a significant difference at 1% level for average yield of brown slab-sugar.

As for group II, monsoon paddy cultivated farmers faced with 62% yield reduction by decreasing the yield from about 3,114 kg/ha to 1,197 kg/ha after flood. Although the monsoon paddy cultivated farmers in group II was moderately affected by flood, the yield reduction was more than sample farmers in group I because they did not make strong decisions on their farm with the older group of household's head. Paired sample t-test showed highly significant differences at 1% level in average yield of monsoon paddy before and after flood. In regard to upland crop, average yield of brown slab-sugar was decreased from 2,209 kg/ha before flood to 642 kg/ha after flood. In moderately affected group, the yield reduction of brown slab-sugar was nearly three quarter 71% due to flood. Therefore, paired sample t-test showed that there was significantly different at 5% level for average yield of brown slab-sugar before and after flood.

Group III monsoon paddy cultivated farmers also experienced with 28% yield reduction with the average yield of 2,703 kg/ha before flood and 1,295 kg/ha after flood. Therefore, the paired sample t-test revealed that there were significantly different in the average yield of group III farmers before and after flood at 1% level. In upland, group III farmers typically cultivated maize. The yield of maize was significantly reduced from 2,319 kg/ha to 1,356 kg/ha occupying 42% yield reduction due to flood.

In study area, all sample farmers experienced with 52% yield reduction of monsoon paddy because they received the yield of over 2,700 kg/ha before flood and 1,200 kg/ha after flood among the three groups. The paired sample t-test showed significant different for average yield of monsoon paddy at 1% level before and after flood. As for upland crop, the average yield of brown slab-sugar was extremely decreased from approximately 2,166 kg/ha to 625 kg/ha before and after flood. As a result, they encountered 71% yield reduction due to flood.

Discussions of farmers and key informants on coping strategies after flood

Participants from focus group discussion of seriously affected group reported that they coped the difficulties by selling households assets and livestock and borrowing money with various interest rate from the broker of brown slab-sugar to solve their basic needs after flood. Participants and key informant of moderately affected group mentioned that the affected farm households sold household assets and livestock and taking money with 7 to 8% interest rate from neighbor or money lender. In addition, participants from less affected group stated that farm income reduced more than before flood due to low crop yield and therefore they used reducing expenditure and borrowing money as the coping strategies.

(Age range 28-60 years, two males, six females, FGD _ Shaw PhuKone Village & 46 and 42 years, two males, KI interviews, Zee Ka Nar and PaukSeinKoneVillages-group I)

(Age range 49-77 years, eight males and one female, FGD, KoeTaungBoet Village & 43 years, male, KI interview, Kya Kyat Aingh Village - group II)

Therefore, paired sample t-test showed that highly significant differences were found in the average yield of brown slab-sugar before and after flood. According to the results, the average yield of maize substantially decreased from 2,599 kg/ha before flood to 939 kg/ha after flood. Therefore, they faced with yield reduction by 64% for maize due to flood. Paired sample t-test showed that there were significantly different at 1% level for the average yield of maize before and after flood among the three groups.

Average annual income of sample farm household groups before and after flood

In the study area, farm income was significantly reduced after flood due to yield reduction. In Table 5, the average annual farm income of all sample farm households was highly declinedfrom 3,137,930 MMK to 1,421,796 MMK after flood. Simultaneously, the average annual household income of all sample farm households was also decreased from 3,641,382 MMK to 1,829,860 MMK after flood. Therefore, the paired sample t-test revealed significant different in the average annual household and farm income of all sample farm households at 1% level before and after flood. In group I, highly significantly differences were found in average annual farm income and average annual household income at 1% level by declining from 4,092,670 MMK and 4,619,215 MMK before flood to 1,712,544 MMK and 2,254,126 MMK. As for group II, the average annual farm income, non-farm income and annual household income of sample farm households drastically decreased from 2,376,130 MMK, 569,836 MMK and 2,945,967 MMK before flood to 981,811 MMK, 383,182 MMK and 1,364,993 MMK after flood respectively. Therefore, paired sample t-test showed significant difference at 1% level for average farm and total household income and at 10% level for non-farm income. Furthermore, highly significant differences at 1% level were found in average annual farm income and annual household income of group III farm households due to reducing from 2,713,464 MMK and 2,904,064 MMK to 1,750,120 MMK and 1,919,232 MMK after flood respectively.

Difficulties in farming faced by sample farm household groups after flood

After flood, difficulties in farming faced by sample farm household groups are shown in Table 6. The impact of flood highly reduced yields of the main cultivated crops in the study

Table 6. Difficulties in farming faced by sample farm household groups after flood

No.	Item	% of farm households				
		Group I	Group II	Group III	Total	Pearson Chi-square
1	Low yield	90.91	89.09	72.00	86.67	0.055*
2	Insufficient farm investment	89.09	76.36	44.00	75.56	0.000***
3	Infestation of diseases or pests	78.18	78.18	52.00	73.33	0.028**
4	Scarcity of farm labor	63.64	63.64	40.00	59.26	0.095**
5	inadequate use of fertilizer amount	58.18	52.73	20.00	48.89	0.005***
6	Inadequate of quality seeds	45.45	63.64	10.00	50.37	0.020**

Note: ***, ** and * are significant at 1%, 5% level and 10% level respectively.

Table 7. Coping strategies used by sample farm household groups after flood

No.	Coping strategy	% of farm households				Pearson Chi-square
		Group I	Group II	Group III	Total	
1	Reducing expenditures	74.55	76.36	48.00	70.37	0.025**
2	Borrowing money	69.09	49.09	32.00	54.07	0.005***
3	Selling of livestock	58.18	34.54	20.00	41.48	0.002***
4	Selling household assets	40.00	34.54	24.00	34.81	0.379ns

Note: *** is significant at 1% level and ns is not significant.

area. Therefore, about 91%, 89% and 72% of group I, II and III farm households reported that they faced low yield as the most serious difficulty due to flood. Insufficient of farm investment and infestation of disease or pests were second and third the most serious problems for all groups. Moreover, the difficulties such as labor scarcity, inadequate use of fertilizer and poor quality seeds in farming were also encountered by about 64% to 46% of farm households in group I, 64% to 53% in group II and 40% to 10% in group III respectively.

In summary, for the three groups, low yield in the agricultural production was the main difficulties for about 87% of all sample farm households due to flood in the study area. As a result, about 76% and 73% of all sample farmers faced insufficient farm investment and pest or disease infestation due to flood. Similarly, about 59% of sample farmers had to face labor scarcity for farm in the study area. Approximately 49% and 50% sample farmers had inadequate amount of fertilizer and poor-quality seeds as the main difficulties in their farming too. Pearson Chi-square test showed that there were significant differences at 1% level for insufficient farm investment and inadequate amount of fertilizer, 5% level for infestation of disease or pests, scarcity of farm labor, poor quality seeds and 10% level for low yield.

Coping strategies used by sample farm household groups after flood

The results from Table 7 show the most common coping strategies adopted by sample farm households in the study area. Majority of the sample farm households in each group used reducing household expenditures as their first most coping strategy and the second most for all groups was borrowing money from relatives/neighbors with high interest rate. Moreover, around 56% of the sample farm households in group I, about 35% in group II and 20% in group III adopted selling livestock to cope their immediate basic needs due to flood while selling household assets especially gold were also employed by about 40% of group I, 35% of group II and 24% of group III farm households as their coping strategies after flood. Pearson Chi-square test showed significant difference at 1% and 5% level for borrowing money, selling livestock and reducing household expenditure of sample farm households among three groups.

Summary and conclusion

This study was an attempt to analyze the short-term impact of flood on socioeconomic conditions and agricultural production of sample farm households before and after flood. The serious losses of farm assets due to flood was found in seriously affected group followed by moderately affected group but slightly losses in less affected group. The average number of chicken and cattle were drastically reduced in seriously affected group and moderately affected group. There were no differences for the average possession of any livestock in less affected group before and after flood. As for crop production, the average yields of main cultivated crops were significantly reduced in all three affected groups after flood. This lower yield resulted to lower farm income which led to insufficient farm investment for the upcoming season in different affected groups. In the study area, sample farm household groups commonly used coping strategies like selling household assets and livestock which could cause the lower living standard for farmers in the longer term and borrowing money with high interest rate which leads to higher debt in the future.

According to FGD and KI interview, all affected farm households faced livelihood difficulties due to the lower farm income due to the high yield reduction of main cultivated crops as compare to before flood. As a consequence, they used some coping mechanisms such as selling households assets and livestock and borrowing money with 5% to 8% interest rate to overcome their difficulties due to flood. FGD and KI interview supported to enrich the results and discussion of data from household survey.

As a result, yield reduction of the common crops grown in this area can be seen as the worst short term impact among the losses. To cope the impact of flood, sample farmers commonly used coping strategies based on their resources and knowledge. It also needed to provide the training program and disaster awareness information to prevent the risk and to cope with the impacts of disasters. On the other hand, there is need to create non-farm income opportunities and provide credit to overcome the impact of flood on significant decrease in revenue of crop production.

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Influence of high temperature and relative humidity on pollen germination and spikelet sterility in improved rice varieties

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Abstract

Global warming is expected to increase the occurrence of heat induced spikelet sterility (HISS) in rice. However, there are few field-scale studies that could support in predicting the potential risks to rice yield and developing countermeasures against yield losses. Therefore, this study was carried out to identify the effect of high temperature on pollen fertility and spikelet sterility in improved rice genotypes and to assess the heat tolerance genotypes within the improved rice varieties during 2016 summer rice season. Under this study, a total of twelve improved rice varieties were planted in the field of Department of Plant Breeding, Physiology and Ecology with Randomized Complete Block design. The tested varieties were sown at three different times to ensure engaged with high temperature stress at flowering time. The microclimate, pollination and spikelet sterility were examined. During observation periods, the maximum air temperature was more than 35 °C, at that time the relative humidity was reduced (19-32 %) with high wind speeds (2–4 m s^{-1}). Under such condition, there was supported microclimate for stable pollination even the temperature more than 35 °C. The average duration of high temperature above 35 °C was around 8 hours. Similarly, the average nighttime temperature (7:00 pm – 7:00 am) ranged from 27°C to 32 °C. Among tested genotypes, Thu Kha Yin, Shwe Thwe Yin, Zi Yar 9 and Shwe Ma Naw had higher seed set percentage of panicles (around 58-75 %). The results revealed that these four genotypes were promising genotypes for future breeding program related to heat tolerance.

Keywords: rice, high temperature, relative humidity, pollination, spikelet sterility

Introduction

Crop growth is seriously affected by the changing of climate thus, global warming has become a major constraint for crop production. High-temperature stress is one of the most serious threats to crop production worldwide (Boyer, 1982). The drastic changes in temperature in recent years have caused more frequent occurrence of extreme weather events such as heat waves and drought. The effect of extreme temperature events on crop production is likely to become more frequent in the near future (Tebaldi, 2007). Rice is one of the most im-

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portant food crop for more than half of the world's population (Carriger and Vallée, 2007). In rice, heat stress at flowering and grain filling stages seriously affects spikelet fertility and grain quality. According to the previous chamber experiments, rice is most susceptible to heat stress at flowering (Jagadish et al., 2008) and in field (Tian et al. 2010). At flowering stage, heat-induced spikelet sterility (HISS) is associated with the reduction in grain yield. This is one of the major uncertainties about the future yield prediction of rice crop (Kim and Morr, 1996). In China, temperature above 38 °C, lasting for 20 days during flowering periods, caused yield loss of about 5.18 million tons of paddy rice in 3 million hectares (Tian et al., 2009). During flowering periods of rice, five days exposure of high temperature over 35 °C caused severe spikelet sterility (Satake and Yoshida, 1978). Decreasing of germinated pollen grains in rice occurred on the following day of the extreme high temperature day (Nabeshima, 1988). Moreover, rice grains filling rate significantly decreased by post anthesis warming at nighttime >28 °C (7:00 pm-7:00 am) observed in China (Dong et al., 2014). Likewise, rice grown under high nighttime temperature (32 °C) shown 72% decreased in spikelet fertility (Mohammed and Tarpley, 2009).

Rice pollen is extremely sensitive to temperature and relative humidity (Matsui et al., 1997) and viability losses within 10 min of shedding (Song et al., 2001). The minimum relative humidity required for rice flowering was 40 % and the optimum being 70-80 % (Vijayakumar, 1996). Nevertheless, fertilization of rice was inhibited by wind speed of less than 1m s^{-1} (Tian et al., 2010) and more than 4 m s^{-1} (Viswambharan et al., 1989). In Australia, temperature >35 °C with RH (15 %) combined with the wind speed of 2-4 m s^{-1} supported transpirational cooling effect within rice canopy (Matsui et al., 2014). In contrast to this, temperature ~35 °C, RH of 70 %, with low wind speed (<1 m s^{-1}) induced significant spikelet sterility observed in China (Tian, et al., 2010).

In Myanmar, the flowering and early grain-filling stages of rice are predicted to coincide with high-temperature conditions, especially in summer rice growing season (Maclean, 2002). Therefore, considering the future climate condition, superior heat tolerance rice genotypes are required. More precise knowledge on the susceptibility and tolerance of improved rice varieties to heat stress would contribute for improving future breeding programs. Accordingly, this research was conducted by the following objectives: (i) to identify the effect of temperature on pollen fertility and spikelet sterility of improved rice varieties under higher temperature and (ii) to access the heat tolerance genotypes within the improved rice varieties.

Materials and methods

The experiment was conducted at the experimental field of Plant Breeding, Physiology and Ecology, Yezin Agricultural University, Nay Pyi Taw, during 2016 summer season. It is located on 19° 52' N latitude and 96° 07' E longitude. Twelve improved rice varieties

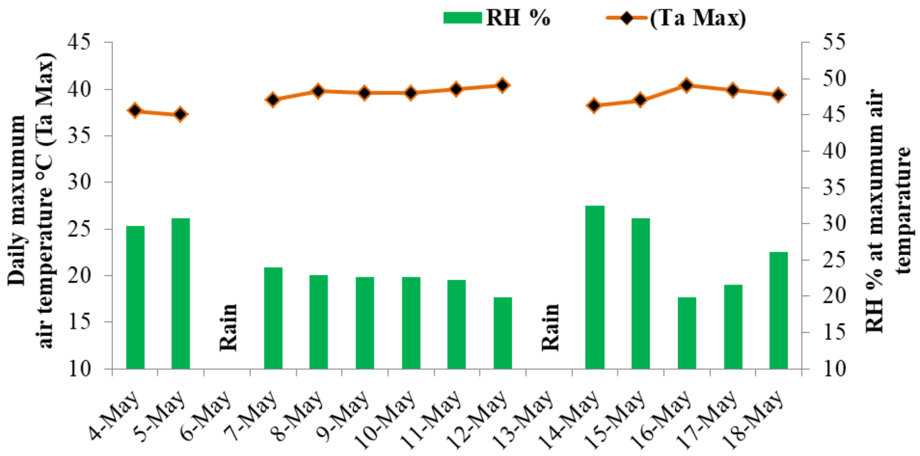

Figure 1. Change in daily maximum air temperature (Ta Max., line) and relative humidity(RH %., bars) at the time of maximum air temperature at the center of the experimental field.

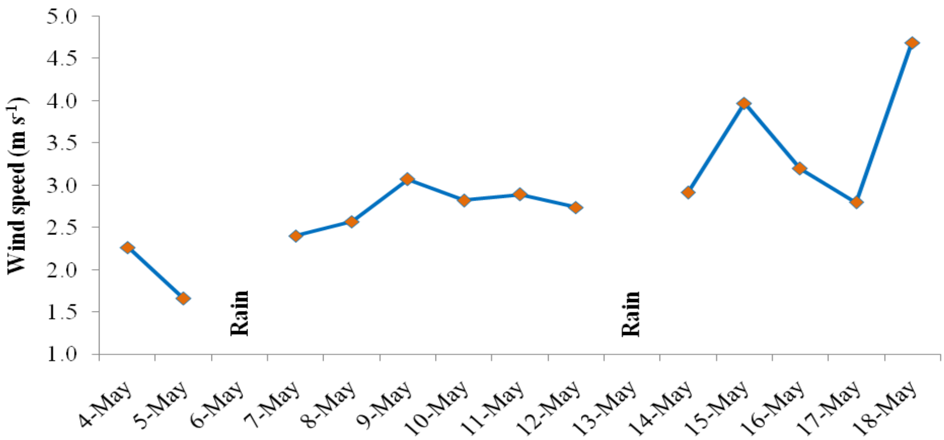

Figure 2. Wind speed (m s^{-1}) at the time of peak flowering (10-12 am).

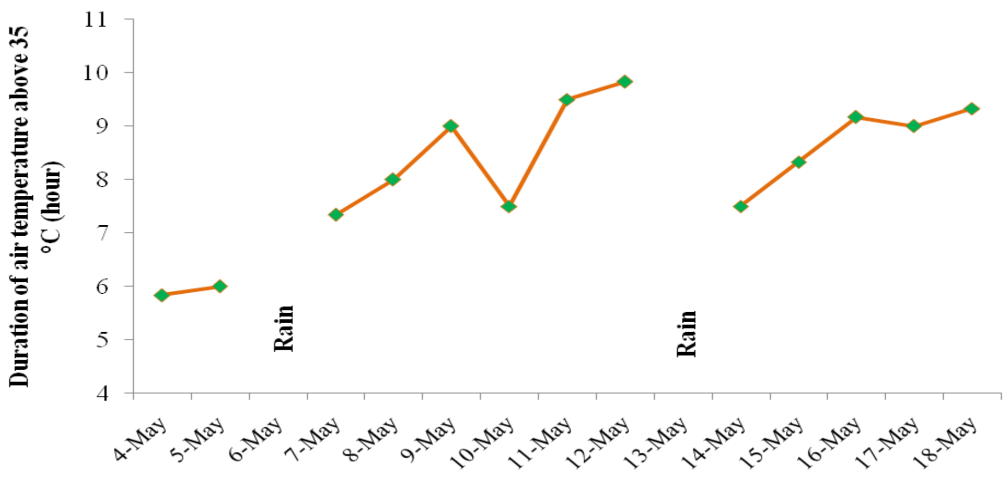

Figure 3.Duration of air temperature above 35 °C (hour) during observation period.

(Appendix 1) that are suitable for summer rice seasons, were sown in a Randomized Complete Block Design with three replications. The size of experimental field was about 2023 m^2. The field was first divided into three parts, for sowing of Crop I, Crop II and Crop III. The sowing dates were 6th -15th Feb (Crop I), 11th -20th Feb (Crop II) and 16th -25th Feb (Crop III) because of different flowering dates within genotypes. These three staggered sowing time enabled to observe pollination of cultivars that require different number of days to heading at the same time in a range of temperatures during the hottest season (late April to early May). Each plot was 2.6 m (east-west) by 1.2 m (north-south) with the spacing of (20 ×15) cm and was divided into two parts in which, pollen germination (25 hills) and panicle fertility (25 hills) were examined. Each block was bordered by five rows of rice (about one meter). When the seedlings were 20-30 days old, they were transplanted to the field. Seedlings were transplanted into the field at a density of 126 hills per plot with 2-3 plants per hill (40 hills m^{-2}). The soil was sandy-loam and the PH was 6.5. Prior to paddling, compound fertilizer (Armo, N:P:K-15:15:15) was applied at the rates of 123 kg per hectare, recommended for sandy-loam soil by the Department of Agricultural Research (DAR). Ten days and thirty days after transplanting, Urea fertilizers were applied at the rates of 62 kg per hectare for top dressing of each crop (I, II and III). The field soil was kept submerged until the ripening stage. The heading dates (50% flowering) of the genotypes are listed in Appendix 2.

Meteorological conditions in the experimental field

The site's microclimate (air temperature, relative humidity and wind speed of the experimental field) was measured at the center of the experimental field. When heavy rainfall occurred, the measurement was stopped. The wind was mainly from the south during experimental period. The temperature and humidity sensor (WXT520, Vaisala Inc., Helsinki, Finland) with radiation shield was measured in the center of the experiment field, about 255 cm above the soil surface (130 cm above the top of the canopy). Measurements were taken every 10-min averages and recorded in data logger (CR10X, Campbell Scientific Inc., Logan, UT, USA).

Pollination and seed set

The pollination and seed set were examined during heading periods of all genotypes 8-17 May (except the rainy day). Genotypes with the same flowering periods were used for the examinations. For observation of pollination, 10 florets on the primary rachis branches were sampled from each genotype in each plot every day from 8-17 May. About 2 hour after anthesis, the florets were sampled, following which the stigmata were detached from the florets and stained with cotton blue. After staining, the numbers of total and germinated pollen grains on the stigmata in each floret were counted with an optical microscope (G-206, Digisystem Laboratory Instruments Inc, Taiwan). For examination of the seed set, panicles that mainly flowered during the observation period were

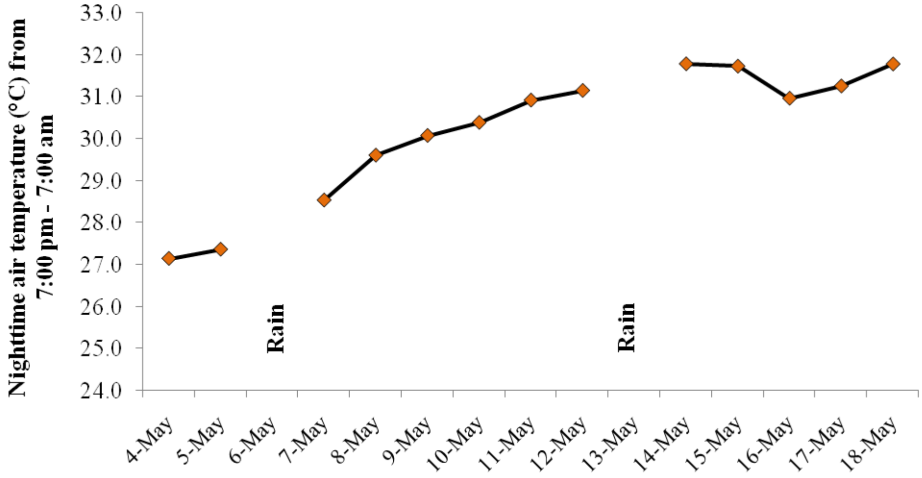

Figure 4.Average nighttime air temperature (°C) from 7:00 pm to 7:00 am during the observation period.

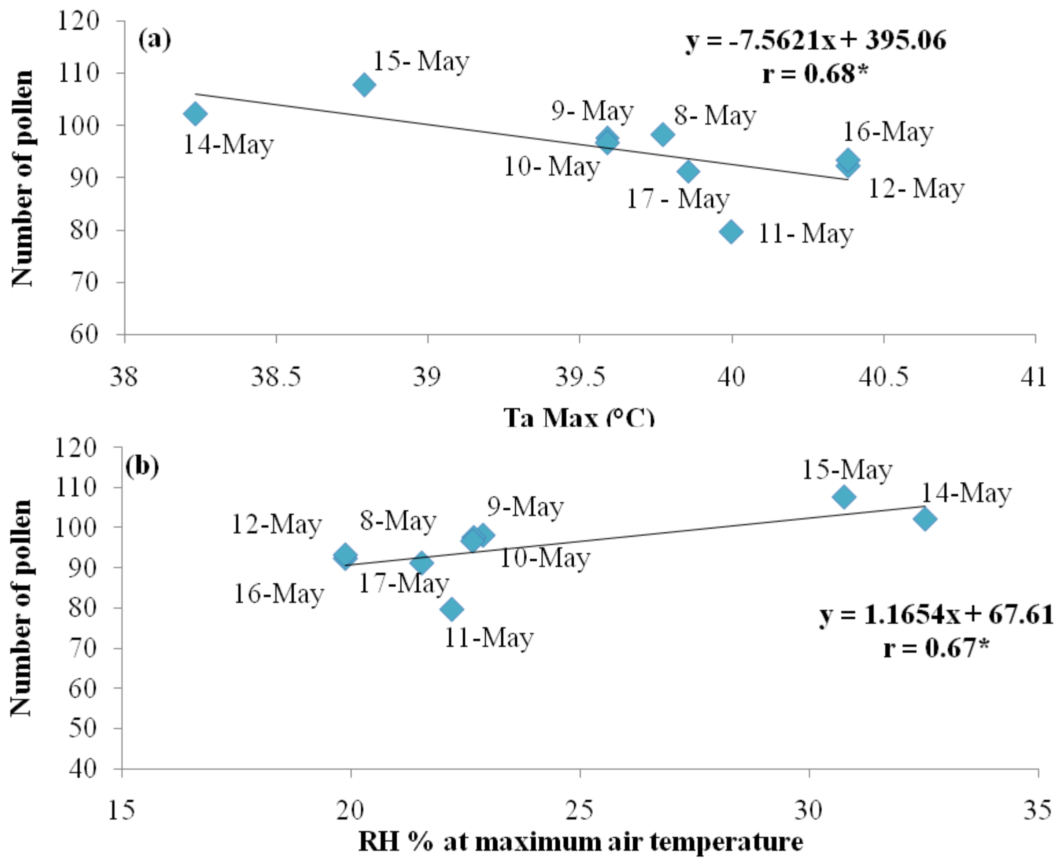

Figure.5 (a). Relationship between Pollen shedding on the stigma and daily maximum air temperature (Ta Max °C) and (b) relationship between pollen shedding on the stigma and relative humidity (RH %) at the time of maximum air temperature.

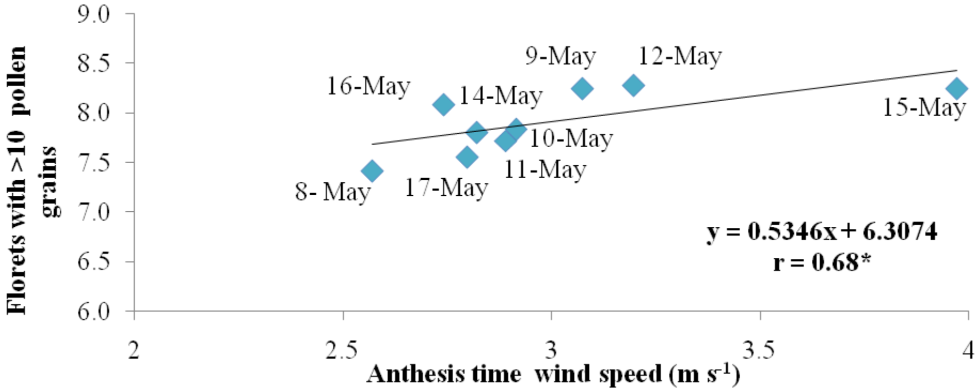

Figure. 6. Relationship between anthesis time (peak flowering) wind speed (m s^{-1}) and florets with more than 10 pollen grains on the stigma.

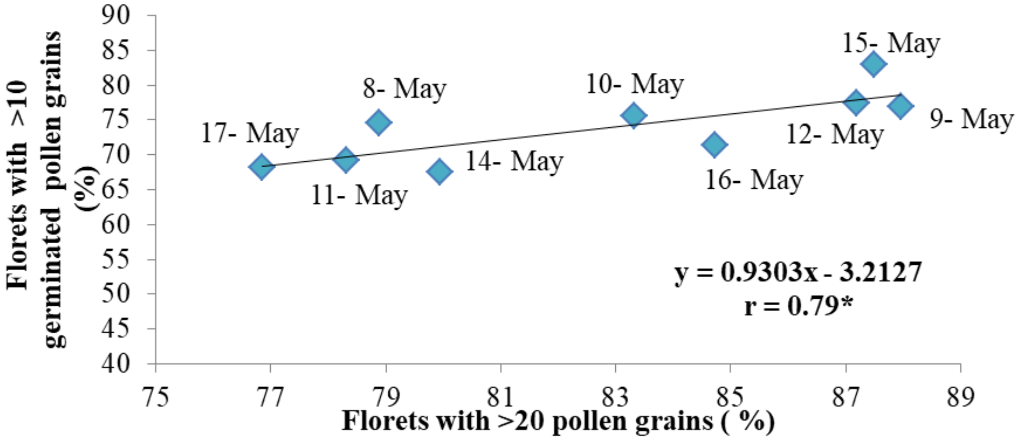

Figure.7.Relationship between percent florets with more than 20 pollen grains and percent florets with more than 10 germinated pollen grains on the stigma.

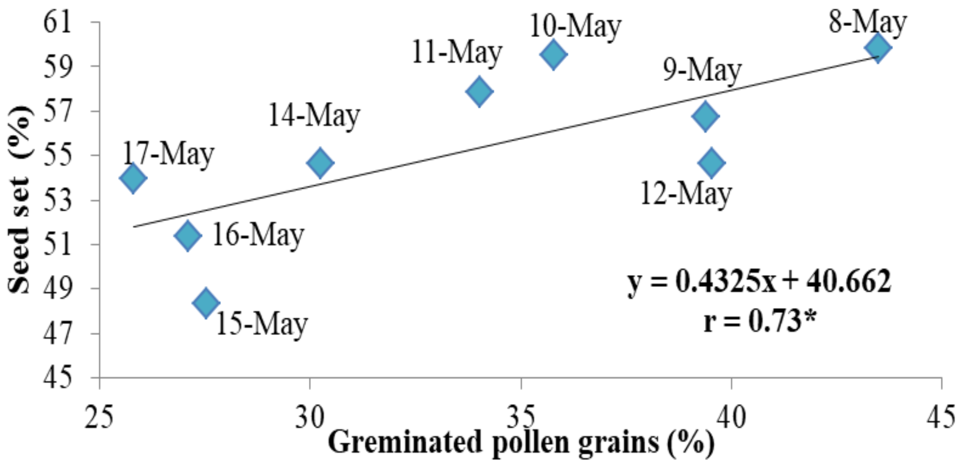

Figure.8.Relationship between germinated pollen grains percentage and seed setting percentage.

Table 1. Mean values of Pollen grains, germinated pollen grains on the stigma and seed set percentage of panicles that mainly flowered during observation period (8-17 May)

Variety	PG No.	GPG No.	GPG (%)	>20 PG (%)	>10GPG (%)	Seed set (%)
Yeanelo-4	144.6 **ab**	43.0 **ab**	32.6 **a-c**	91.3 **a**	85.6 **ab**	50.6 **cd**
Yet 100	67.0 **d**	24.6 **c-e**	38.3 **ab**	85.0 **a-c**	74.3 **a-c**	49.4 **cd**
Thu Kha Yin	90.0 **cd**	32.0 **a-e**	34.3 **a-c**	90.3 **ab**	81.0 **ab**	75.5 **a**
ShwePyiHmwe	119.0 **bc**	37.0 **a-c**	31.6 **bc**	94.0 **a**	88.0 **a**	47.4 **d**
Shwe Myanmar	61.3 **d**	22.6 **c-e**	38.0 **ab**	83.6 **a-c**	71.3**b-d**	50.1 **cd**
MR 9	65.3 **d**	20.3 **de**	33.0 **a-c**	69.6**cd**	56.3 **de**	49.0**cd**
Shwe Ma Naw	102.0 **cd**	31.0 **a-e**	32.0 **bc**	85.3 **a-c**	79.3 **ab**	57.8 **b-d**
Yar 2 Tun	62.3 **d**	17.6**e**	30.3 **bc**	63.3 **d**	49.6 **e**	51.7**cd**
ZiYar 9	95.3 **cd**	31.6 **a-e**	34.6 **a-c**	81.6 **a-c**	76.0 **a-c**	66.0 **a-c**
Thee Htet Yin	90.0**cd**	27.3 **b-e**	30.0**bc**	74.6 **b-d**	60.0 **c-e**	47.4 **d**
ShweThwe Yin	85.3 **cd**	35.6 **a-d**	42.3 **a**	85.0 **a-c**	82.3 **ab**	71.2 **ab**
KTD	162.3 **a**	43.6 **a**	27.0 **c**	87.6 **ab**	81.3 **ab**	29.8 **e**
LSD $_{0.05}$	**42.0**	**15.8**	**10.1**	**16.0**	**16.0**	**17.3**
Pr>F	**	**	**	**	**	**
CV%	**14.8**	**17.4**	**10.1**	**6.5**	**7.3**	**10.8**

Note: **Note**: **PG No.**= Pollen grain number, **GPG No**.= Germimated pollen grain number, **GPG (%)** = Germinated pollen grain percentage, **>20 PG (%)** = Floret with greater than 20 pollen grain percentage, **>10 GPG (%)** = Floret with greater than 10 germinated pollen grain percentge, **Seed Set (%)** = Seed setting percentage on panicle. Mean value with the same letters are not significant at p<0.05 level (Tukey's HSD test).

tagged and sampled at maturity and their seed setting were examined by manual inspection.

Data analysis

The effects of genotypes and observation periods on the percentage of seed set were examined with the analysis of variance. Then, the differences between the mean of seed set percentage of samples were analyzed by Tukey's HSD test at a probability level of 0.05.

The percentages of florets having more than 20 pollen grains and more than 10 germinated pollen grains on the stigma were calculated. The effects of sampling dates and genotypes were examined with analysis of variance. The correlation between the observation dates, pollen grains percentage on the stigmata, germinated pollen grains percentage on the stigmata and percentage of seed set on the panicles were analyzed with Statistical tools for Agricultural Research (STAR) software, version, 2.0.1.

Results

The daily maximum air temperature during the flowering period (4-18 May) ranged from 37.2 to 40.4 °C and at that time the relative humidity were 19.9-32.5 % (fig. 1). On the other hand wind speed at the time of peak flowering (10-12 am) ranged from 1.7 to 4.7 m s^{-1} (fig. 2). Moreover, the duration of air temperature over 35 °C (that cause heat induced spikelet sterility) during observation periods ranged from 5.83 to 9.83 °C (fig. 3). Furthermore the averaged night time air temperature (°C) from 7:00 pm to 7:00 am reached between 27.1 to 31.8 °C during the observation period (Fig. 4).

Pollination

From 8 to 17 May (evaluation period), it was observed that, the number of pollen grain shedding on the stigma were negatively correlated (r= 0.68*) with the daily maximum air temperature in twelve genotypes (fig. 5, a). However, the number of pollen that shedding on the stigma were positively correlated (r=0.67*) with the relative humidity (RH %) at the time of maximum air temperature (fig.5, b). Similarly the wind speed at the time of anthesis (peak flowering) was positively correlated (r=0.68*) by florets with more than 10 pollen grains on the stigma (fig. 6). Moreover, percent floret with more than 20 pollen grains on the stigma was positively correlated (0.79*) with percent florets with more than 10 germinated pollen grains (fig. 7).

Seed set

According to the effect of observation dates, the percentage of germinated pollen grain was positively correlated (r=0.73*) with the seed set percentage of twelve genotypes (fig. 8). On the other hand the effects of genotypes and observation period on the percentage of pollen grains, germinated pollen grains shedding on the stigma and seed setting percentage were significant at p= 0.01** across all genotypes. The percentage of seed set of florets that mainly flowered in the observation period ranged from 29.8 to 75.5 % across genotypes (Table.1).

Discussion

Environmental factors related to pollination and fertilization

The daily maximum air temperature during the evaluation period (8-17 May) reached to the threshold temperature over 35 °C which induced pollen and spikelet sterility. However the relative humidity (RH %) at the time of daily maximum temperature was lower than the optimum RH (60-80 %) for rice flowering period. Moreover, wind speed at the time of peak flowering (10 AM -12 PM was seem to be supportive (3-4 m s^{-1}) transpirational cooling effects for pollination and fertilization. Although, the negative correlation observed between daily maximum temperature and pollen grains number that shedding on the stigma (fig. 5,a), there were positively correlated in RH % at maximum temperature, wind speed (m s^{-1}) at peak flowering with pollen grains (fig. 5,b) and florets with more than 10 pollen grains shedding on the stigma (fig.6). The same results revealed in flooded-irrigated field in New South Wales, Australia, strong transpirational cooling effect for pollination was supported by very lower RH % (15 %) combined with the wind speed of 2-3 m s^{-1}, even the daily maximum temperature over 35 °C (Matsui et al., 2014). In contrast, the daily maximum air temperature around 35 °C under humid condition (RH=70 %) with very low wind speed (<1m s^{-1}) caused poor fertilization and seed setting. Therefore, humidity and wind speed should regard as the important factors while the temperature around 35 °C in the open field conditions.

Moreover, percent florets with more than 20 pollen grains on the stigma ranged from 63 to 94% (n=81) and percent florets with more than 10 germinated pollen grains on the stigma were among 49 to 88% (n=81) as shown in Table 1. Furthermore, percentage of florets with more than 20 pollen grains was positively correlated with percent florets with more than 10 germinated pollen grains on the sitgma (fig.7). More than five or ten germinated pollen grains were required on the stigma of each floret for successful fertilization (Satake and Yoshida, 1978). Many florets with five or more germinated pollen grains had more than 10 total pollen grains on the stigma in field condition (Tian et al., 2010). The above finding stated that the successful fertilization strongly depended on the germinated pollen grains on the stigma. This study agreed with the above statements because the 49 to 88 % of germinated pollen grains on the stigma seem adequate for successful fertilization.

Effect of temperature duration and high nighttime temperature on seed setting

On the other hand, the percentage of germinated pollen grains on the stigma was positively correlated (r=0.73*) with the seed setting percentage of panicles that mainly flowered during the evaluation period (8-17 May) (fig. 8). However, the seed set percentage of twelve genotypes during evaluation period ranged from 29.8 to 75.5%. Thus, there was a problem to explain the lowering of seed setting percentage while germinated pollen grains percentages were adequate for successful fertilization. During flowering periods, five days exposure of air temperature over 35 °C caused serious spikelet sterility (Satake and Yoshida, 1978). Moreover, post anthesis warming at nighttime (7:00pm-7:00am) temperature over 28 °C induced significant decrease in rice grain filling rate in China (Dong et al., 2014). Similarly, rice grown under high nighttime temperature (32 °C) shown 72 % decreased in spikelet fertility (Mohammed and Tarpley, 2009). In this experiment, the duration of high temperature over 35 °C ranged from 7 to 9 hours during evaluation period (8-17 May) might have induced the serious seed setting (fig. 3). During evaluation period, the averaged nighttime temperature (7:00 pm- 7:00 am) was between 29 to 31 °C (fig.4), while the affected average nighttime temperature was revealed >28 °C (Dong et al., 2014). Therefore in this study observed that the main cause of lowering seed setting percentage might consider by the effect of higher temperature (>35 °C) duration and high nighttime temperature during flowering periods.

In addition, this study revealed four promising genotypes (Shwe Ma Naw, Zi Yar 9, Shwe Thwe Yin and Thu Kha Yin) for the seed setting percentage of panicle that mainly flowered during evaluation periods because their seed setting percentage on panicle ranged from 58-75 % during observation period (table. 3). In growth chamber experiment, six hour exposure of high air temperature (38 °C), N22 (highly heat tolerant) cultivar resulted 71% of spikelet fertility (Jagadish et al., 2009). Accordingly, these four genotypes may be valuable sources for further breeding programs related to heat tolerance evaluation studies.

Conclusion

According to the observation results, the sufficient pollination and fertilization for seed setting were observed, however the seed setting of the panicle might consider on other factors such as duration of higher temperature and higher nighttime temperature during flowering periods. Moreover, the relative humidity and wind speed could be considered as important factors when the temperature is higher (35 °C). For more precision of the result, further studies under different regional and climatic condition should be conducted.

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Appendix 1. Sources and origins of twelve improved rice varieties used in this study

No.	Name	Source	Origin
1	Yeanelo – 4	Rice Section, DAR	IRRI
2	Yet – 100	Rice Section, DAR	-
3	Thu Kha Yin	Rice Section, DAR	Myanmar
4	Shwe Pyi Hmwe	Rice Section, DAR	IRRI
5	Shwe Myanmar	Rice Section, DAR	India
6	MR – 9 (IR 59673)	Rice Section, DAR	IRRI
7	Shwe Ma Naw	Rice Section, DAR	India
8	Yar 2 Tun	Rice Section, DAR	Indonesia
9	ZiYar – 9	Rice Section, DAR	-
10	Thee Htet Yin	Rice Section, DAR	IRRI
11	ShweThwe Yin	Rice Section, DAR	IRRI
12	KTD (Ayer Min/Shwe Myanmar)	Rice Section, DAR	-Myanmar

Appendix 2. Heading dates (50% flowering) of twelve improved rice varieties

No.	Variety	Crop I	Crop II	Crop III
1	Yeanelo-4	6.5.2016	15.5.2016	NA
2	Yet 100	6.5.2016	15.5.2016	NA
3	Thu Kha Yin	5.5.2016	8.5.2016	NA
4	Shwe Pyi Hmwe	7.5.2016	11.5.2016	NA
5	Myanmar	6.5.2016	15.5.2016	NA
6	MR 9	7.5.2016	13.5.2016	NA
7	Shwe Ma Naw	7.5.2016	16.5.2016	NA
8	Yar 2 Tun	5.5.2016	11.5.2016	NA
9	ZiYar 9	7.5.2016	12.5.2016	NA
10	Thee Het Yin	7.5.2016	13.5.2016	NA
11	Shwe Thwe Yin	8.5.2016	12.5.2016	13.5.2016
12	KTD	5.5.2016	13.5.2016	NA

Review methodology of Myanmar initial FRL submitted to UNFCCC

Myat Su Mon[1], Khine Zaw Wynn[2], Nay Lin Tun[3]

Abstract

The Government of Myanmar is fully aware of the causes and potential impacts of climate change. Myanmar actively participated in global climate change mitigation efforts as a non-Annex 1 party. Nationally Determined Contribution (NDC) was submitted in 2016. Under the NDC, forestry is a key sector and quantitative targets are likely to be included. Myanmar's Initial National Communication (INC) was submitted to UNFCCC in 2012 and the Second National Communication (SNC) is now under preparation.

Following the suggestion of decision 12/CP.17, Myanmar prepared its Forest Reference Level (FRL) using a stepwise approach. Myanmar submitted its initial FRL report on January 2018 and was revised following to the suggestions from Assessment Team (AT) of United Nations Framework Convention on Climate Change (UNFCCC). The FRL submission will be a benchmark for assessing its performance in implementing REDD+ activities in contribution to climate change mitigation. The main objective of the FRL submission is to support the climate change mitigation efforts under the national context of Myanmar.

This paper on **"Review methodology of FRL setting in Myanmar"** is prepared based on the lessons learnt during the preparation process of initial FRL, the technical challenges and suggestions from technical assessment team of UNFCCC. The objective of this paper is to understand the current status of FRL setting in Myanmar and to support information for future development plan of Myanmar FRL in order to support information concerning with climate change mitigation efforts.

Keywords: climate change, forest reference level, REDD+, deforestation, emission factors

Brief on Myanmar FRL

Following the suggestion of Decision 12/ CP.17, Myanmar prepared the initial Forest Reference Level (FRL) using a stepwise approach and submitted to the United Nations Framework Convention on Climate Change-UNFCCC during January 2018. During the week of 19th -23rd March 2018, there was an assessment section on it in Bonn, Germany and currently Myanmar submission is under the assessment process.

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Myanmar initial FRL is a benchmark for assessing its performance in implementing REDD+ activities in contribution to climate change mitigation. FRL submission is also one of the key technical reports and the main objective of the Myanmar FRL submission is to support the climate change mitigation efforts under the national context of Myanmar (MoNREC, 2018). In addition, further objectives of the submission are to provide information on emission projections to multi-stakeholders on a clear, transparent and consistent basis, and to evaluate sustainable forest management practices, the performance of REDD+ policies and measures.

Currently, Myanmar views REDD+ initiatives as a contribution to the green development of Myanmar as well as supporting the mitigation of, and adaptation to, climate change. In addition, the Government of Myanmar stressed that the national REDD+ Programme is critical to their mitigation and adaptation pledges according to its country statement to COP 23. The development of the FRL was initiated by a group of experts in a Technical Working Group (TWG) on Measuring Reporting and Verification (MRV), representing a cross-section of ministerial agencies and organizations. The submission is largely due to the effort and commitment of the members of this TWG. The following are the brief information of Myanmar FRL submission;

Forest definition: The definition of 'forest' follows the definition that is used in FAO Forest Resource Assessment (FRA): "Land spanning more than 0.5 hectares with trees higher than 5 meters and a canopy cover of more than 10 percent or trees able to reach these thresholds in situ." Land use is also considered in identifying areas that fall under this forest definition. Therefore, forest refers to all areas under forest cover which meet the above criteria, both under Permanent Forest Estate (PFE) and outside PFE that areas are defined according to Forest Law. Therefore, the submission covers all natural forests, covering approximately 52% of the total country land area in 2005 (FRA 2010 Source Data).

Deforestation definition: Deforestation is defined as **the conversion of forest land use into non–forest land use** (i.e. 100% loss of all four carbon pools included in Emission Factor (EF) calculations). This FRL submission considers only the complete conversion of forest land use to other land use during the period 2005—2015, not including land that was temporarily de-stocked (and subsequently restocked) during this period.

Enhancement of forest carbon stocks through reforestation/afforestation activities definition: Enhancement of forest carbon stocks through reforestation/afforestation is defined as **the development of new carbon pools resulting from the change of non-forest land use to forest land use.** Although enhancement of forest carbon stocks also occurs in forest land not transitioning to other land cover types, this submission excludes this latter aspect of enhancement due to data limitation. However, it will be included once the measuring capacities through an improved National Forest Monitoring System (NFMS) are established, most likely after completion of the first measurement cycle of the upcoming National Forest Inventory after 2022.

Scope: The scope covers one REDD+ activity (reduced deforestation), three carbon pools (AGB, BGB and litter), and CO_2 only, with the final Forest Reference Emission Level (FREL) calculation expressed in tons of carbon dioxide equivalent per year (tCO_2 eq).

Scale: In accordance with the draft REDD+ strategy, Myanmar FREL is at national level scale. A national scale FREL is appropriate as all the existing land and forest monitoring and measurement capacities are at the national level and there is currently limited capacity at the sub-national level.

Reference Period: Myanmar decided the period of 2005 to 2015 as reference period according to the results of technical meetings.

Data selection and analysis

Activity data: Myanmar used a sample-based approach as an independent method to derive estimates between 2005 and 2015 of forest, non-forest and areas of deforestation only. Among various types of probability-based sampling design, stratified random sample (STRS) design has been used. The STRS offers the option to increase the sample size in change class and forest loss in a portion of the total area, and reduce the standard errors of the class-specific accuracy estimates for rare classes such as deforestation. In addition, STRS is one of the easier designs to implement and have unbiased variance estimators (Olofsson et al., 2014). Detailed methodology of STRS has been described in Myanmar FREL submission and the following shows the summary. The followings are expressed briefly on Activity Data (AD) development.

Step 1: Forest change map 2005—2015

- **Generation of Forest/non-Forest Map 2005:** Forest/Non-Forest Map 2005 was developed by combining of Forest/Non-Forest map 2000 (≥10% canopy cover threshold from the tree cover 2000 map) and gross forest cover loss event (loss year) 2001—2005 by Hansen et al. (2013).
- **Generation of forest/non-forest Map 2015:** Generation of Forest/Non-Forest Map 2015 was generated by combining of Forest/Non-Forest map 2005 and gross forest cover loss event 2006—2015 (Hansen et al., 2013).
- **Stratification: Forest change map 2005—2015:** Stratification of Forest Change Map 2005—2015 was conducted by three strata (Forest, Non-Forest and Loss) based on the Forest/Non-Forest 2005 Map and Forest/Non-Forest 2015 Map.

Step 2: Generate stratified samples

[2] Table 4.4 of Chapter 4: Forest Land in 2006 IPCC Guidelines for National Greenhouse Gas Inventories

Table 1. Four different plot designs of district management inventories (2005 – 2017)

No.	Plot Design	Plot Size	Parameters collected
1	Systematic (Square)	100m × 100m (1 ha) 50m × 50m (0.25 ha) 25m × 25m (0.0625 ha)	Trees (> 20cm dbh) Trees (> = 10 and < 20cm dbh) Trees (> = 5 and < 10cm dbh)
2	One Shot (Circular)	50m radius (0.7854 ha)	Trees (> = 5 dbh)
3	One Shot (Square)	1 ac or 0.4047 ha Plot	Trees (> = 5 dbh)
4	Systematic (L – shaped)	1.05 ha 15m radius (0.0707 ha) 10m radius (0.0314 ha)	Trees (> = 20cm dbh) Trees (> = 10 and < 20cm dbh) Trees (> = 5 and < 10cm dbh)

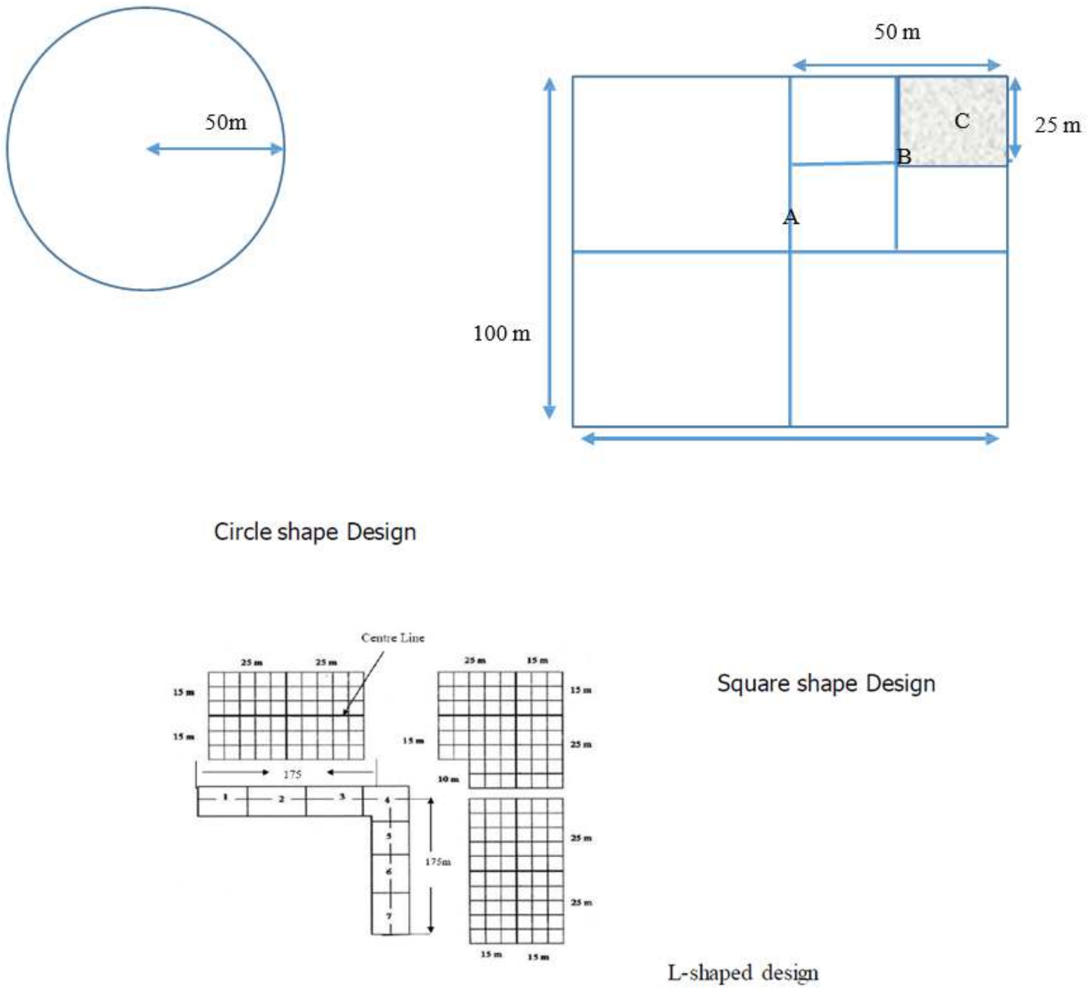

Figure 1: Different plot designs applied by FD in district management inventory

- Sample generation was conducted by System for earth observation, data access, processing, analysis for land monitoring (SEPAL) platform (http://sepal.io) using the stratified forest change map 2005—2015 and sample size formula of Cochran (1977). **Sample survey design was created** by Open Foris Collect.

Step 3: Sample assessment

- **Sample assessment** was conducted using Collect Earth Tool in Open Foris Collect. Interpreters' of RS and GIS section of Forest Department checked every sample for Forest or Non-Forest cover, using available high-quality validation datasets in Google Earth, Bing Maps and Google Earth Engine; accessible through Collect Earth.

- **Quality control:** Following a standard operating procedure, all interpreters were allocated 70 samples randomly selected followed by consistence check. All assessed samples were randomly rechecked for quality control through open discussion for assurance of quality check.

Step 4: Stratified estimator analysis

- **Prepare master sample assessment file:** By combining all files from different interpreters following quality control.

- **Stratified Estimator** – Analysis was conducted using SEPAL platform (http://sepal.io)

- **Sample-based area estimates** of three land cover classes: Forest, Non-Forest and Loss were generated from a stratified random design sampling estimators and from a theoretical simple random design sampling estimators.

Emission factors- Emission factors (EF) was drawn upon the data generated from 11,284 inventory plots of district level forest inventory that were collected during 2005 to 2017. Step 1: Above Ground Biomass (AGB) of individual trees in each plots was estimated using allometric equations developed for pan-tropical forest by the following equation from IPCC GPG for Land Use, Land Use Change and Forestry (LULUCF): (IPCC, 2006).

Equation 1

$$AGB=EXP((-2.289+2.649*LN(DBH)-0.021*(LN(DBH))^2)$$

Where AGB= Above Ground Biomass in Kg Dry Matter/ Tree

The total AGB for each plot was quantified by the sum of AGB of all individual trees and then converted into a per hectare value based on the respective sample plot area/sampling design. There were four different plot designs applied by FD in the period 2005—2017 (Table 1 and Figure 1).

Step 2: In order to calculate the Below Ground Biomass (BGB), the mean AGB (ton per ha) based on forest types was multiplied with R (Ratio of BGB to AGB). The R values are mentioned according to different forest types as described in IPCC Guidelines. Although the forest type categories according to forest inventory Field Instruction (1985) are different from the global forest type categories, they have similar characteristics. The forest types are then simplified according to global categories in order to select the appropriate ratio of BGB to AGB.

Step 3: The sum the AGB and BGB values (ton per ha) were converted into tons of carbon per ha by the multiplication with the default value of carbon fraction of dry matter 0.47 (IPCC 2006).

Step 4: The default litter values (tons of carbon per ha) of IPCC Guidelines were used according to respective forest types.

Step 5: Total tons of carbon per ha was estimated by the sum of three values of AGB, BGB and litter.

Step 6: The default factor of 3.664 was used to convert the total tons of carbon per ha to tCO_2 eq per ha value for three carbon pools.

FREL/FRL construction approach:

Myanmar proposes an initial FREL by historical average of emissions during the reference period from 2005 to 2015. *The bias-corrected area of annual deforestation is estimated* ***428,984 ha per year*** *during 2005—2015.* One National Emission Factor will be used as an uncertainty test is needed for forest type stratification and national data sources are currently insufficient at the current status. Myanmar use weighted mean values of tCO_2 eq per ha for a national level EF based on 40 districts, i.e. ***125.43 tCO_2 eq per ha.***

Annual CO_2 emission from deforestation = annual deforestation (428,984 ha per year) x 125.43 tCO_2 eq per ha

Annual CO_2 emission from deforestation during the historical reference period 2005—2015 is estimated as ***53,807,463 tons per year***.

For carbon removal from historic enhancement efforts based on forest plantation establishment and for the same historic reference period the proposed amount is3,351,332 tonnes of CO_2e. This level would be used to measure additional carbon removal as a result of the 10-year National Reforestation and Rehabilitation Programme in Myanmar (NRRPM) that is also part of the national REDD+ strategy of Myanmar.

Uncertainty test

The uncertainty test for activity data and emission factor was conducted according to the IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories. The uncertainty only includes sampling error through the propagation of errors and not allometric equation errors. In calculation of the uncertainty % of activity data, especially deforestation estimate, the following equation was applied,

Equation 2[4]

$$\% \, Uncertainty = \frac{\frac{1}{2}(95\% \, Confidence \, Interval \, Width)}{\mu} \times 100$$

Where μ=mean of the distribution

As described in the equation, the 95% Confidence Interval for all 40 districts are calculated with the equations of:

Equation 3

$$95\%\ Upper\ Confidence\ Interval = Mean\ CO_2\ Ton\ Per\ Ha + 1.96 * (Standard\ Deviation / \sqrt{Sample\ Size\ In\ Ha})$$

Equation 4

$$95\%\ Lower\ Confidence\ Interval = Mean\ CO_2\ Ton\ Per\ Ha - 1.96 * (Standard\ Deviation / \sqrt{Sample\ Size\ In\ Ha})$$

$$95\%\ Confidence\ Interval\ Width = 95\%\ UCI - 95\%\ LCI$$

The uncertainty of the overall inventory was calculated by the error propagation equation,

Equation 5

$$U_{total}{}^{5} = \sqrt{(U1 * x1)\ 2 + (U2 * x2)\ 2 + \cdots + (Un * xn)^2} / (x_1 + x_2 + \cdots + x_n)$$

$U\ total$ = the uncertainty percentage in the sum of the quantities

xn *and* Un are the uncertain quantities and the percentage uncertainties associated with them, respectively.

The *uncertainty of AD %* , forest loss area, i.e. ***8.97%*** whereas the *uncertainty % of 40 district forest inventory* and resulting *overall % is* ***12.10*** for EF.

Combined uncertainty was finally estimated by using the uncertainty of AD, especially uncertainty % of forest loss (deforestation) and that of EF as follows:

Equation 6

$$Combine\ Uncertainty\ (\%) = \sqrt{Uncertainty\ \%\ of\ AD2 + Uncertainty\ of\ \%\ EF2}$$

Regarding the above calculation, *uncertainty % of AD, deforestation area estimation and EF were 9.89 % and 12.10 %* respectively and therefore, *combined uncertainty % of* ***15.06%*** is estimated for this submission.

Review methodology

Consistency with national GHG inventory and FRA

Myanmar considered the consistency with Green House Gases (GHGs) Inventory, Forest Resource Assessment (FRA) reporting and FREL submission. The reference period does not overlap with the INC, which used data from the year 2000. Data used in INC were generated by expert assumption and judgement. The INC used EF based on IPCC global default factors and AD based on the projected data of FRA 2000. Therefore, there is difference in reference periods and different estimation methods for annual deforestation, resulting in different figures.

The AD used in FREL was based on real time estimation of 2005 and 2015 and EF from management plan inventories of 40 Districts. The EF is therefore considered as national specific data and more detailed compared to the previous GHGs inventories mentioned in INC. The value of EF factor used in initial submission is 125 tonnes of CO_2e per ha while in the INC, the respective value was 80 tonnes of CO_2e per ha. FD intends to use the national specific data also for GHG inventory in the future. Data generated in this FREL development process will benefit the current SNC preparation and the Biennial Update Report (BUR) to the UNFCCC.

Completeness: Myanmar FREL submission covers all natural forests, covering approximately 52% of the total country land area in 2005.

Comprehensiveness: The scope of this FREL submission covers one REDD+ activity (reduced deforestation), three carbon pools (AGB, BGB and litter), and CO_2 only, with the final FREL calculation expressed in tons of carbon dioxide equivalent per year (tCO_2 eq).

Degradation was not included in the FREL although it is likely an important activity following from forest resource uses and shifting cultivation. Myanmar is considering including forest enhancement activities in its next FREL submission, efforts toward estimating the effects of degradation are important.

Since FREL report covers only emissions of GHGs, not removals, it is considered a Forest Reference Emission Level (FREL), rather than a Forest Reference Level (FRL). Myanmar intends to expand the scope of the FREL as more extensive and better quality data become available.

In addition, Myanmar did not include non-CO_2 gases although non-CO_2 gases were included in the INC. Soil organic pool was also excluded in its estimates.

Myanmar aims to include data on enhancement of forest carbon stocks, in recognition of the potential importance of plantation and forest restoration measures to climate change mitigation efforts. Work on improvement of data on historical forest enhancement is currently ongoing.

Transparency

The proposed Myanmar FREL is entirely based on historical data which Myanmar considers to be transparent.

Accuracy

Myanmar prepared its initial FREL based on the available and the existing national data and reported by uncertainty test.

Challenges of existing AD and EF

Activity Data: Wall-to-wall maps for the years 2005, 2010 and 2015 have been prepared by the Remote Sensing and GIS (RSGIS) unit of Myanmar Forest Department. These wall-to-wall maps were pixel-based and are produced through supervised maximum-likelihood classifiers using imagery from Landsat (30 m), for the years 2005 and 2015, and using imagery from IRS (23.5 m) for the year 2010. The eleven national land use/cover categories are compatible with IPCC land use/cover classes and FAO-FRA classes. The three wall-to-wall maps were produced by different personnel in the RS

& GIS unit without defining standard operating procedures which could be followed to maintain quality control or reproduced in the context of a long-term forest monitoring system.

Emission factor: The emission factor (EF) used in the submitted FREL is based on the preliminary analysis of existing inventory data that are represented for 40 districts throughout the country. Although Myanmar does not have the full NFI analysis before, there were efforts on inventory to support information on forest management. Forest Department, Myanmar regularly conducts district level management inventory every year. District level management inventory data are being used for the calculation of Annual Allowable Cut of timber species. Past inventories within the base-year for FREL only covered 40 districts due to the inaccessible topography and some restriction because of national security.

Due to the limited capacity and facility, Forest Department did not conduct the carbon stock estimation by using of the existing inventory data in the previous time. EF calculation and carbon stock estimation are the first time for Myanmar by using a combination of Tier 1 and 2 approaches. Those data are used as an average and expanded the calculation by simplified version of the gain-loss method for other areas where there are no inventory data available. Therefore, current EF could be considered as **conservative interim value** in the meantime. A new project of supporting National Forest Inventory in Myanmar is in the pipeline and FD intends to update the EF data with the information supported by that project.

Conclusion and suggested next steps for improvement of FRL

- Much uncertainty exists in identification of forest gain (enhancement) classes while using remote sensing technologies. Therefore, forest gain has not been considered for sample-based estimates of current study and has been identified as one of the areas of future improvement for the FRL.
- There is a need to develop a standard operating procedure to detect land cover change under the six IPCC land cover classes through remote sensing-based and ground-based information to provide a more robust estimate of carbon emissions and removals.
- Further developments may include analysis of degradation with particular attention to the definitions in the national context (e.g. the types of plantations which can be classified as forest).
- Although this submission is at national level, strengthening of land and forest monitoring and measurement capacities under various projects, like the National Forest Inventory/ National Forest Monitoring and Information System (NFI/NFMIS) and One Map Myanmar, future FREL/FRL submissions may be divided into sub-national levels based on the available improved datasets.
- FD conducted district forest inventories every year and many forest parameters are available. But there is no database management system or standardization of parameter

coding system. The forthcoming NFI/NFMIS project will focus on the national forest monitoring and information system and will provide more qualified data and information to inform future FREL/FRL submissions.

- The NFI/NFMIS project will also improve accuracy of geo-location of the sample plots and integrated application of remote sensing data/satellite and forest inventory data for effective estimation of forest resources.
- At the moment, soil data has been partially collected and analyzed by the Forest Research Institute. Monitoring of soil organic carbon will be possible in the future and planned to be conducted with the support of the Finland Forest Research Institute (LUKE) and the NFI/NFMIS project.
- An integrated approach will be adopted by the existing NFMS projects, such as Nesting a REDD+ project carbon accounting and monitoring system under the (sub-) national system by FFPRI, Japan; Capacity Building of Relevant Stakeholders for REDD+ Readiness of Myanmar by KFS; and REDD+ Himalayas: Developing and using experience in implementing REDD+ in the Himalayas by ICIMOD.

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The potential of agroforestry as a climate-smart agricultural practice for enhancing local livelihood opportunities in central dry zone, Myanmar: A case study in Pakokku district

Phyu Phyu Thinn[1], Idd Idd Shwe Sin[2], Myo Min Latt[2]

Abstract

In Central Dry Zone (CDZ), most of the farmers rely mainly on rain-fed agriculture to secure their livelihoods and their crop cultivation was constrained by climate change and variability. Agroforestry is a climate smart production system that sustainably diversifies environmental and socio-economic benefits of subsistence farmers. The study was conducted with the main objective to assess the potential of agroforestry practice in buffering against climate variability and enhancing livelihood opportunities in dry zone of Myanmar. Myaing and Yesagyo Townships in Pakokku District were selected as the study areas and totally 108 respondents were interviewed. Respondents were chosen by using purposive sampling method and interviewed by using structured questionnaire sets. The study employed a combination of methods of 'Participatory Rural Appraisal (PRA)'. Descriptive statistics, multiple regression analysis and financial analysis were used to fulfill the research objectives. According to income function analysis, presence of perennial trees on farmlands was positively and significantly influenced on annual household income at 1%. Total tree varieties on farm influenced on average annual household income at 10% significant level. Number of income sources was significantly influenced on average annual household income at 5% level. In financial analysis of agroforestry cultivating Thanakha (Hesperethusa crenulata (Roxb) Roem.) and crops, the initial capital expense for establishing a hectare was 832,812 MMK. The internal rate of return (IRR) for agroforestry was 14%. Net Present Value (NPV) for agroforestry was 1,396,310 MMK and benefit cost ratio (BCR) was 1.3. Therefore, this type of agroforestry was acceptable and can significantly cushion the communities in dealing with impacts of climate change in the present time and increase resilience for future impacts.

Keywords: climate change, agroforestry, adaptation strategies, financial analysis, dry zone

Introduction

In Central Dry Zone, rainfall determines the crop production (DAP, 2007). Inadequacy and uncertainty of rainfall often caused partial or complete failure of crop production (Peprah, 2014) which led to instable and/or low production in this area. Local people could not produce expected amount of crops and faced problems such as insufficient in-

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come for households. As a consequence, climate change severely threatens the livelihoods of smallholder farmers living in rural areas with low adaptive capacity for changing condition (Moe, 2015). As agriculture is very sensitive to climate variability such as changes in temperature, precipitation and other extreme events such as drought, flood etc., agricultural practices that are more resilient and adapted to changing conditions as well as contributes to the mitigation and adaptation of climate change by local farmers is urgently needed (Wollenberg, et al., 2011). Therefore, agricultural farming practices that are compatible with CSA are required to practice so that crop production and households' income could sustain in the future.

CSA is defined as an approach for transforming and reorienting agricultural development under the new realities of climate change (Lipper et al, 2014). It has three objectives: (1) sustainably increase in agricultural productivity and incomes; (2) adapting and building resilience to climate change; and (3) reducing and/or removing greenhouse gases emissions, where possible (FAO, Climate-smart Agriculture Sourcebook, 2013). Agroforestry is a climate smart production system and it can sustainably diversify environmental and socio-economic benefits of smallholder farmers. The diversification of crops in agroforestry provides a number of resilience and adaptation benefits, including an economic buffer in case of crop failures. As agricultural land expansion encroaches on forests, practicing Community Forestry and formulation of Forest User Groups may be a promising way for encouraging sustainable agroforestry practices.

Problem statement

In Myanmar, the Dry Zone is located in the central part of the country and belongs to one of the most vulnerable areas to climate change and variability in the country where large population is already food insecured. Drought and extreme heat were the most serious climatic stresses in Pakokku Township, Pakokku

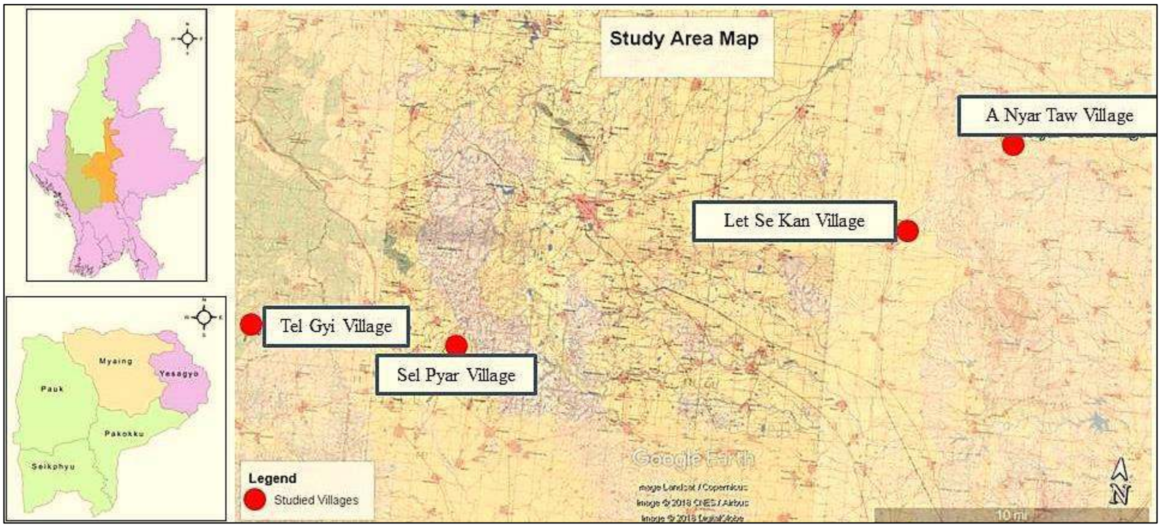

Figure 1: Map of Pakokku District showing the Study Area

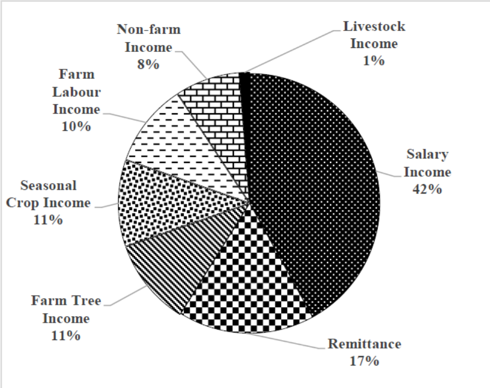

Figure 2: Income sources and share for sample households

Table 1: Descriptive statistics of dependent and independent variables of average annual household income function

Description of variables	Unit	Mean	SD
Dependent variable			
Annual HH income	MMK	1089882.41	1396967.95
Independent variables			
Age	Years	49.09	14.35
Gender	Male/Female	1.42	0.49
Education	Year	1.50	0.82
Family number	No.	4.88	1.68
Farm size	ha	2.99	2.47
No. of Income source	No.	2.36	0.86
Income from trees on farms	Yes/ No	0.79	0.411
Total tree varieties	No.	2.59	1.28

Table 2: Income function of sample households

Independent variables	Unit	B	t - value
Constant		0.933	0.353
Age	Year	-0.056ns	-0.545
Gender	Male/Female	-0.132ns	-1.497
Education	Year	0.025ns	-1.497
Family number	No.	0.052ns	0.558
Farm size	ha	-0.038ns	-0.417
No. of income source	No.	0.215**	2.382
Income from trees on farms	Yes/ No	0.335***	3.103
Total tree varieties	No.	0.149*	1.673
	R-Square	**0.384**	
	Adjusted R-Square	**0.320**	

Note: Dependent variable = Average annual household income B= Standardized coefficient
***, ** and * are significant at 1%, 5% and10% level respectively and ns = not significant

District in 2008, 2009 and 2010 and flood was major climatic effect in 2011 due to heavy rain (The, 2012). Deforestation and land degradation in the past have reduced crop productivity and yields and highly seasonal, dry climate make highly vulnerable to water availability or quality driven by climate change in Pakokku District (Fee, et al., 2017). According to Business as Usual Scenario by Fee et al. (2017), Pakokku will experience lower incomes because of a lack of irrigation, less predictable rainfall, and resultant lower access to water in the dry zone. Impacts of climate change were directly affected to livelihoods of rural farmers and these have been found in agriculture, livestock and socio-economic condition of rural households.

Agroforestry is one of the best alternative way to cope climate change and there is insufficient literature on the potential of agroforestry in combating impacts of climate change with specific focus on the investment that is required for successful integration of agroforestry in current agricultural practices in the study area. Climate change is a global phenomenon and adaptation is largely site-specific. Therefore, changes in farming systems and technologies need to be suited to the specific environmental and socio-economic conditions of local farmers, without increasing risk or dependence on external input. Therefore, area-specific agricultural systems are needed to secure the livelihoods of rural farm households in those resource poor regions.

Objectives of the study

The main aim of research is to assess the potential of agroforestry practice in buffering against climate variability and enhancing livelihood opportunities in dry zone of Myanmar.

Specific objectives are;

1. To examine the contributions of on-farm trees to farmers' income for enhancing local livelihoods

Table 3: Cash Flow of Agroforestry Plantation (Thanakha (Hesperethusa crenulata (Roxb) Roem.) and Crop Combination based on 1 ha)

	Year 0	Year 1	Year 2	Year 3	Year 4-12
Revenue (MMK/ha)					
Thanakha	0	0	0	0	1,245,453
Crops	0	698,675	698,675	698,675	2,794,701
Total revenue	0	698,675	698,675	698,675	4,040,154
Costs (MMK/ha)					
Thanakha	549,986	293,090	293,090	293,090	0
Crops	282,826	282,826	282,826	282,826	1,131,306
Total costs	832,812	575,916	575,916	575,916	1,131,306
Cash flow (MMK/ha)	(832,812)	122,759	122,759	122,759	2,908,847
			NPV		**1,396,310**
			IRR (%)		**14%**
			B/C		**1.3**

2. To assess the potential of agroforestry as an adaptation strategy to the impacts of climate change

Research methodology

Study area

The study area was selected in Pakokku Distirct, Magway Region. The rationale for choosing Pakokku District for the study was three-fold. First, it is the core region of the hottest area in the dry zone (MOAI, 2015), which is facing irregular climatic impacts and more vulnerable to the impacts of climate change. Secondly, as its annual average rainfall is 671.03 mm (2007-2016) (Department of Meterology and Hydrology, Pakokku Township), it is representative of dry zone area and biophysical and socio-economic characteristics in that district are assumed to be typical. Thirdly, poverty and food insecurity are major problems for many villages in the townships of Pakokku District (FAO, Myanmar Dry Zone Development Programme, 2014). Although Pakokku District is comprised of five townships, only two townships, Myaing and Yesagyo townships, were selected because these townships were closely located and had similar general conditions (homogeneity of population); thus, were considered as one case study while conducting the analysis.

Data collection

The research employs a case study approach for collection and analysis of data and combines both qualitative and quantitative methods (Mixed Methods Approach) for an effective assessment. The study employed a combination of methods including 'Participatory Rural Appraisal (PRA)'. These were: (i) Reconnaissance Survey, (ii) Household Survey, (iii) Focus Group Discussion, (iv) Direct Field Observation and also secondary data were used.

Data analysis

Descriptive statistics, multiple regression analysis and financial analysis were used to fulfill the research objectives.

Result

Contribution of farm trees to farmers' income

Household income was derived from seven main sources; seasonal crop income, farm tree income, livestock income, salary income, farm labor income, remittance and non-farm income. Income sources and their share for sample households are illustrated in Figure 2. In the sample households, the main income source was salary income which contributed 42% of the household income. About 11% of the household income earned from seasonal crop production and farm trees, respectively. Moreover, households with migrant household member earned more annual household income (about 17% of household income) because they received a lot of remittance money from the migrants. In addition, farm labor had about 10% contribution to the household income. Only about 8% and 1% of the household income were non-farm income and livestock income respectively.

Factors affecting average annual household income

Eight independent variables such as age, gender, education, family number, farm size, number of income sources, presence of farm tree income, number of tree varieties on farmland, were used to identify the factors affecting average annual household income. Descriptive statistics of dependent and independent variables of average annual household income were presented in Table 1.

In the result of regression analysis in Table 2, number of income sources significantly influenced the average annual household income at 5% level. If the household had income diversification, the average annual household income would increase significantly by 0.22%. There was a strong positive relationship between the average annual household income and presence of trees on farmlands, which statistically significant at 1% level. This means that planting or retaining trees on their farmlands can increase in average annual household income and was expected to be increased by 0.34%. Households earned high income from perennial trees because perennial crops cultivation could give high profit. Number of tree varieties on farms influenced on average annual household income at 10% significant level, and if the household had grown or retained high varieties of trees on farm, the average annual household income would be increased significantly by 0.15%.

Financial analysis of agroforestry

The study determined and analyzed the cost and benefit of agroforestry including Thanakha (Hesperethusa crenulata (Roxb) Roem.) and crops (pigeon pea, groundnut, sesame and maize) because most of the farmers had been practicing the Thanakha (Hesperethusa crenulata (Roxb) Roem.) and crop combination system on their farms and in community forestry established by Forest Department. The costs included expenditures on land preparation, seed collection, planting, weeding and fertilizer application, but costs on final harvesting was not included because brokers bought the desired trees from the farms. In the study, both family labors and hired labors were considered in the calculation. The return primarily includes sale revenues at the time of each felling.

In financial analysis, market prices were used for all inputs and outputs. In this study, the actual costs of each operation per hectare were used to be as realistic as possible. Non-market benefits were not valued in financial analysis. The most popular measures for defining the financial criterion are the Net Present Value (NPV), the Internal Rate of Return (IRR) and the Benefit Cost Ratio (BCR).

In agroforestry plantation, during the initial year, a cost of about 830,000 MMK per hectare was incurred for site preparation, planting, and fertilizer or manure application. The total cost of 12 years old farm cultivating Thanakha (Hesperethusa crenulata (Roxb) Roem.) and crops was about 3,700,000 MMK per hectare. The benefit of final felling yield at the rotation age of 12 years amounted to 6,100,000 MMK per hectare and the net benefit at the age of 12 years was about 1,400,000 MMK per hectare. The internal rate of return was 14%. This means that agroforestry cultivating Thanakha (Hesperethusa crenulata (Roxb) Roem.) and crops can be profitable until 14% of interest rate. Net Present Value (NPV) for agroforestry was 1,396,310 MMK. If the NPV remained constant within 12 years, farmers would earn 14% of profit from investment in Thanakha (Hesperethusa crenulata (Roxb) Roem.) farms. The return per unit of capital or benefit cost ratio (BCR) of Thanakha (Hesperethusa crenulata (Roxb) Roem.) farm was 1.3, and this means that it can get profit from agroforestry.

Discussion

In the study, the annual average total household income amounted to 3.5 million MMK per household per year. The highest amount of annual income (1.4 million MMK) earned from salary jobs, however, only 6% of respondents had salary income. The main income source of the sample households was seasonal crops which contributed 11% of the household income. Among the sample farmers, almost all of the respondents had perennial trees on their farms and got income from trees, and the average annual income earned from trees was 379,000 MMK per household per year which contributed to total income about 11% of the household income. The study urged with the results from Htwe (2017) which mentioned that the main income source was perennial crop income (57.4%), seasonal crop production (14.2%) and non-farm jobs (11.2%). The reason was that most of the farmers encountered crop failure owing to the irregular rainfall patterns in the area and contribution of both perennial and seasonal crops to household income was lower than salary income and remittance income. In dry zone area, crop cultivation mainly depends on rainfall and crop production is not uncertain under climate variability.

According to income function analysis, presence of trees on farmlands was positively and significantly influenced on annual household income at 1% level. Almost all sample farmers grow and/or retain perennial cash crops such as Tamarindus indica L., Ziziphus jujuba Lam., Hesperethusa crenulata (Roxb) Roem in their upland areas and households earned high income from perennial crops because perennial crops cultivation could give high profit. Income from farm tree was vital to raise income level of the rural household for combating climate change impact and it should be enhanced. According to Htwe (2017), having of perennial crop income significantly influenced on average annual household income and, if the household had perennial crop income, the average annual household income will increase significantly.

In financial analysis of agroforestry, the initial capital expense for establishing a hectare was about 830,000 MMK per hectare. The internal rate of return (IRR) for agroforestry was 14%. This means that agroforestry can stand up to 14% of interest rate. If the NPV remain constant within 12 years, farmers earn 14% of profit from agroforestry. The benefit cost ratio (BCR) of agroforestry was 1.3, so this type of agroforestry practice was acceptable, but not profitable enough for farmers. The fact why benefits was less for farmers was that the study considered both family labors and hired labors in the financial analysis. And, most of the farmers assumed that their crop cultivation is profitable based on only hired labor costs and material costs, and they didn't consider their work force in calculation of profits as opportunity costs. Thus, financial benefit seemed to be profitable and their current practice is just acceptable for their socio-economic conditions.

And, the government interest rate mentioned that the agroforestry practice, cultivating Thanakha (Hesperethusa crenulata (Roxb) Roem.) and crops, did not generate sufficient income to cover the investment and incurred costs. The results of the financial analysis suggested that the alternative agroforestry practice or tree species or crops could produce a positive change in the net household income. Therefore, the analysis and results presented in the research might be used as a model for future evaluations of potential agroforestry practice intended to assist poor smallholders.

Conclusion and recommendations

Climate change and its impacts had threatened agriculture, forest ecosystems and the livelihoods of local communities in Central Dry Zone of Myanmar. Subsistence agriculture is the most vulnerable to climate change, as smallholder farmers did not have adequate resources to adapt to climate change. While agroforestry may play a significant role in mitigating the atmospheric accumulation of greenhouse gases (GHG), it also has a role to play in helping smallholder farmers to adapt to climate change.

Perennial trees make significant contribution to total income of farmer in the study area. Although, trees on farms were not the main livelihood activity for the farmers, the income received from them was used for expected and unexpected expenditures including: income generation, domestic subsistence, safety net and livelihood security. Agroforestry has potential to practice in the dry zone because income from planting and/or retaining trees on farms contributed to 11% of the total annual household incomes and the 3rd contributor of the total income. According to the regression analysis, planting and/or retaining trees on farms was significantly influenced on total annual household income and hence, it can be concluded that promoting agroforestry practices in the area could increase the livelihood conditions of smallholder farmers.

Another fact is that the BCR of current agroforestry practice was acceptable and it has high potential to increase welfare of farmers if this practice was properly promoted by technical, financial and institutional supports. Forest Department is now taking some measures to upgrade the socioeconomic status of the local people through the practice of community forestry, agroforestry, proper grazing, and income generation with their full participation. Agroforestry is therefore a viable option of obtaining farmers participation in tree planting.

The major recommendations from the study are:

1. Income from trees on farmlands had im-

portant contribution to household income and it should be enhanced to raise household income level of the smallholder farmers for adapting climate change impacts.

2. In Community Forestry Instruction (2016), section 24 (f) states that ***Forest User Group (FUG) or FUG members can practice for agroforestry which suited for the region in implementation of CF.*** Therefore, more demonstration sites for agroforestry and model community forestry area should be established to raise awareness of local farmers in the implementation of agroforestry and community forestry.

3. In the study, two objectives of CSA, adaptation and advancing food security of agroforestry, are focused and the third objective, mitigation, is not mentioned. Thus, further study should be conducted to emphasize on mitigation (especially carbon sequestration) of agroforestry practices.

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Distribution, habitat association and species composition of tiger beetles (Coleoptera: Cicindelidae) in Myanmar

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Abstract

Species inventory was conducted to investigate the distribution, habitat association and species composition of tiger beetle in the selected areas of Myanmar during February, June, July and August in 2016 and May and June in 2017. The selected areas were Htoogyi (Ayeyarwaddy Region); Taungoo, Bago, Phyu, Latpadan (Bago Region); Deemoso (Kaya State), Pwintphyu, Magway, Pakoku (Magway Region); Nay Pyi Taw Union; Nyaung Oo (Mandalay Region); Kyaikhto, Belin, Theinzayat (Mon State); Taunggoke (Rakhine State); Hsihseng, Pindaya, Nyaung Shwe and Zalae Village (Shan State) and Shwe Bo, Khin Oo, Yinmarbin (Lattaunggyi Village and Monethwin Village) (Sagaing Region). A total of 20 tiger beetle species: one species from Ayeyarwaddy Region, 6 species from Bago Region, 4 species from Magway Region, 16 species from Mandalay Region, 2 species from Mon State, 3 species from Sagaing Region, one species from Kayah State, 2 species from Rakhine State and 3 species from Shan State recorded during the study period from these areas. Nine species occurred as the riparian habitat and eleven species occurred as forest habitat. Calomera angulata was observed as the common species occurred in the riparian habitat.

Keywords: species inventory, tiger beetle, distribution, habitat

Introduction

Tiger beetles have worldwide distribution (except Tasmania, Antarctica and some remote oceanic Islands) that covers a variety of habitats ranging from alpine meadows to desert grasslands and tropical rain forests (Pearson 1988; Rodriguez et al. 1998). The total number of species presently known is over 2700 (Cassola 2010). Most of the species require habitats with access to bare ground, such as stream and pond edges, salt flats, dunes and open patches in grasslands (Pearson 1988). Each species rarely occurs in more than one or a very few habitat types (Pearson 1984; Rodriguez et al. 1998).

Since invertebrates make up the largest component of land diversity, invertebrate inventories are being used for making resource management decisions in park lands (Selness

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1999). The majority of studies using indicator taxon have relied on vertebrates, especially species the public has taken an acute interest in. Vertebrates tend to live long, have a low population increase rate, have long generation times and comparatively low habitat specificity. All of these things take time and budgets. Recently, there has been an effort to overcome these problems by using insects, instead of vertebrates as indicators. For example, the family of tiger beetles (Cicindelidae), is an appropriate indicator taxon for determining patterns of biodiversity because: (1) its taxonomy is unvarying, (2) its biology and general life history are well discerned, (3) individuals are easily observed, (4) each species tends to dwell within a narrow habitat range and (5) patterns of species richness can be correlated with those for other vertebrate taxa (Selness 1999). Additionally, tiger beetle specie numbers can be reliably determined within 50 hours on a single site, compared to months or even years for birds and butterflies (Selness 1999). Moreover, because of tiger beetles' preferences for specific habitats and their presence in the predator trophic level, they are likely to be highly vulnerable to habitat changes.

Plate 1 Tiger beetle collection from Stream and Riparian Habitat during the study period

Plate 2 Tiger beetle collection from Forest Habitat during the study period

The family Cicindelidae has also come to the attention of conservation biologists in recent years due to the fact that significant population declines have been noted in many species around the world (Knisley and Schultz 1997; Pearson et al. 2006). The primary cause of decline in many cases has been the loss of suitable habitat through human activities (Knisley and Schultz 1997). The flightless or near-flightless species of the genera Manticora Fabricius, Megacephala Latreille and Dromica Dejean are especially susceptible to local extinction due to habitat loss (Oberprieler and Arndt 2000; Cassola 2002). Species inventories and field surveys are a valuable first step towards the effective conservation of tiger beetle populations (Knisley and Schultz 1997; Mawdsley 2007). Inventories and surveys provide valuable baseline information about the

Table 1 The collected tiger beetle species, location, previous record and habitat during the study period in the selected areas.

No.	Species	Location	Time	Previous Record	Habitat
1.	Calochroaflavomaculata(Hope, 1831)	Seven Step Lake, Deemso, Kayah State	June 2016	Acciavatti and Pearson 1989 Wiesner 1992 Wiesner 2006 Cassola 2010	Lake area
2.	Calomeraangulata (Fabricius, 1798)	Yezin Dam, Yezin, Mandalay Region	June 2016	Acciavatti and Pearson 1989	Dam area
		Sin Thay Stream, Pyinmana, Mandalay Region	June 2016		Riparian
		Sittaung Riverside, Theinzayat, Mon State	June 2016	Wiesner 2004	Riverside
		Kinmon Riverside, Kyaikhto, Mon State	July 2016	Uniyal and Sivakumar 2007	Riverside
		Sittaung Riverside, Taungoo, Bago Region	August 2016		Riverside
		Thetkaetan Stream, Shwebo, Sagaing Region	April 2017	Wu and Shook 2007	Riparian
		Kyunkalay Riverside, Leptadan, Bago Region	May 2017		Riparian
		Ma Zin Dam, Bago Region	May 2017		Dam area
		Mone Stream, Pwintphyu, Magway Region	May 2017		Riverside
		MineInn Stream, Pindaya, Shan State	May 2017		Riparian
		MyaukYamar Creek, Yinmarbin, Sagaing Region	May 2017		Riparian
		Bone Myoe and BawdiPauk Stream, KhinOo, Sagaing Region	May 2017		Riparian
		TaungkyarStream, Zalae Village, Taunggyi, Shan State	May 2017		Riparian
		Ma Mya Stream, Htugyi, Ayeryarwaddy Region	April 2017		Riparian
3.	Calomerafunereaassimilis (Hope,	Kine Shay Stream, TaungKoke, Rakkhine State	August 2016	Wiesner 2004	Riparian
4.	Calomeraplumigerascoliographa (Rivalier, 1953)	Ayearwaddy River, NyaungOo, Mandalay Region	April 2017	Shook and Wu 2007	Riverside
		Sarrpwak River, Tabin Village, Minbu, Magway Region	May 2017		Riverside
5.	Cincindelaatkinsoni (Gestro, 1893)	Maungyan forest, Ottarathiri, Mandalay Region	June 2016	Fowler 1912	Forest
6.	Cincindelacorbetti (W. Horn, 1899)	Yezin Dam, Zayarthiri, Mandalay Region	June 2016	Wiesner 2002	Dam area
7.	Cosmodelaaurulentajuxtata	Phokyar Elephant Camp, Taungoo, Bago Region	July 2016	Wiesner 2002	Forest
8.	Cylindera (Ifasina) foveolata (Schaum, 1863)	Maungyan Village forest, Ottarathiri, Mandalay Region	June 2016	Wiesner 2004 Wiesner 2006	Forest
9.	Cylinderaholosericea (Fabricius,	Aunglan Monastery, Ottarathiri, Mandalay Region	June 2016	Shook and Wu 2007	Forest

Table 1 Contd.

No.	Species	Location	Time	Previous Record	Habitat
10.	Cylinderaminuta(Olivier, 1790)	Kine Shay Stream, TaungKoke, Rakkhine State	February 2016	Wiesner 2004	Riparian
		Aunglan Monastery, Ottarathiri, Mandalay Region	June 2016		Forest
		Yayhlway village waterfall, Taungoo, Bago Region	July 2016		Forest
		Sin Thay Stream, Pyinmana, Mandalay Region	April 2017		Riparian
		Sarrpwak River, Tabin Village, Minbu, Magway Region	April 2017		Riverside
		Sittaung River, Theinzayat, Mon State	May 2017		Riverside
		Kyaik Tal River, Belin, Mon State	May 2017		Riverside
		KyunKa Lay River, Letpada, Bago Region	May 2017		Riverside
		Ma Zin Dam, Bago Region	May 2017		Dam area
		Mone Stream, Pwintphyu, Magway Region	May 2017		Riparian
11.	Cylinderaspinolae(Gastro, 1889)	Maungyan forest, Ottarathiri, Mandalay Region	June 2016	Wiesner 2004	Forest
		Maungyan forest, Ottarathiri, Mandalay Region	June 2017		Forest
12.	Lophyracancellata	Sin Thay Stream, Pyinmana, Mandalay Region	May 2017	Acciavatti and Pearson 1989	Riverside
		KyoeKie Stream, Phyu, Bago Region	May 2017		Riparian
		Bone Myoe and BawdiPauk Stream, KhinOo, Sagaing Region	May 2017		Riparian
13.	Myriochiledubia (W. Horn, 1892)	Aunglan Monastery, Ottarathiri, Mandalay Region	June .2016	Acciavatti and Pear-son 1989	Forest
		KyunKa Lay River, Letpadan, Bago Region	April 2017		Riverside
		Sarrpwak River, Tabin Village, Minbu, Magway Region	May 2017		Riverside
		Innpawkhone, NyaungShwe, Shan State	May 2017		Lake area
14.	Myriochilesinica(Fleutiaux, 1889)	KyunKa Lay River, Letpadan, Bago Region	April 2017	Sawada and Wiesner 2000	Riverside
		Bone Myoe and BawdiPauk Stream, KhinOo, Sagaing Region	May 2017		Riparian
		Sarrpwak River, Tabin Village, Minbu, Magway Region	May 2017	Wiesner 2017	Riverside
		Innpawkhone, NyaungShwe, Shan State	May 2017		Lake area
15.	Neocollyrisbonelliibonellii(Guerin-Meneville, 1834)	Maungyan forest and Phozaung forest, Ottarathiri Township, Mandalay Region	June 2016 June 2017	Wiesner 2006	Forest
16.	Neocollyrisfuscitarsis (Schmidt-Goebel, 1846)	Maungyan forest, Ottarathiri Township, Mandalay Region	June 2016	Wiesner 2006	Forest
17.	Neocollyrislinearislinearis(Schmidt -Goebel, 1846)	Maungyan forest, Ottarathiri Township, Mandalay Region	June 2016	Sawada and Wiesner 2000	Forest
18.	Neocollyrismoestamoesta (Schmidt	Maungyan forest, Ottarathiri Township, Mandalay Region	June 2017	Jaskula 2008	Forest
19.	Neocollyrisvariicornis (Chaudoir,	Phozaung forest, Ottarathiri Township, Mandalay Region	June 2017	Sawada and	Forest
20.	NeocollyriszercheiNaviaux, 1991	Maungyan forest, Ottarathiri Township, Mandalay Region	June 2017	Naviaux and	Forest

Cosmodela flavomaculata

Calomera angulata

Calomera funereal assimilis

Calomera plumigera scoliographa

Plate 3 Recorded tiger beetle species during the study period.

distribution and relative abundance of tiger beetle species that can help inform long-term monitoring programmes for these species (Knisley and Schultz 1997). Field surveys can also be structured to identify suitable micro-habitats for individual tiger beetle species (Mawdsley and Sithole 2008). There are a few documents on the species composition of tiger beetle in Myanmar. In this regard, the inventory of the species composition of tiger beetle survey was done in the selected area, Myanmar.

Materials and methods

The field survey of the tiger beetle fauna of Htoogyi (Ayeyarwaddy Region), Taungoo, Bago, Phyu, Latpadan (Bago Region), Deemoso (Kaya State), Pwintphyu, Magway, Pakoku (Magway Region), Nay Pyi Taw Union, Nyaung Oo, (Mandalay Region), Kyaikhto, Belin, Theinzayat (Mon State), Taunggoke (Rakhine State), and Hsihseng, Pindaya, Nyaung Shwe and Zalae Village (Shan State), Shwe Bo, Khin Oo, Yinmarbin (Lattaunggyi Village and Monethwin Village) (Sagaing Region) was conducted in February, June, July and August in 2016 and May and June in 2017. Most of the survey activities were timed for the beginning of the rainy season, when adult tiger beetle activity is also at its peak (Werner 2000a; Werner 2000b). The species inventory was done throughout these areas by walking forestland, river side, riparian

Cincindela atkinsoni

Cincindela corbetti

Cosmodela aurulenta juxtata

Cylindera (Ifasina) foveolata

Plate 4 Recorded tiger beetle species during the study period.

and dam areas. Habitat type was also noted at this time. The observed species were collected by sweeping up in an aerial net and placed in a collecting tube for pinning and labeling at a later date. Each site was surveyed two times for 4-5 hours at a time for a total of 20 hours during the study period.

Sandy beach located in the river side and riparian of Nyaung Oo, Pobbathiri and Ottathiri Township in Mandalay Region, Taungoo, Phyu, Bago, Latpadan area in Bago Regoin, Deemoso Township in Kayah State, Kyaikhto, Belin, Theinzayat Township in Mon State, Taunggoke Township in Rakkhine Stae, Pwintphyu, Magway, Pakoku (Magway Region), and Hsihseng, Pindaya, Nyaung Shwe Township and Zalae Village Shan State, Thandaung (Kayin State), Shwe Bo, Khin Oo, Yinmarbin (Lattaunggyi Village and Monethwin Village) (Sagaing Region). The muddy river bank area was located in Htoogyi (Ayeyarwaddy Region). Forestland was located in the Ottarathiri Township and Pobbathiri Township covered by deciduous forest with the most common trees including Than-dahat and Inn-daing. Another forest area is located at Elephant Sanctuary (Phokyar Elephant Camp) near Taungoo City is covered by the deciduous forest with the most common trees including Teak (Plate 2). Dam is located near Yezin Agricultural University, Zayyarthiri Township and Ma Zim Dam in Taungoo City, Bago Region. Riverside and riparian area in Taunggkoe Township, Deemoso Township (Plate 1).

The collected specimens were identified using the text book of "The tiger beetles of Thailand" (Naviaux and Pinratana 2002) and "Tiger beetles of Yunnan" (Shook and Qiang 2007). Personal confirmation was done by the help of Dr Michio Hori (Professor Emeritus of Kyoto University, Japan).

Cylindera holosericea

Cylindera minuta

Cylindera spinolae

Lophyra cancellata

Plate 5 Recorded tiger beetle species during the study period.

Results and discussions

Observed tiger beetle species distribution and microhabitat associations

Twenty species of tiger beetles have been recorded from the study areas. Table 1 describes the list of species, locations, previous record and habitat status where specimens of these beetles have been collected from. For each species of tiger beetle found in the field was described the microhabitat that combined information of associated substrates (mud, sand, rock, etc.) and physical features (sandbar, sandy riverbank, muddy pool, etc.). The forest habitat was recorded with information of associated substrates (kinds of trees, shrubs and the forest structure).

List of the observed tiger beetles species

1.*Calochroa flavomaculata* (Hope, 1831)

Four individuals were observed in July 2016 at the Seven Step Lake, Kayah State. Adult was collected from the riparian area with sandy loam in open patches of grass clump. Ten individuals were collected from Hsihseng Township, and microhabitat is the riparian area red clay soil in open corn field and the forest with Inn tree (Plate 3). This species was recorded from Pakistan by Cassola (2010). Generally occurring throughout the Indian subcontinent eastward into Southeast Asia and the Philippines (Acciavatti and Pearson 1989; Wiesner 1992) and from China, Yunnan Province (Wu and Shook 2007). It was recorded in Shan State and Kachin State, Myanmar (Wiesner 2006). This finding was firstly recorded in Kayah State, Myanmar.

2.*Calomera angulata* (Fabricius, 1798)

Twelve individuals were observed in June and July 2016 at the riverside, Kinmon River, Kyaikhto Township, Mon State (Plate 3). The rainy season microhabitat was composed of riparian area with sand and rock in open patches of shrubs and Djenkol Bean and

Myriochile dubia

Myriochile sinica

Neocollyris bonellii bonellii

Neocollyris fuscitarsis

Plate 6 Recorded tiger beetle species during the study period.

Neocollyris linearis

Neocollyris moesta

Neocollyris variicor-

Neocollyris zerchei

Plate7 Recorded tiger beetle species during the study period.

Pink Cedar trees. Ten individuals in June 2016 from the Sittaung riverside of Taungoo Township, Bago Region, and microhabitat. The muddy riparian area was covered with Kans grass and shrubs.

Twenty seven individuals were collected in June 2016 from Yezin Dam area, Mandalay Region and the open sandy microhabitat was covered with grass clumps and shrubs. Thirty five individuals were observed in June 2017 from Sin Thay Stream, Pyinmana, Mandalay Region. The riparian area was covered with sandy bank and Indian grass. One individual was observed in April and May 2017 from the riverside of Sittaung River, Thainzayat, Mon State. The microhabitat for the adult in rainy season is the riparian areas cover with mud along with Kans grass and shrubs. One individual each was observed in late April 2017 and mid May 2017 from Kyun Kalay Riverside and Ma Zin Dam, Bago Region. One individual was observed in mid May 2017 from Mine Inn Stream, Shan State. Three individuals were observed from Taungkyar Stream, Shan State. One individual was recorded from Thetkaetan Stream, Sagaing Region; two individuals were observed from Myauk Yamar Creek, Bone Myoe Stream and Pauk Stream, Sagaing Region in early May 2017. Two individuals were observed from Ma Mya Stream, Ayeyarwaddy Region in late April 2017.

In 2004, Wiesner reported that this species was recorded as new in Sein Yay Forest Camp, Bago Region in 1998. Calomera angulata was occurring throughout the Indian subcontinent eastward into Southeast Asia (Acciavatti and Pearson 1989). It was known from India, Himachal Pradesh (Uniyal and Sivakumar 2007), recorded from China (Wu and Shook 2007).

3.*Calomera funerea assimilis* (Hope, 1831)

Two individuals were observed from the muddy riparian area in open patches of shrubs, rain trees and Acacia trees from Kine Shay River, Taunggoke Township, Rakhine State in August 2016 (Plate 3). Wiesner (2004) reported that this species was observed as new record from Alaungdaw Katthapa, Sagaing Region in 2003. It was also recorded from Kachin State (Wiesner 2004). This finding was new record in Rakhine State from this study.

4.*Calomera plumigera scoliographa* (Rivalier, 1953)

One individual was collected in June 2017 each from the riverside of Ayearwaddy River, Mandalay Region and Sarrpwak River, Magway Region (Plate 3). It was recorded from Yunnan Province, China (Shook and Wu 2007). It was the first record in 2017 from Myanmar during this study.

5.*Cincindela atkinsoni* (Gestro, 1893)

One individual was collected from the deciduous forest with the most common trees including Than-dahat and Inn-daing in June 2016 at the forest area of Ottarathiri Township, Mandalay Region. Three individuals were collected in July from Pobbathiri Township, Mandalay Region and the microhabitat was same as Ottarathiri Township (Plate 4). It was recorded in Burma (Fowler 1912). It was the first record from Mandalay Region during this study.

6.*Cincindela corbetti* (W. Horn, 1899)

One individual was collected from the dam area of sandy and rock in an open with the most common trees of Eucalyptus in June 2016 from Yezin Dam, Zayarthiri Township, Mandalay Region (Plate 4). This species was recorded from Chatthin Wildlife Sanctuary, Sagaing Region in 2002 (Wiesner 2004). Therefore, this finding was new record in Mandalay Region from this study.

7.*Cosmodela aurulenta juxtata* (Acciavatti& Pearson, 1989)

One individual was collected in June 2016 from Phokyar Elephant Camp, Taungoo, Bago Region. Adult rainy season microhabitat is the riverside with sandy and rock bank in an open forest with the most common trees including Teak (Plate 4). This species was recorded from Sein Yay Forest Camp, Bago Yoma, Bago Region in 1998 (Wiesner 2004). It was also recorded from Shan State (Wiesner 2006).

8.*Cylindera (Ifasina) foveolata* (Schaum, 1863)

Two individuals were collected in June 2016 from Maungyan Village forest, Ottarathiri Township, Mandalay Region. Adult rainy season microhabitat is the deciduous forest with the most common trees including Than-dahat and Inn-daing (Plate 4). It was recorded from Chatthin Wildlife Sanctuary, Sagaing Region in 2002 (Wiesner 2004). It was also recorded from Kachin State and Shan State (Wiesner 2006). It was the first time record in Mandalay Region from this study.

9.*Cylindera holosericea* (Fabricius, 1801)

One individual was collected in June 2016 from Aunglan Monastery, Ottarathiri Township, and Mandalay Region. Adult rainy season microhabitat is the deciduous forest with the most common trees including Than-dahat and Inn-daing (Plate 5). It was recorded from Yunnan Province, China (Shook and Wu 2007). It was the first record from Myanmar.

10.*Cylindera minuta* (Olivier, 1790)

One individual was observed in February 2016 at the riverside, Kine Shay River, Taunggoke Township, Rakhine State (Plate 5). Adult microhabitat is the riparian area with mud in open patches of shrubs, rain trees and Acacia trees. Fourteen individuals collected in June 2016 from Aunglan Monastery, Ottarathiri Township, Mandalay Region; adult rainy season microhabitat: deciduous forest with the most common trees including Than-dahat and Inn-daing. Four individuals collected in July 2016 from Yayhlwe village waterfall, Taungoo, Bago Region; adult rainy season microhabitat: stream habitat with sandy and rock riverside in an open shrubs and bamboo. It was also collected in April 2017 from Sin Thay Stream, Pyinmana Township, Mandalay Region and Sittaung River, Theinzayat Township, Mon State. It was observed in May 2017 from Kyaik Tal River, Belin Township, Mon State; Kyun Ka Lay River, Letpadan Township, Bago Region; Sarrpwak River, Tabin Village, Minbu Township, Magway Region; Ma Zin Dam, Bago Region; Mone Stream, Pwintphyu Township, Magway Region. It was recorded from Myitkyina, Kachin State and Chatthin Wildlife Sanctury, Sagaing Region in 1999 (Wiesner 2004).

11. Cylindera spinolae (Gestro, 1889)

One individual was documented from the deciduous forest with the most common trees including Than-dahat and Inn-daing in June 2016 and 2017 at the forest area of Aunglan Monastery, Maungyan forest, Ottarathiri Township, Mandalay Region (Plate 5). It was recorded from Zan Phut, Putao, Kachin State in 2000 (Sawada and Wiesner 2000). This species was also recorded from Kalaw, Shan State; Indawgyi Lake, Putao, Kachin State; Alaungdaw Katthapa, Sagaing Region in 1999 (Wiesner 2004). It was the first record in Mandalay Region from this study.

12.*Lophyra cancellata* (Dejean, 1825)

Two individuals were observed in late April 2017 from Kyoe Kie stream, Phyu Township, Bago Region. One individual was observed in May 2017 from Sin Thay stream, Pyinmana Township, Mandalay Region. One individual was observed in May 2017 from Bone Myoe and Bawdi Pauk stream, Khin Oo Township, Sagaing Region (Plate 5). It was recorded in India, Pakistan and Thailand (Acciavatti and Pearson 1989). It was the first record in Myanmar from this study.

13.*Myriochile dubia* (W. Horn, 1892)

One individual was collected in June 2016 from Aunglan Monastery, Ottarathiri Township, Mandalay Region. Adult rainy season microhabitat is the deciduous forest with the most common trees including Than-dahat and Inn-daing. One individual was also observed in May 2017 from the riverside of Sarrpwak River, Tabin Village, Minbu Township, Magway Region. It was also observed from the muddy bank of Innpawkhone, Nyaung Shwe Township, Shan State and Kyun Ka Lay Riverside, Letpadan Township, Bago Region (Plate 6). Acciavatti and Pearson (1989) from India

(Asam, Nagaland) and Thailand. This finding was the first record from Myanmar in these areas.

14.*Myriochile sinica* (Fleutiaux, 1889)

Six individuals were collected in May 2017 from Bone Myoe and Bawdi Pauk Stream, Khin Oo Township, Sagaing Region. One individual was collected in May 2017 from Sarrpwak River Tabin Village, Minbu Township, Magway Region. One individual was examined in May 2017 from Innpawkhone, Nyaung Shwe Township, Shan State. One individual was observed in late April 2017 from Kyun Ka lay River, Letpadan Township, Bago Region (Plate 6). It was observed in Cambodia in 2015 (Wiesner 2017). It was first recorded in Namti, Kachin State, Myanmar in 2000 (Sawada and Wiesner 2000).

15.*Neocollyris bonellii bonellii* (Guérin-Méneville, 1834)

Two individuals were collected from the deciduous forest with the most common trees including Than-dahat and Inn-daing in June 2016 at Maungyan forest, Ottarathiri Township, Mandalay Region (Plate 6). It was recorded from Shan State (Wiesner 2006).

16.*Neocollyris fuscitarsis* (Schmidt-Goebel, 1846)

Two individuals were collected from the deciduous forest with the most common trees including Than-dahat and Inn-daing in June 2016 at Maungyan forest, Ottarathiri Township, Mandalay Region (Plate 6). It was recorded from Shan State (Wiesner 2006). This finding was first record in Mandalay Region, Myanmar.

17.*Neocollyris linearis linearis* (Schmidt-Goebel, 1846)

One individual was collected from the deciduous forest with the most common trees including Than-dahat and Inn-daing in June 2016 at Maungyan forest, Ottarathiri Township, Mandalay Region (Plate 7). It was recorded from Kumon range, Zan Phut, Kachin State in 2005 (Sawada and Wiesner 2000).

18.*Neocollyris moesta moesta* (Schmidt-Goebel, 1846)

One individual was observed from the deciduous forest with the most common trees including Than-dahat and Inn-daing in June 2017 at Maungyan forest, Ottarathiri Township, Mandalay Region (Plate 7). It was from Shan State, Myanmar (Jaskula 2008; Wiesner 2017). It was the first record in Mandalay Region from this study.

19. *Neocollyris variicornis* (Chaudoir, 1864)

Two individuals were observed from the deciduous forest with the most common trees including Than-dahat and Inn-daing in June 2017 at Maungyan forest, Ottarathiri Township, Mandalay Region (Plate 7). It was recorded from Kumon range, Zan Phut and Namti, Kachin State in 2005 (Sawada and Wiesner 2000). It was the first record in Mandalay Region from this study.

20. *Neocollyris zerchei* (Naviaux 1991)

One individual was observed from the

deciduous forest with the most common trees including Than-dahat and Inn-daing in June 2017 at Maungyan forest, Ottarathiri Township, Mandalay Region (Plate 7). It was the first record in Myanmar from this study. It was recorded by Naviaux and Pinratana (2004).

Conclusion

The species inventory effort was made to increase the number of documented tiger beetle species of the selected area in Myanmar. A total of 20 tiger beetle species observed from the selected areas during the study period that were undocumented before. Among the observed species, Calomera angulata was observed as the common species in riparian habitat. Nine species occurred in riverside and riparian habitat and 11 species were observed as confined in the forest habitat. These findings provided the increased number of tiger beetle species sites which was reported in Myanmar.

Myanmar has been known internationally for its rich biodiversity and the depletion of natural forest. It was assumed that since most species, including many tiger beetles were associated with forest environment, few could adapt to secondary forest or to non-forested habitat and would have led to mass extinction. Based on the findings in this study, however, the species richness of tiger beetles in Myanmar showed that the country's biodiversity is in good shape. Although concerned over depletion of natural resources are valid, what is overlooked is the ability of species to adapt, which has been the story of how species diversity in this country came to be. Just as specification occurred by differential adaptation of populations in different islands and habitat types, species have also thrived amidst a century of deforestation and habitat destruction. This is stated not to advocate such practices but to focus our attention not only on the number of species but also on the extant populations. In order to assess if the species of tiger beetles are endangered or not, genetic variation among different populations must be assessed. It is unfortunate that although the tiger beetle fauna in the Southeast Asia is richest among the world's biogeographic regions, very little information in this region have been generated apart from taxonomic studies.

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Comparison on forage crop performance of three selective grass cultivars

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Abstract

Field experiment was conducted at Yezin Agricultural University from 2016 October to 2017 October. Three forage grass cultivars: Mombasa, Cayman and Mulato II were compared for their performance. Randomized Complete Block Design was used with four replications. In this experiment, total plant height, fresh weight and dry weight were significantly different among the tested cultivars. Mombasa was the highest followed by Cayman and the Lowest one was Mulato II. However, for the tiller number of Mulato II gave higher than the two others. Total Crude Protein, Acid Detergent Fiber, Neutral Detergent Fiber and Organic Matter were significantly different among tested cultivars. Mombasa produced high forage yield with high nutritive composition during the whole year. The result from this experiment suggested that Mombasa can be accepted to increase forage production in study area. However, Cayman and Mulato II have potential in nutrient composition for livestock productivity.

Keywords; mombasa, cayman, mulato II, yield, nutrient composition

Introduction

In Myanmar, most of the people live in rural areas and their livelihood depends on agricultural activities and livestock breeding. Crop-livestock farming system plays a multi-purpose role in developing country and is essential for the livelihood of the rural population. Most rural households raise livestock which contributes significantly to household protein and supports the farm economy through draught power, meat and milk (MOAI and MLFRD 2015). Increased productivity of livestock is required to meet the increasing demand for animal products and to improve the livelihood of farmers. In most developing countries, natural pastures and crop residues are the main feed resources for livestock. Poor quality natural pasture and crop residues cannot support the effective livestock production and even maintain current productivity because of their inherent nutrient deficiencies, low digestibility and limited intake capacity for bulky feeds (Van Soset, 1965).

Forage is an essential part of ruminant animal diet and an important factor in a profitable farm business. Pasture grass is one of the most important sources of nutrients for ruminants

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(Taweel et al. 2005). Herrera (2004) reported that grass pasture turns on to be an appropriate source of food for ruminants, mainly in tropical countries. There are many grass species used for pasture due to their high dry matter yield (DMY) potential and good animal feed quality. During prolonged dry period, grazing animals subsist on dry mature fodder of poor quality. Extreme climatic events lead to tissue senescence that strongly decrease forage quality. Under moderate heat stress, plant maturation is faster, water content of plant tissues decreases while water sustainability and climate (WSC) increase (Moore and Jung, 2001). Heat stress usually decreases DM digestibility (Lu, 1989). In addition, water availability may play a major role in the response of pasture lands to climate change although there are different in species response (Izaurralde et.al, 2011).

Although cattle are very important in agricultural works, fodder needs and demands have challenges including low quality feeds in Myanmar. Most of the fodders consist of poor quality grasses and a limited range of edible shrubs. A simple and effective way to improve livestock production is the development of

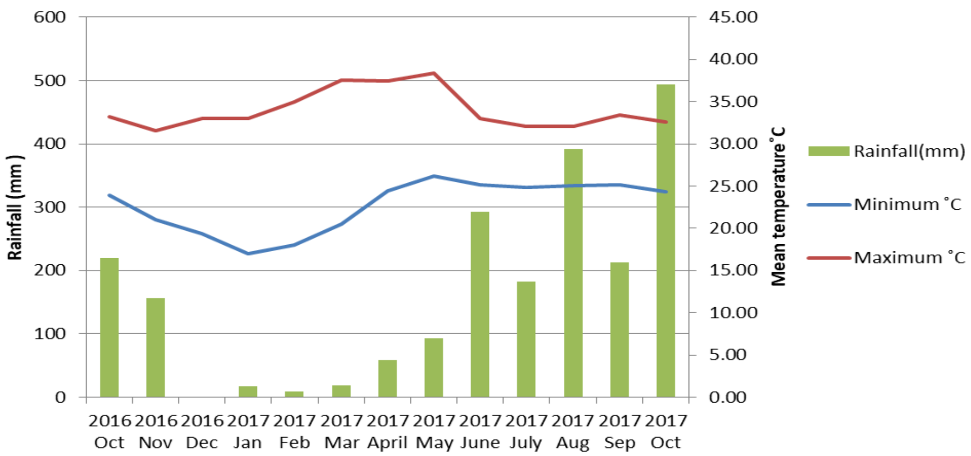

Figure 1. Weather conditions during planting time to harvesting time of three forage grass cultivars

Table 1. Mean comparison for agronomic performance of three forage grasses,October 2016 -October 2017

Cultivars	**Plant heights (cm)**	**Tiller number**	**Fresh weight ($t\ ha^{-1}$)**	**Dry weight ($t\ ha^{-1}$)**
Mombasa	122.51 a	26 b	73.54 a	18.38 a
Cayman	60.59 b	64 a	44.53 b	11.14 b
Mulato II	55.64 b	79 a	28.86 b	7.22 b
$LSD_{0.05}$	14.76	22.89	22.59	5.65
Pr>F	0.0001**	0.003**	0.008**	0.008**
CV%	10.72	23.38	26.67	22.67

Means followed by the same letter within the column are not significantly different at 5% level.

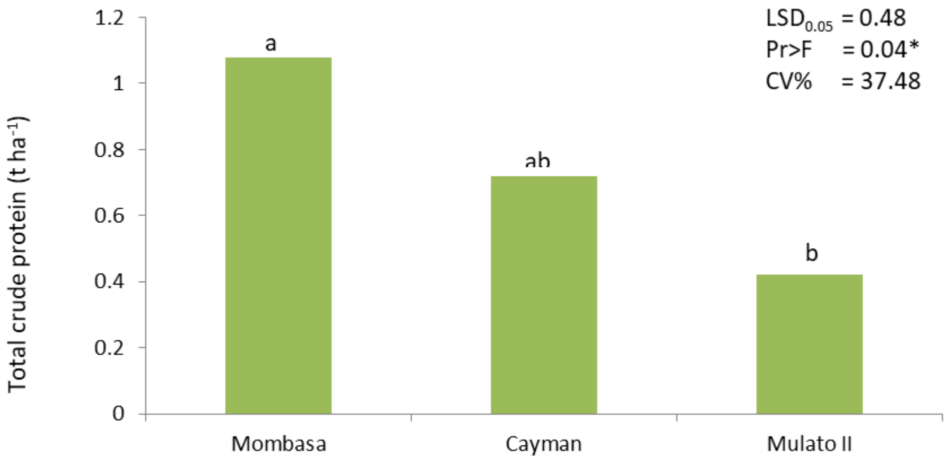

Figure 2. Total crude proteins from three forage grass cultivars, 2016-2017

good quality pasture production in Myanmar (Kywe and Aye 2007).

The main constraints for high productivity of pasture in Myanmar are less of suitable cultivars for pasture and awareness in pasture cultivation. Moreover, a little has been known on the cultivation and management on pasture in Myanmar. This study was, therefore, carried out with the following objectives:

1. To study the agronomic characters of three grass cultivars and to investigate the most appropriate cultivar among them, and
2. To examine the nutritive quality and yield of three forage grass cultivar in study area.

Materials and methods

Experimental site and layout

The experiment was conducted at the upland field of Department of Agronomy, Yezin Agricultural University from October 2016 to October 2017, located at 19° 5´ N latitude and 96° 07´ E longitude with the elevation of 213 meters above sea level. The study area received an annual rainfall of 1275 mm and mean annual maximum and minimum temperature of 34.08˚C and 21.15˚C, respectively. The experiment site was on an upland sandy loam soil that was moderate alkaline (pH 7-8) with low in N (0.03%). Field experiment was designed

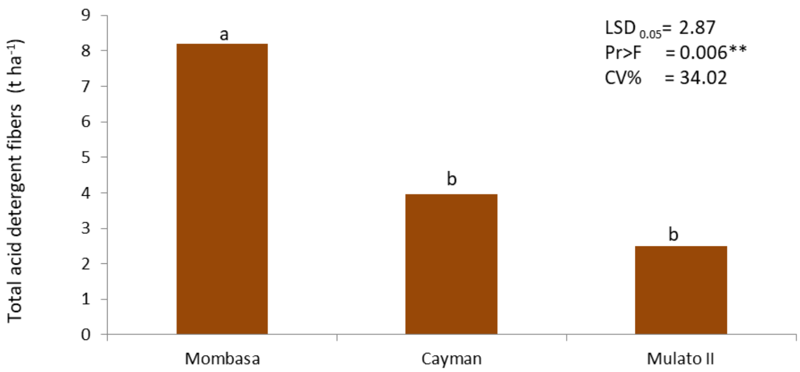

Figure 3. Total acid detergent fibers from three forage grass cultivars, 2016-2017

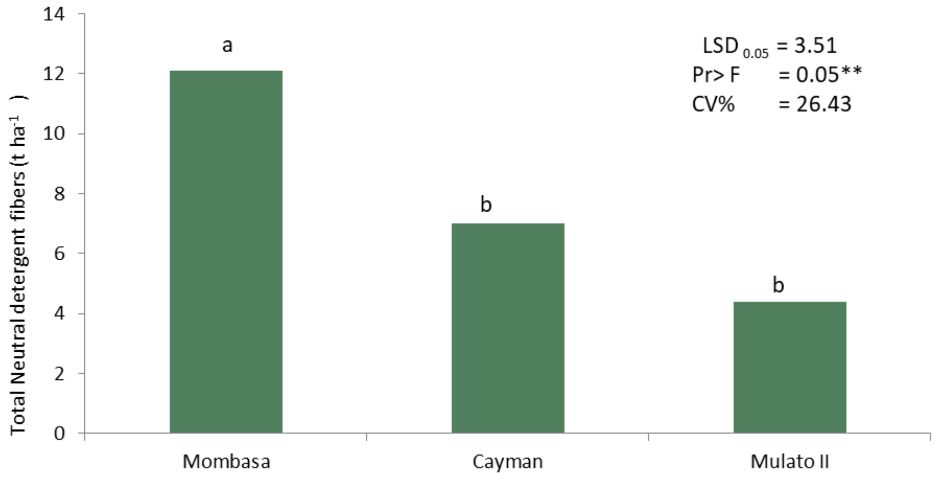

Figure 4. Total neutral detergent fibers from three forage grass cultivars, 2016-2017

as randomized complete block design with four replications. The individual plot size was 4 m x 6 m. In each plot, 8 rows of stem cuttings were sown with the spacing of 50 cm x 50 cm.

Land preparation and crop establishment

Ploughing was carried out on 18th October 2016. Harrowing and leveling were done on 21st October 2016. The tested varieties were Mombasa (Panicum maximum), Cayman (Brachiaria hybrid) and Mulato II (Brachiaria brizantha × B.decumbens × B. ruziziensis). Planting materials that were introduced from Thailand were obtained from the field of Department of Agronomy. Six inches cutting height were cut at the plant base including root to use as planting material. One stem cutting was planted in one hole on 22th October 2016. The plants that failed to survive after 14 days of planting were replaced to have a complete final stand. In this experiment, 100 kg/ha of compound fertilizer (15:15:15) was applied as basal application. Hand weeding was carried out whenever necessary.

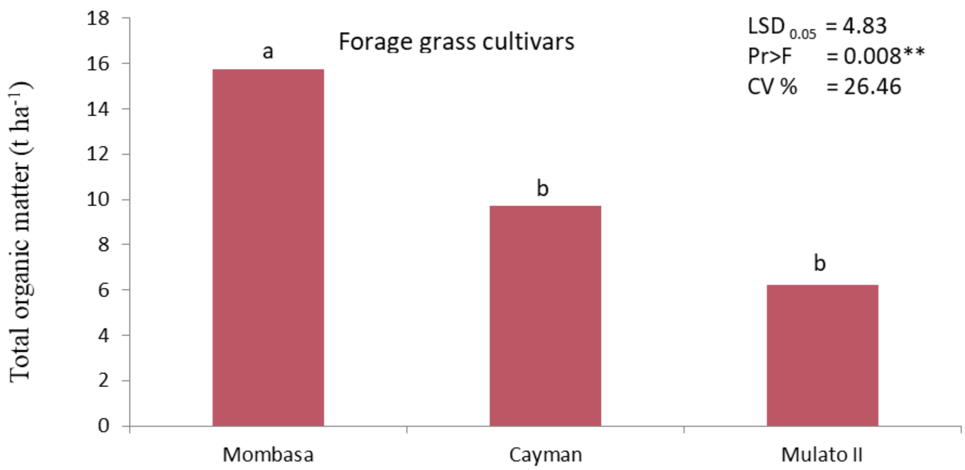

Figure 5. Total organic matters from three forage grass cultivars, 2016-2017

Data collection

Cutting was done by hand. Six months after planting, the plants were cut with sickle at the height of 15 cm above ground level. The second time cutting of the tested varieties was done during October 2017.

Agronomic characters

Before cutting, three hills from sampling area of each plot were measured for plant height and number of tillers per hill. Four hills from harvested area of each plot were cut and the fresh weight were recorded and then dried at 60˚C for 72 hours to obtained dry matter yield.

Nutrient composition

The dried sample were analyzed for total nitrogen (N) to calculate crude protein level, neutral detergent fiber (NDF) content (%), acid detergent fiber (ADF) content (%) and organic matter content (%). All chemical analyses were carried out at the laboratory of Department of Physiology and Biochemistry, University of Veterinary Science, Yezin.

Data analysis

The data were subjected to analysis of variances by using Statistix (8th version) software and treatment means were compared by using Least Significant Difference (LSD) test at 5% level of significance.

Results and discussion

Weather conditions

In planting time, rainfall on mid-October was 219 mm and harvest time on mid- October was 493 mm. After planting, the rainfall was decreased 157 mm in November. There was no rainfall in December and a slightly increased from January to May. The rainfall dramatically increased in the rainy season (June to October).

At planting time, the maximum and minimum temperature was 33.17 ºC and 23.91 ºC, respectively. In May, highest maximum temperature was observed and decrease gradually to later months (June – October).

Agronomic performance of three forage grass

Different plant heights were observed in different grass cultivars (Table 1). Mombasa was found to have the highest plant height (122.51 cm) and was highly significant different among tested cultivars. There was no significant difference in plant height between Cayman and Mulato II, however Cayman was little taller (60.59 cm) than Mulato II (55.64 cm) numerically.

There was highly significant difference in tiller number and the lowest tiller numbers (26) was observed in Mombasa. Although Mulato II provided the highest tiller numbers (79), they was no significant difference with Cayman (64). Vegetative growth (height, spread and tiller number) can be attributed to the morphological and physiological differences among the cultivars. The rapid spread of the cultivars indicates that they can play an important role in quick soil stabilization for erosion control and can be utilized in the stabilization of terrace banks in semi-arid areas. Plant spread can be attributed to individual growth habits of the cultivars (Nguku, 2016).

Among three grass cultivars, the most herbage fresh yields (73.54 t ha^{-1}) was observed in Mombasa due to the tallest plant height though fewer tiller numbers. It was followed by Cayman (44.53 t ha^{-1}) and the lowest one (28.86 t ha^{-1}) was obtained from Mulato II. However, Laidlaw (2005) suggested that, tillers increase the chance of survival and the available forage resource of grasses and number of tillers is an indicator of resource use efficiency by different grass species. The weight of a plant's tillers will determine its productivity (Nelson and Zarrough 1981).

There were significant differences among tested cultivars in dry matter yields. Mombasa (18.38 t ha^{-1}) produced highest dry matter yield. The lowest dry matter yield was recorded from Mulato II (7.22 t ha^{-1}) though this value was not significant with Cayman (11.14 t ha^{-1}). Average yields of dry matter in well fertilize soil can be expected to fluctuate between 20-40 t ha^{-1} for high yielding grasses, 10-25 t ha^{-1} for medium-yielding grasses and 3-10 t ha^{-1} for poor yielding grasses. Yield of individual species also vary within wide limits depending on climate, weather condition of year, water supply, soil fertilities, the fertilizers applied and the managements (Bogdan, 1977).

Nutrient composition of three forage grass cultivars

Crude protein

Crude protein (CP) is the most important measure of nutritive values of forages. The crude protein in herbage is determined as nitrogen content and then, because most nitrogenous compounds in plant contain on average 16% N, the total is multiplied by 6.25 to estimate crude protein. Normally, 70-90% of the total nitrogen in herbage is in the form of proteins, the remainder being non protein nitrogen (NPN) as peptides, amino acid, amines and inorganic nitrate (Holmes 1980).

The significant difference among three tested cultivars was observed for crude protein content (Figure 2). Maximum crude protein (1.08 t ha^{-1}) was resulted from Mombasa followed by Cayman (0.72 t ha^{-1}) and Mulato II (0.42 t ha^{-1}) in all year round. Generally, there have been instances of high CP concentration in hybrid brachiaria (Cayman and Mulato II) which could provide average of 7 - 11 % crude protein in leaf in Thailand (Hare et al. 2007b). In this experiment, Cayman and Mulato II produced lower dry matter yield than Mombasa, therefore the highest crude protein was observed in Mombasa during the whole year (Table 1). Evitayani (2004) concluded that differences in CP digestibility of the forages also arise as a result of differences in species or genotype, stage of growth, environmental conditions and management practice.

Minson (1990) showed that the crude protein concentrations of 560 tropical forages samples, grown and determined in different parts of the world, ranged from 2% to 27% of the dry matter yield according to growth stage and soil fertility.

Acid detergent fiber

The fiber fraction in forage varies in degree of development, chemical composition and structural complexity. The nature of the fiber depends on the deposition on primary cell walls. Acid detergent fiber consists of cellulose, lignin, bound protein, and acid insoluble ash protein of a feed. It is negative indicator of energy level in forage (Dewhurst et al. 2009).

Figure 3 showed different acid detergent fiber on three tested grass cultivars which were highly significant difference especially in Mombasa. The most acid detergent fiber (8.19 t ha^{-1}) was resulted from it. There were not significant differences between Cayman and Mulato II, however Cayman (3.95 t ha^{-1}) included more acid detergent fiber than Mulato II (2.49 t ha^{-1}) in numerically.

Evitayani (2004) reported that species and season had significant effect on chemical composition and mineral concentration. Pasture quality parameters decreased from the young to mature stages as a result of differences in plant composition between levels of maturity (Reling et al., 2001). The quality of available bites is depressed when green leaf material is scarce and largely dispersed among senescent material especially in the case of older pasture for which the NDF and ADL fractions increased with level of maturity (Aganga and Tshwenyane 2004).

Neutral detergent fiber

Neutral detergent fiber (NDF) is the total insoluble fiber. It is better than ADF and the more common measurement (Dewhurst et al. 2009).

The different neutral detergent fibers were resulted from different grass cultivars (Figure 4). The maximum NDF was obtained from Mombasa (12.11 t ha^{-1}) followed by Cayman (7.01t ha^{-1}) while the minimum was from Mulato II (4.39 t ha^{-1}).

According to the report of Bula et al. (1977), dry matter digestibility of forage during the grazing stage can vary considerably, and is related to change in the chemical composition particularly in fiber, lignin and silica contents. Gőhl (1975) stated that wide variation of CP was mainly related to different content of crude protein in the grass and fiber component.

Organic matter

Organic matter is critical for healthy soils that supports productive pastures. It makes soils resilient by providing food for soil microbes, provides a store of relatively available nutrients, and bonds soil particles for a stable structure. This organic matter includes living plants, animals and microbes, as well as litter on the soil surface and degrading and decomposing materials.

Different organic matter was observed in different forage grass cultivars (Figure 5). Mombasa could produce maximum organic matter (15.76 t ha^{-1}) which was significantly different from Cayman (9.71 t ha^{-1}) and Mulato II (6.21 t ha^{-1}). Pieterse et al. (1997) reported that the highest DM producers, had the best water use efficiency, a well balance nutrient concentration and a high IVDOM (in vitro digestibility organic matter) and low NDF and NDF concentrations. Therefore organic matter also play important role in forage quality.

Conclusion

According to the experimental results, it could be concluded that for the forage yield and nutritive value of the selective grasses in the study area, Mombasa was relatively higher than that of Cayman and Mulato II. Therefore, Mombasa is often considered as one of the suitable species for livestock production. However, further experiments would need to be conducted for Mombasa to improve livestock production.

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Assessment of farmers attitude on the use of farmyard manure and chemical fertilizers or cotton production in dry zone

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Abstract

Cotton production is one of the main agricultural activities in Myanmar Dry zone. The farmers' fertilizer management practices are important for researchers to develop appropriate technologies in order to increase cotton yield and quality. Manure and chemical fertilizers play important roles in the maintenance of soil fertility in cotton production. The use of farmyard manure and chemical fertilizer in appropriate combinations may alleviate the problem of declining soil fertility and hence lead to increase cotton yields. The objectives of this study were to: (i) assess the use of farmyard manure and chemical fertilizer and (ii) determine the constraints with regards to use of organic and inorganic fertilizers by smallholder farmers in Dry zone The survey conducted in four regions as Upper, Central-1, Central- 2, and Lower Dry zone area at summer season in 2017. A survey of 160 randomly selected farmers was conducted using a standard questionnaire. An interview schedule was the main tool of data collection while descriptive statistics were the main analytical technique. The majority of cotton- cultivated farmers were 95 %. *Gossypium hirsutum* cotton grown farmers were 86%, and *Gossypium arboretum* varieties grown farmers were 14%. Only 65% of the farmers had easy access to urea fertilizer application and 92.5% accessed compound fertilizer application. Farmyard manure using farmers were 97% in Dry zone. The majority of the farmers are unaware of recommended dose, time of application and method of application of the chemical fertilizers. High price of chemical fertilizers is one of the hindrances in the use of recommended doses of fertilizers by the cotton farmers. Based on the results of this study, majority of farmers could not afford chemical fertilizers due to the lack of access to credit. Fertilizer accessibility was still a problem in some areas. Extension services, especially information regarding the appropriate use of manure and chemical fertilizers, were not accessible to most farmers.

Keywords: farmyard manure, chemical fertilizer, variety, cotton production

Introduction

The king of the natural fibres is one of the cotton crops. Myanmar introduced cotton since Pyu era. Cotton is a traditional crop grown and is the principal fibre crop in Myanmar. All of the cotton production is consumed domestically in Myanmar. The extreme limits of its production region stretch from about 400 N to about 350 S. Annual production of cotton in

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the world stood at 68.3 million metric tons (FAO, 2010). In the world, the major cotton producing countries are the China, India, U.S.A., Pakistan, Uzbekistan, Egypt, Mexico, Russian, Japan, Turkey and Sudan. In Africa major cotton producing countries are Egypt, Sudan, South Africa, Zimbabwe and Tanzania (Nasiru Habu Kura, 2012). The world high standard of contton production and cotton lint yield are noted in India, China and USA as 26.5, 21, and 16 million bales respectively (One bale weight 480 lb). Myanmar has decreased production such as 0.73 million bales in 2017 (USDA, 2018).

CSA is critical for limiting warming to 2º or 1.5º C globally, which can only be achieved through effective partnerships and an improved enabling environment. The level of ambition across the private and public sectors need to increase and governments and companies should increasingly look to set quantified science-based targets for the land use sector to drive progress and finance. The CSA is identified by FAO at the Hague Conference on Agriculture, Food Security and Climate Change in 2010, which integrates the three dimensions of sustainable development (economic, social and environmental) by jointly addressing food security and climate challenges. It is composed of three main pillars:

Agricultural production is receiving big challenges from the impact of climate change, energy scarcity, resource degradation and rising food prices, as well as the deterioration of one-third of agricultural land because of erosion, salinity, stress, and chemical pollution of the soil. Increased productivity and profitability of farming is an important pathway to reduce poverty in the rural areas of Myanmar. Soil fertility and crop management are two of the most important factors in modernistic cotton production. Research in these areas is needed to intensify production to obtain higher yields. Managing the balance of vegetative and reproductive growth is the essence of managing cotton crop. Inadequate supply of nutrients due to declining soil fertility is one of the major constraints to crop production faced by the smallholder farmers in Vhembe District of Limpopo Province, South Africa (Ramaru et al., 2000).

Majority of smallholder farmers in Dry zone are resource poor and cannot afford the high costs of the fertilizers. Chemical fertilizer use is risky for two reasons. First, yields and output prices can vary widely on a year-to-year basis and therefore, farmers fear that their crop income will not be high enough to cover their fertilizer costs. Second, yield vary widely with the climate: rainfall is highly uncertain and in drought years, the crop response to fertilizer can be practically non-existent. Chemical fertilizers on the other hand do not improve soil physical structure or enhance soil biological activity (McGuiness, 1993). One such strategy is the use of compost or organic manure. The enhancement of fertility factors by using organic fertilizers causes an immediate improvement in the utilization of chemical fertilizers. Increased water availability, for example, improves the utilization of fertilizer by cotton. Irrigation is important to offset insufficient growing season rainfall and to maintain optimum seed cotton yield.

Table 1. Main study areas and respondents farmers in Dry zone.

No.	Region	Districts	Township	Village	Total Re-spondentfar mers	Cotton cultivated farmers	% of Re-spondents farmers
1	Upper	Pakokku	Pakokku	Thanetaw	20	20	100
2			Myaing	Ooyinn	20	19	95
3	Central-1	Magway	Yenangyaung	Kangye	20	18	90
4			Myothit	Magyegone	20	20	100
5	Central-2	Minbu	Minbu	Pytethin	20	19	95
6			Salin	Lapantawe	20	20	100
7	Lower	Thayet	Thayet	Htonetaung	20	16	80
8			Aunglan	Yaepaw	20	20	100
Total					160	152	95

Table 2. Distribution of education level in different dry zone area

No.	Educated level	% of the respondents			
		Upper (N=39)	Central-1 (N=38)	Central-2 (N=39)	Lower (N=36)
1	Primary School	56.4	70	82.1	69.4
2	Middle School	28.2	15	7.7	25.0
3	High School	12.8	2.5	5.1	2.8
4	Graduate Level	2.8	7.5	2.6	2.8

(Source: survey data)

The main activity of this study was to analyse the farm survey data on farmyard manure and chemical fertilizer use on cotton production farms in Myanmar. The trends in farmyard manure and chemical fertilizer usage are important statistics to collect so that fertilizers use trends can be determined over time and compared with other data such as cropping pattern, choice of variety and management of fertilizer application The objectives of this study, therefore, were to: (i) assess the use of farmyard manure and chemical fertilizer and (ii) determine the constraints with regards to use of manure and chemical fertilizers by smallholder farmers in Dry zone.

Research methodology

Dry zone sits approximately between north latitude 18° 50' to 22° 47' and east longitude 93° 47' to 95° 55'. The district is generally tropic, subtropical region with rainfall ranging from 300 to 1200 mm per year. Four districts were selected from Dry zone: Pakokku (Upper), Magway (Central - 1), Minbu (Central - 2), and Thayet (Lower) districts. Two townships were selected from each districts and one village was selected from each township of cotton production area. The number of farmers selected for interview from each village was 20. The total number of respondents came to be

Table 3. Cotton cultivated area distribution in Myanmar (2015-16 post-monsoon)

No	Division	% of total area	% of *Hirsutum* cultivation	
			In Country area	In Division area
1	Magway	51.68	52.15	78.39
2	Mandalay	27.49	29.08	82.16
3	Sagaing	16.43	16.57	78.33
4	Bagoo	2.86	0.33	8.95
5	Naypyitaw	1.42	1.83	100
6	Shan	0.09	0.04	34.12
7	Chin	0.03	0	0

(Source: Department of Agriculture)

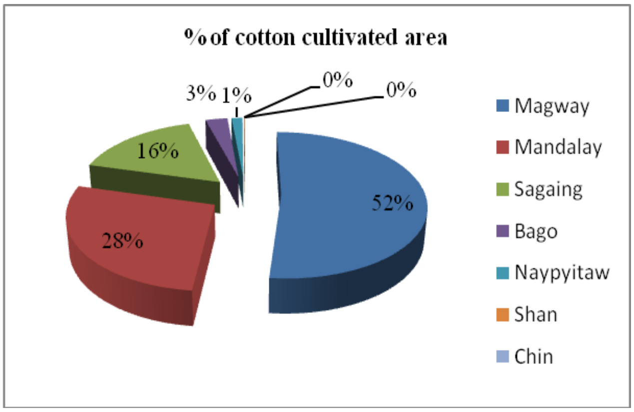


Figure 1. Myanmar cotton cultivated area distribution in country (2015-16).

Table 4. Cotton cultivated area distribution in dry zone- Magway division (2015-16 post monsoon)

No	Districts	Total area (ha)	% of total cotton area	% of *Hirsutum* cultivation	
				In Division area	In District area
1	Magway	31870.04	23.71	22.67	95.61
2	Minbu	31312.55	23.29	22.11	56.65
3	Pakokku	22203.24	16.52	9.36	94.92
4	Thayet	48946.96	36.41	22.25	66.60
5	Gangaw	91.90	0.07	0	0
	Total	134424.69			

(Source: Department of Agriculture)

160 farmers. Since the area is mainly tropical dry zone, most farmers grow cotton in rainfed condition. Consequently, all the farmers interviewed in this study were using fertilizers mainly as farmyard manure for their cotton production. An interview schedule was the main tool of data collection while descriptive statistics were the main analytical technique. Where farms were owned individually, the farmers were interviewed individually. The collected data was analyzed by using the Statistical Package for Social Sciences version 23.

Table 5. Cotton cultivated varieties distribution in survey area, Division area and Country area post monsoon season in 2015-16.

No.	Variety	% of grown cotton cultivation		
		Survey area	Division area	Country area
1	Ngwechi-6	55.00	55.10	43.36
2	Ngwechi-9	5.63	16.56	11.65
3	Shwedaung-8	7.50	1.49	13.71
4	Raka	17.50	4.72	7.18
5	China-411	6.25	0	0.20
6	5011	0	0	0.04
7	Seingaba	0	0	0.22
8	Iseral	0	0	0.56
9	Lungyaw-3	6.25	0	0
10	Other	1.88	0.52	0.37
11	Mahlaingwa(*G. arbordium*)	0.94	3.14	8.39
12	Wagye	12.5	18.47	13.93

(Source: survey data and DoA)

Results and discussion

Background of the farmer's interview

While 97% of the respondents were male, the remaining 3% were female. A few smallholder farmers in Dry zone use farmyard manure or crop residue but lack sufficient knowledge of handling and storage of farmyard manure. In addition, due to the limited number of animals kept by the smallholder farmers, the amount of farmyard manure produced is never sufficient. Table-1 shows main study areas and respondents farmers in Dry zone.

Table -2 shows distribution of education level in different Dry zone. 56.4 % of the respondents possessed the primary school education and 28.2 % of middle school, 12.8 % reached high school education and 2.8% of graduate level in the upper region. 70 % of the respondents possessed the primary school education and 15 % of middle school, 2.5 % reached high school education and 7.5 % of graduate level in the Central-1 region. 82.1 % of the respondents possessed the primary school education and 7.7% of middle school, 5.1 % reached high school education and 2.6 % of graduate level in the Central-2 region. 69.4 % of the respondents possessed the primary school education and 25 % of middle school, 2.8 % reached high school education and 2.8 % of graduate level in the Lower region.

Landholding of farmers

All the sample respondents grew cotton in upland area. Farmer owned maximum farm size was 35 ac (14.17 ha) in upper region, 24 ac (9.72 ha) in central-1 region, 40 ac (16.19 ha) in central -2 region and 35 ac (14.17 ha) in lower Dry zone. Mean of farmers owned farm size was 11 ac (4.5 ha) in upper region, 9 ac (3.64 ha) in central-1 region, 15 ac (6.07 ha) in central-2 and 13 ac (5.26 ha) in lower Dry zone. Of all the farmers interviewed, maximum farm size of cotton cultivated area was 7 ac (2.83 ha) each in upper region and in central -1 region, 15 ac (6.07 ha) in central-2 region, and 18 ac (7.29 ha) in Lower Dry zone. The mean landholding size was 3.02 ac (1.22 ha) in upper region, 3.39 ac (1.37 ha) in central -1 region, 4.89 ac (1.98 ha) in central-2 region and 5.24 ac (2.12 ha) in Lower region (Table 7 and 8).

The size of holding of agriculture land per family in 1997-98 indicates 25% of farm families owns less than 5 acre, 32% of farm families owns 5-10 acre, 27% of farm families owns 10-20 acre, 11% of farm families owns 20-50 acre, 0.5% of farm families owns 50-100 acre and 2% of farm families owns 100 acre and above (Nyein Zin Soe, 2000).

Cotton production

In Myanmar, cotton is mainly grown in Sagaing, Mandalay, Magway and Bago divisions. Magway region covers about 52 % of the total cotton area, Mandalay region covers about 28 %, Sagaing region covers 16 %, Bago region covers less than 3 % and Chin State about 0.03 % of total cotton area in the country. Table 4 showed cotton cultivated areas distribution at 2015-16 post monsoon in Myanmar.

Cotton varieties

In Dry zone area, *G. hirsutum* cotton type was grown in 23.71% of the cotton total area and 95.61% in Magway districts. In Minbu district 23.29% of the total area was cultivated with cotton of which *G. hirsutum* cotton was grown in 56.65% area. Of 16.52% of the total cotton cultivated area in Pakokku district *G. hirsutum* cotton was grown in about 94.92% area.. Similarly, out of 36.41% of total cotton cultivated area 66.6% of this was grown with *G. hirsutum* in Thayet districts. Gangaw districts did not grow *G. hirsutum*. Table 5 shows cotton cultivated area distribution in 2015-16 post monsoon season in Dry zone (Magway Division) (DOA—2016).

95% of the cotton farmers lived in Dry zone. 85.63 % of farmers grew *G. hirsutum* and the *G. arboretum* type cotton growing farmers were 13.75%. Consequently, farmers grow various varieties of cotton in Dry zone. . Shwedaung-8 was cultivated in 13.71% area, 11.65% area cultivated with Ngwechi-9, 43.36% with Ngwechi-6, and 7.18% with Raka (India) in 2015-16 seasonal years. However, Ngwechi -6 was cultivated in 55%, Ngwechi-9 in 5.63%, Shwedaung - 8 in 7.5% and Raka in 17.5% in post monsoon season in Dry zone. *Gossypium arboretum* varieties (Mahlaingwa in 0.94% area and Wagye in 12.5% area) was also cultivated in Dry zone. Additionally, each Lungyaw-3 and China -411 varieties were sown in 6.25%. Table-6 show cotton cultivated varieties distribution in Dry zone post monsoon season in 2015-16 (DOA—2016).

Myanmar produced the long staple cotton bollworm resistant Bt variety Ngwechi -6 (Silver-6). Farmers' practice of fertilizer

Table-6 Distribution of Livestock in Dry zone area.

No.	Distribution categories	Do of practices (N=152)		Undo of practices (N=152)	
		frequency	%	frequency	%
1	Cow	147	96.71	5	3.29
2	Dairy	10	6.58	142	93.42
3	Pig	13	8.55	139	91.45
4	Goat	7	4.61	145	95.39
5	Chicken	25	16.45	127	83.55

(Source: survey data)

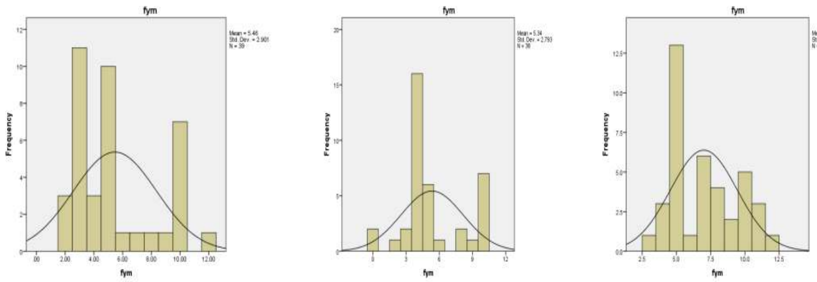
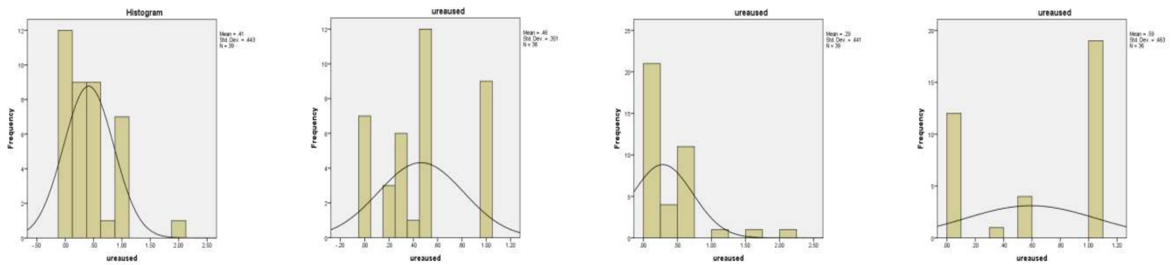
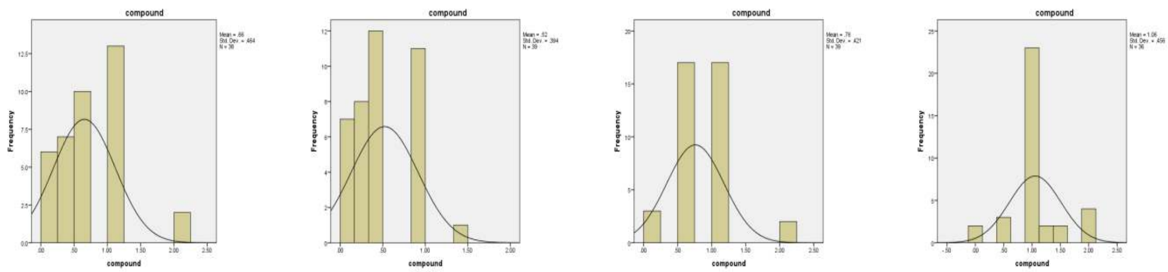


Fig- 2 The application of farmyard manure practices in different Dry zone



(i)Upper (ii) Central-1 (iii) Central-2 (iv) Lower

Fig- 3 The application of Urea fertilizer application practices in different Dry zone .



(i) Upper (ii) Central-1 (iii) Central-2 (iv) Lower

Fig- 4 The application of Compound fertilizer application in different Dry zone .

Table 7. Farmer's fertilizer management practices in different dry zone

No.	Category	Means of farmers practices			
		Upper (N=39)	Central-1 (N=38)	Central-2 (N=39)	Lower (N=36)
1	Total area (ac)	11.13	9.32	15.95	13.92
2	Cotton area (ac)	3.02	3.39	4.89	5.24
3	FYM use (carts)	5.42	5.36	7.00	5.06
4	Urea use (bag)	0.41	0.46	0.29	0.59
5	Compound use (bag)	0.52	0.66	0.76	1.06
6	Foliar use (time)	1.87	2.58	3.59	3.08
7	Herbicide using(time)	0.70	0.9	0.93	0.08
8	Seed cotton yield (Viss/ac)	321.15	272.76	357.56	388.19
9	Price (Kyat/viss)	1191.03	1384.21	1305.13	1294.44
10	Income (Kyat)	1344538	1500697	2725820	3093506
11	Family member (Nos)	5.21	5.18	5.49	4.67

(Source: survey data) ** 2 cart= 1 ton : 1bag =50 kg : 1 viss = 1.2 kg : 1 ac =0.405 ha

Table 8. Maximum usage of farmers practices in different dry zone

No.	Category	Maximum usage of farmers practices			
		Upper (N=39)	Central-1 (N=38)	Central-2 (N=39)	Lower (N=36)
1	Total area (ac)	35	24	40	35
2	Cotton area (ac)	7	7	15	18
3	FYM use (carts)	12	10	12	10
4	Urea use (bag)	2	1	2	1
5	Compound use (bag)	1.5	2	2	2
6	Foliar use (time)	4	7	7	5
7	Herbicide using	1	1	1	2
8	Seed cotton yield (Viss/ac)	800	750	800	800
9	Price (Kyat/viss)	1400	1800	1500	1450
10	Income (Kyat)	4900000	5250000	9750000	13050000
11	Family member	11	9	9	9
12	Education Level	4	4	4	4

(Source: survey data)

** 2 cart= 1 ton : 1bag =50 kg : 1 viss = 1.2 kg : 1 ac =0.405 ha

(Education level ; 1 = primary. 2 = middle. 3 = High, 4 = graduate) management produced the highest seed cotton yield and lint yield. Similarly, from the interaction effect of cotton variety and Farmer's practice of fertilizer management also produced the highest seed cotton yield and lint yield. Hence as a high yielding cotton variety and farmers' practice as improved fertilizer management could be recommended for higher yield of cotton in Jessore region of Bangladesh (Farid Uddin, 2004).

Distribution of livestock

The smallholder farms are located mostly in the former homeland areas. Farming under smallholder system is characterized by low level of cattle livestock production approximately 96.71% in Dry zone. Dairy cow production (6.58%) was primarily for subsistence production with little marketable surplus in Dry zone. The smallholder farmers also rear livestock such as pig, goat, and chicken. Table-7 shows distribution of livestock in Dry zone. Integrated agricultural farming was not enough, indicating that the farmers kept very few livestock. Farmers used manure from their owned cattle livestock.

Rate of the farmyard manure

Application of farmyard manure at the recommended rate is 4.6 ton ha^{-1} in cotton cultivation (MCSE 2012). However, on an average the amount of manure applied was 2.7 ton ac^{-1} (6.6 ton ha^{-1}) with a minimum rate applied of 1 ton ac^{-1} (2.47 ton ha^{-1}) and maximum rate of 6 ton ac^{-1} (14.8 ton ha^{-1}). Amount of manure was used at 5.42 carts ac^{-1} (6.69 ton ha^{-1}) in upper region, 5.35 carts ac^{-1} (6.6 ton ha^{-1}) in central -1, 7 carts ac^{-1}(8.65 ton ha^{-1}) in central -2 region, and 5.06 carts ac^{-1} (6.24 ton ha^{-1}) in lower Dry zone.

Maximum rate was used of 12 carts ac^{-1} (14.82 ton ha^{-1}) in each upper and central-2 regions and 10 carts ac^{-1} (12.35 ton ha^{-1}) in each central -1 and lower regions of Dry zone (Table 7 and 8).

More farmyard manure usage was 3 carts ac^{-1} (3.7 ton ha^{-1}) 26.8 % in upper region, 4 carts ac^{-1}(4.94 ton ha^{-1}) 40 % in central-1 region, 5 carts ac^{-1} (6.18 ton ha^{-1}) 33.3 % in central -2 region, and 5 carts ac^{-1} (6.18 ton ha^{-1}) 36.1 % in lower region. Fig. 2 show the application of farmyard manure practices in different Dry zone. Farmyard manure was used only basal application for cotton cultivation. It is inadequate in all farmers fields. 97.5% of the farmyard manure used in Dry zone. Continuing nutrient mining of soils means a future of increased poverty, food insecurity, environmental damage and social and economic instability. Seed cotton yield and lint yield varied significantly due to different fertilizer management (Tomar et al. 2000). Adequate supply of nutrients influences cotton plant to grow vigorously with greater yield component thus elevating the yields. Use of mineral and organic fertilizers as straight fertilizers or in combinations may help to alleviate declining soil fertility (Gruhn et al., 2000).

Rate of chemical fertilizers

The most of the respondents farmers used urea at the rate of 0.5 bag ac^{-1} (62 kg ha^{-1}) to 1 bag ac^{-1}(124 kg ha^{-1}). Of the farmers surveyed, urea was applied 0.41 bag ac^{-1} (50.64 kg ha^{-1}) in upper region, 0.46 bag ac^{-1} (56.81kg ha^{-1}) in central-1 region, 0.29 bag ac^{-1}(35.82 kg ha^{-1}) in central -2 region, and 0.59 bag ac^{-1} (72.87 kg ha^{-1}) in lower region of Dry zone. Maximum rate of urea used was 1 bag ac^{-1} (124 kg ha^{-1}) in central - 1 and lower region, and 2 bags ac^{-1} (247 kg ha^{-1}) in each central – 2 and upper regions (Table - 7 and 8). More farmers urea fertilizer application was 0.5 bag ac^{-1}(62 kg ha^{-1}) about 22 % in upper region and 28.2 % in central-2 region, 1 bag ac^{-1} (124 kg ha^{-1}) 32.5 % in central -1 region and 51.8 % in lower region (Fig. 3).

Fertilizer availability can limit growth in fertilizer consumption. Of the farmers interviewed, 90% stated that the fertilizer was always available when needed. The study indicated that urea fertilizer application is a common practice in farmers' fields. In Myanmar, urea, triple super phosphate, and mureate of potash are mainly used for cotton at recommended rate ranging from 62-62-62 kg ha^{-1} to 124-62-62 kg ha^{-1} depending on soil type, availability of irrigation water (Pye Tin 2006). It is recommended that 40% of urea, 70% of T-super and 60% of potash should be applied at the soil preparation and 10% of urea, 40% of T -super and 10% of potash at the sowing time. Then, 25% of urea and 30% of potash at the beginning of flowering time and last 25% of urea at the peak flowering time (MCSE, 2001). However, fertilizers applied only on an estimated 50 percent of cotton area and at an average rate of 30 to 40 percent of the recommended rate for cotton.

Information on rate of compound fertilizer

Farmers are using many kinds of compound fertilizer in their cotton field. Compound fertilizer a applied by 92.5% farmers and 7.5% did not use compound fertilizer in Dry zone. The rate of compound fertilizer used was 18.52 kg ha^{-1} to 248 kg ha^{-1}. Compound fertilizer (N: P: K -15:15:15) was mostly used. Compound fertilizers (15:15:15) applied from 124 kg ha^{-1} to less than 248 kg ha^{-1}in most of the cotton fields. Amount of compound fertilizer used was 0.52 bag ac^{-1} (64.22 kg ha^{-1}) in upper region, 0.66 bag ac^{-1} (81.51 kg ha^{-1}) in central-1 region, 0.76 bag ac^{-1}(93.86 kg ha^{-1}) in central - 2 region, and 1.06 bag ac^{-1} (130.91 kg ha^{-1}) in lower Dry zone. Maximum rate of compound fertilizer used was 1.5 bag ac^{-1} (185.25 kg ha^{-1}) in upper region, and 2 bags ac^{-1} (247 kg ha^{-1}) in each central -1, central-2 and lower regions of Dry zone (Table-7 and 8).

More compound fertilizer usage was 1 bag ac^{-1}(124 kg ha^{-1}) about 28.2 percent in upper region, 34.2 percent in central-1region, 0.5 bag ac^{-1} and 1 bag ac^{-1} (62 and 124 kg ha^{-1}) equally 43.6 percent in central -2 region, and 1bag ac^{-1} (124 kg ha^{-1}) about 63.9 percent in lower region (Fig-4). In most of the fields, compound fertilizers (15:15:15) is recommended to be applied in cotton at the rate of 247 kg ha^{-1} (MCSE 2012).

This indicates that as long as the farmers can access a fertilizer depot, they can always get the fertilizers that they need. Untimely local availability may prevent farmers from purchasing the fertilizer they want. Most soils in Dry zone are fragile and low in plant nutrients. The nutrient recycling mechanisms that sustain soil fertility are insufficient to support increased production without fertilizers. Soil nutrient mining is usually associated with low agricultural production and land productivity under severe constraints of poverty in terms of physical capital (infrastructure) and human capital (health and education) (ECAPAPA, 2006). A number of cotton cultivated pattern are using crop intensification systems in the Dry zone region. This includes the mixed/multiple cropping systems and the sequence cropping systems. However cotton growing farmers used mono cropping as 65 % in survey area. Cultivated areas are mostly rainfed condition in Dry zone. Labour was dependable on their family member.

Seed cotton yield

The main target yield of seed cotton was 1600 kg ha^{-1} to produce in Myanmar, (MCSE 2012). Of the farmers interviewed seed cotton yields are 321.15viss ac^{-1} (1292 kg ha^{-1}) in upper region, 272.76 viss ac^{-1} (1098.16 kg ha^{-1}) in cetral -1 region, 357.56 viss ac^{-1} (1439.57kg ha^{-1}) in central-2 region, and 388.19 viss ac^{-1} (1562.89 kg ha^{-1}) in lower region of Dry zone (Table- 7). In Africa, cotton yields are extremely variable from small holdings which range on average, from 250 to 800 kg with Nigeria having 400 to 500 kg ha^{-1} .(Adeniji, 2007) seed cotton with world average of 756 kg ha^{-1} and lint yield from 85 to 310 kg ha^{-1}. On large scale mechanized farms the average seed cotton yields vary between 2,000 and 2,500 kg ha^{-1} in China, India and U.S.A. with world average of 756 kg seed cotton per hectare (Nasiru Habu Kura, 2012).

Cotton' price was one of their expectant factors. Cotton yield of lint quantity and quality depend upon availability of nutrients and weather conditions of cotton-cultivated site during growing season. Fertilizer is a primary source of cotton nutrition. Maintaining or improving soil health is essential for sustainable and productive agriculture. Fertilizer application is an important factor in profitable cotton production in Myanmar. Fertilizer quality has significant effects on the plant growth and distribution of cotton higher yield. Cotton (*Gossypium hirsutum L.*) yields may be limited unless adequate amounts of all required nutrients are accumulated in the plant during its growth. Most soils where cotton is grown commonly have deficiencies of at least one nutrient (e.g. N, P or K) that requires addition of fertilizers to optimise production. (Ian J. Rochester et al., 2010).

Conclusion

The amounts of farmyard manure and chemical fertilizer applied did not correlate with the level of education of famers, also with the size of farmland as well. Fertilizer availability can limit growth in fertilizer consumption. Based on the results of this study, majority of farmers could not afford fertilizers due to the lack of access to credit facilities. Fertilizer accessibility was still a problem in some areas. Fertilizer applications are below the recommended rates. A high percentage of the farmers indicated that they had the information on methods, times and rates of chemical fertilizer application. For those farmers who afforded fertilizers, accessibility was still a problem in some instances and the rates applied were below the recommended rates. Right choice of fertilizer, timing, methods, and rates of application are all crucial factors in order to obtain maximum cotton plant growth and yield.

Extension staff should train farmers on the advantages of proper farmyard manure storage in order to minimize nutrient losses during storage as well as to encourage farmers to use appropriate combinations of both chemical and farmyard manure fertilizers in order to minimize costs and build up soil organic matter. Based on the information gathered, it was evident that very few smallholder farmers in Dry zone in Myanmar could afford fertilizers.

High price of fertilizers is one of the hindrances in the use of recommended doses of chemical fertilizers by the farmers. Chemical fertilizer management is difficult to make a general conclusion about the timing and levels of fertilization to cotton. Potential losses are equally variable from both timings and that loss at each timing is related to rainfall/soil moisture conditions at the time of chemical fertilizer application. The combined application of chemical and manure reduced the nutrients loss and reduced the total cost of the fertilizers application. On the other hand, the amounts of chemical fertilizer applied showed slight correlation with the total annual household income from agriculture. In addition, increasing expense of agrochemicals application, especially expense of chemical fertilizer application, affects the farmer's annual income. Moreover, it affects to their life that depends on low income from their agricultural products. Furthermore, the survey showed that 92% of farmer in the village wants to change their practice to sustainable practice in the future. Therefore, agricultural education such as providing technical training, workshop is necessarily required for promoting sustainable use of agrochemicals as well as alternative ways based on organic farming practices and farming practice with low chemical input.

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Identification for sources of resistance against major diseases of mungbean germplasm under natural field condition

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Abstract

In order to identify sources of resistance against mung bean major diseases such as mungbean yellow mosaic virus (MYMV), cercospora leaf spot (CLS) and powdery mildew, evaluation was conducted in post-monsoon (2017), pre-monsoon season (2018) and monsoon (2018) under natural condition. A total of 196 germplasm accessions obtained from Seed Bank, Department of Agricultural Research (DAR), Myanmar were tested. Based on the MYMV disease reaction, eight accession, three accessions and two accessions showed highly resistant (HR), resistant (R) and moderately resistant (MR) reaction, respectively. The rest of the tested accessions exhibited moderately susceptible (MS) and susceptible (S), and highly susceptible (HS) reaction. On the basis of disease reaction against CLS disease, 3 accessions and 32 accessions were found highly resistant (HR) and resistant (R) respectively whileother 161 accessions were categorized as moderately resistant (MR), susceptible (S) and highly susceptible (HS). Among 196 mung bean germplasm accessions, no accessions was found to be highly resistant and resistant (R1) reaction against powdery mildew disease. The 3 accessions were grouped for resistant (R2). The rest exhibited moderately susceptible (MS) and susceptible (S), and highly susceptible (HS) reaction., Some of mung bean germplasm accessions showed resistance to multiple diseases. Two accessions (4188 and 4189) exhibited multiple diseases resistant reaction against CLS and powdery mildew. Other 12 accessions (4145, 7639, 7643, 8964, 10266, 10271, 10733, 10734, 10735, 10736, Yezin-11, Yezin-14) showed resistant to MYMV and cercospora leaf spot, although not shown resistant to powdery mildew disease. The results indicated that, some of the germplasm showing resistant accessions can be used as parents to disease resistant breeding program. Moreover, yield performance evaluation of these resistant accession is necessary to be carried out for adaption under different agro ecological zone.

Keywords: mung bean germplasm, MYMV, CLS, powdery mildew

Introduction

Mung bean (Vigna radiata L. Wilzcek) is one of major pulse crops of Myanmar and cultivated in an area of 1.2 million hectare with average yield of 1.11 metric tons per hectare

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and produced about 1.4 million metric tons in 2015- 2016 (DOA, 2017). In general, mung bean is mostly grown in two seasons: (i) monsoon season (May-July) and (ii) post-monsoon season after harvest of rice (October-December) in Myanmar. Moreover, mung bean is also grown in summer season (February - May) with available irrigation water.

There are several constraints in mung bean production such as low yield potential, lack of yield stability, vulnerability to biotic (major pests and diseases) and abiotic stresses (sensitivity of photoperiod and temperature). Among them, the infestation of insect pests and diseases occurred to mungbean crop from the young seedling to harvest is very important. Among the diseases, mung bean yellow mosaic virus (MYMV), cercospora leaf spot (CLS) and powdery mildew are becoming serious in most mungbean growing area and its damage varies depending on growing seasons (Fernandez and Shanmugasundaram, 1988).

Mung bean Yellow Mosaic Virus (MYMV) disease caused by virus was first reported in India in 1955 and is transmitted by the insect vector, white fly (Bemisia tabaci) (Nariani, 1960). MYMV infects several leguminous crops such as mung bean, soybean, moth bean, cowpea and urdbean and some other leguminous hosts (Dhingra and Chenululu, 1985; Qazi et al., 2007; Oo et al., 2008). MYMV disease is the most destructive viral disease not only in Myanmar, but also in India, Bangladesh, Srilanka and contiguous areas of South East Asia (Bakar, 1981; Malik, 1991; Biswass et. al., 2008; John et. al., 2008; Oo et al. 2008). Depending on the severity of MYMV, grain yield losses between 10 - 100% has been recorded under natural field condition (Nene, 1972; Chenulu et al., 1979; Marimuthu et al., 1981). Oo et al. (2008) studied the severity of MYMV in Myanmar and reported that MYMV can cause yield reduction ranging from 51% to 98% in susceptible variety depending on severity of disease mostly in summer season.

Another disease, cercospora leaf spot (CLS) caused by Cercospora canescens was first reported in Delhi, India (Munjal et al., 1960). It can occur in all parts of the humid tropical areas of Asia and many other countries (Pandey et al., 2009) and is prevalent in all parts of humid tropical areas of India, Bangladesh, Indonesia, Malaysia, Philippines, Taiwan and Thailand (Pandey et al., 2009). Cercospora leaf spot is spreaded by spores of infected leaves and encountered during the rainy season of relatively hot and high humid conditions (Poehlman, 1991). Yield loss was found up to 100 % depending on the severity of disease under natural epiphytotic conditions (Quebral and Cagampang, 1970; AVRDC, 1984; Amin and Singh, 1987; Grewal, 1988; Iqbal et al., 1995; Pandey et al., 2009).

During cool-dry and winter season of mung bean production, the most serious disease is powdery mildew caused by fungus Erysiphe polygoni because of the condition favourable for powdery mildew. However, it can be occurred throughout the year (Chankaew et al., 2013). Depending upon the temperature and humidity, these diseases spread rapidly in

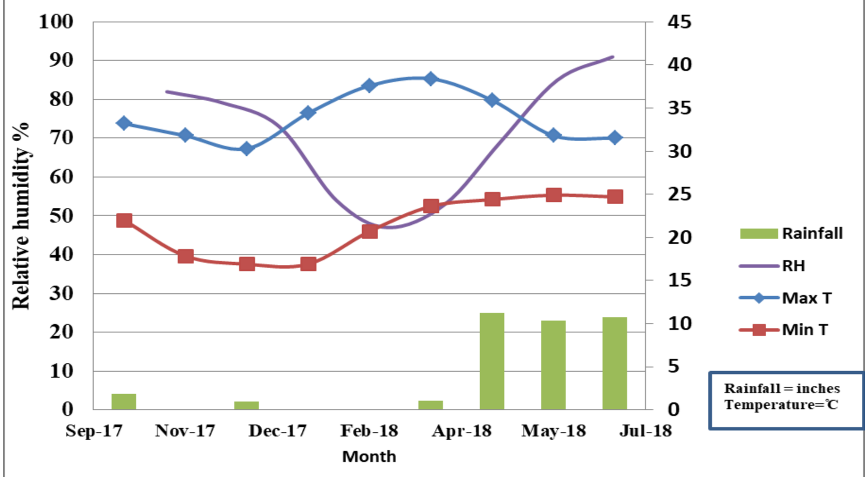

Chart.1 Rainfall, Temperature and Relative Humidity at growing season

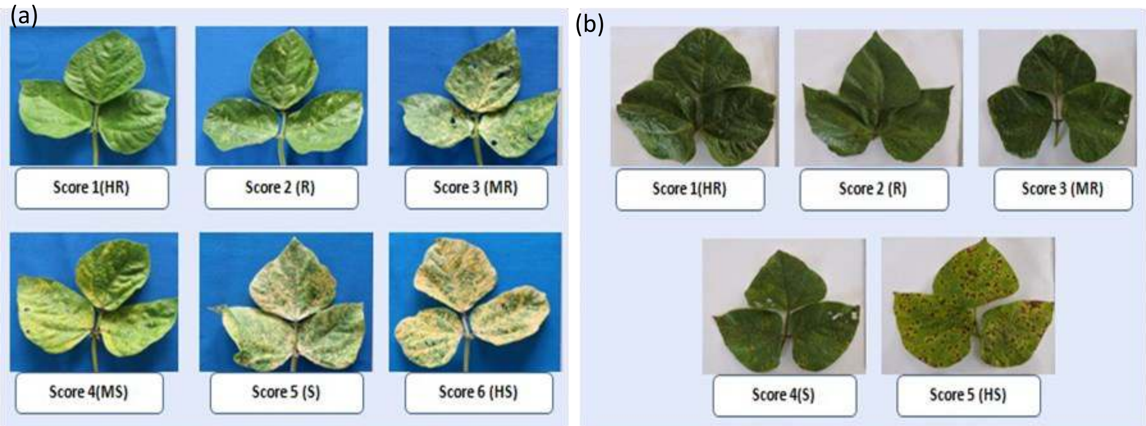

Figure 1. Disease rating scale used for categorization of mungbean genotypes against MYMV (Nair et al., 2017) (a) and cercospora leaf spot (CLS) (Park, 1978) (b)

susceptible varieties. Powdery mildew (Erysiphe polygoni D.C.) is one the most devastating disease of mung bean in India, South East Asia and other countries such as Australia, India, Philippiens, Sri Lanka, Taiwan, Colombia, Ethiopia, Thailand, Korea and U.S.A. Yield reduction from seedling to reproductive stage can be occurred on farmers field ranges from 9 to 50% (Park and Yang, 1978; AVRDC, 1982; Fernandez and Shamugasundaram, 1987; Reddy et al., 1994; Reddy et al., 2008; Pandey et al., 2009).

In Myanmar, there are different agroeco-system of mung bean production depending on the growing seasons and location. Meanwhile the infected diseases and severity of diseases are quite diverse relating rainfall pattern, day and night temperature and relative humidity for favoring the best condition for disease development which attack plant health (Chankaew et al., 2013; Moghe and Uttikar, 1981: Oo et al. 2008; Poehlman, 1991; Suman et al., 2016)). Management practices especially chemical control are not the best option for ecofriendly approach however, the use of resistant and

Table 1. Disease rating score used for categorization of mungbean genotypes against powdery mildew disease (Reddy et al., 1994)

Score	Percent of leaf area infested	Reaction
0	0	Highly resistant (R_0)
1	1 - 5	Resistant (R_1)
2	5.1 - 30	Resistant (R_2)
3	30.1 - 65	Moderately susceptible (MS)
4	65.1 - 90	Susceptible (S)
5	90.1 - 100	Highly susceptible (HS)

Table 2. Reaction of mungbean germplasm lines against MYMV in 2018 pre-monsoon season

Infection	Disease Score	No. of Accession	Accession Number
Highly resistant (HR)	1	8	4145, 7639, 10266, 10269, 10733, 10734,10736, Yezin-11
Resistant (R)	2	3	8964, 10735,Yezin-14
Moderately resistant (MR)	3	2	7643, 10271
Moderately susceptible (MS)	4	3	7630, 7635, 10272
Susceptible (S)	5	12	4156, 4161, 4163, 4178, 7374, 7616, 7618, 7628, 7642, 7644, 10264, 10731
Highly susceptible (HS)	6	168	4135, 4136, 4137, 4138, 4139, 4140, 4141, 4142, 4143, 4144, 4146, 4147, 4148, 4149, 4150, 4151, 4152, 4153, 4154, 4155, 4157, 4158, 4159, 4160, 4162, 4164, 4165, 4166, 4168, 4169, 4170, 4171, 4172, 4173, 4174, 4175, 4176, 4177, 4179, 4180, 4181, 4182, 4183, 4184, 4185, 4186, 4187, 4188, 4189,4190, 4191, 4192, 4193, 4194, 4195, 4196, 4197, 4198, 4199, 4200, 4201, 4202, 7347, 7348, 7349, 7350, 7352, 7353, 7355, 7357, 7358, 7359, 7360, 7361, 7363, 7364, 7365, 7366, 7367, 7368, 7370, 7371, 7372, 7375, 7376, 7377, 7380, 7614, 7615, 7617, 7619, 7620, 7621, 7622, 7623, 7624, 7625, 7626, 7627, 7629, 7631, 7632, 7633, 7634, 7636, 7637, 7638, 7640, 7641, 7645, 7646, 7647, 7648, 7649, 7650, 7651, 7652, 7653, 7654, 7655, 7656, 7657, 7658, 7659, 7660, 7661, 7662, 7663, 7664, 7665, 7666, 7667, 7668, 8960, 8961, 8962,8963, 10257, 10258,10259, 10260, 10261, 10262, 10263, 10265, 10267, 10268, 10270, 10273,10274, 10729, 10730, 10732, 10737, R-020954, R-020955, R-021018, R-021040, R-021090-A, R-021090-B, Yezin -1, Yezin-10, Yezin-5, Yezin-6, Yezin-7, Yezin-9, MAS-1,Pai Kyar Lwi

tolerance varieties are the best way for the sustainable production of mung bean. Therefore, there is a need to identify resistant genotypes against major diseases. Hence, this study was carried out to evaluate available mung bean germplasm for identification of resistance sources to breed disease resistance cultivars.

Materials and Methods

Trials were conducted in randomized complete block design with three replications at Food

Table 3. Reaction of mungbean germplasm lines against CLS in 2018 monsoon season

Infection	Disease score	No. of accession	Accession numbers
Highly resistant (HR)	1	3	4188,4189,7656
Resistant (R)	2	32	4138,4144,4145,4150,4170,4182,4184,4193, 4197,4198,4199,7350,7358,7359,7361,7364, 7375,7377,7380,7614,7641,7648,7657,7662, 8961,8962,8963,10257,10260,10265,R-020954,R-021090-B
Moderately resistant (MR)	3	84	4142,4148,4157,4158,4159,4160,4163,4171, 4176,4178,4179,4180,4181,4183,4186,4187, 4190,4191,4192,4195,4200,4201,4202,7347, 7349,7352,7355,7357,7363,7365,7366,7367, 7368,7371,7372,7376,7615,7617,7618,7619, 7624,7628,7631,7635,7638,7639,7640,7642, 7643,7644,7645,7651,7652,7655,7658,7659, 7660,7661,7664,7666,7668,8960,8964,10259,10266,10268,10269,10271,10272,10274,10729,10731,10733,10734,10735,10736,R-020955,R-021018,R-021040,Yezin-1, MAS-1,Yezin-7, Yezin-11,Yezin-14,
Susceptible (S)	4	49	4135,4136,4137,4140,4143,4147,4149,4151, 4156,4162,4165,4166,4168,4172,4175,4177, 4194,7348,7353,7360,7370,7374,7616,7620, 7621,7623,7625,7630,7633,7634,7636,7637, 7646,7647,7649,7653,7654,7663,7667,10258,10261,10263,10264,10732,10737,R-021090-A,Yezin-10,Yezin-6,Pai Kyar Lwi
Highly susceptible (HS)	5	28	4139,4141,4146,4152,4153,4154,4155,4161, 4164,4169,4173,4174,4185,4196,7622,7626, 7627,7629,7632,7650,7665,10262,10267,10270,10273, 10730,Yezin-5,Yezin-9

Legumes Section, Department of Agricultural Research, Myanmar (19º 51′ N latitude and 96º 7′ E longitude at 97 m altitude). A total of 196 mung bean accessions from Seed Bank, Department of Agricultural Research, Myanmar were identified diseases reactions in post-monsoon(2017), pre-monsoon season(2018) and monsoon (2018) under natural condition. The meteorological data (maximum and minimum temperature, rainfall and relative humidity) at growing season were presented in Chart 1.

Reactions of germplasm against MYMV, CLS and powdery mildew disease

The tested germplasms were classified into six reactions that is, highly susceptible (HS), susceptible (S), moderately susceptible (MS), moderately resistant (MR), resistant (R) and highly resistant (HR) on the basis of disease scores and level of disease symptoms by using modified rating score of Nair et al. (2017). This was done with the estimation of the average score for the top 5 leaves of each of 5 random plant within each lines when 95% of the

Table 4. Reaction of mungbean germplasm lines against powdery mildew disease in 2017 post-monsoon season

Infection	Disease score	No. of accession	Accession numbers
Highly resistant (R_0)	0	0	
Resistant (R_1)	1	0	
Resistant (R_2)	2	3	4188,4189,7358
Moderately Susceptible (MS)	3	24	4137,4147,4156,4160,4179,4183,4184,4185,4186,4187,4192,4193,4195,4201,7352,7361,7375,7377,7380,7654,7668,10737,R-020954,R-021090-B
susceptible (S)	4	106	4136,4138,4139,4140,4143,4146,4149,4150,4154,4157,4158,4159,4162,4165,4166,4168,4171,4174,4175,4178,4180,4181,4182,4190,4191,4198,4200,4202,7347,7348,7349,7350,7355,7357,7359,7360,7363,7364,7367,7368,7370,7371,7372,7374,7615,7616,7617,7618,7619,7622,7625,7626,7627,7633,7634,7636,7637,7638,7639,7640,7641,7642,7643,7644,7645,7646,7647,7648,7649,7651,7652,7653,7655,7656,7657,7658,7659,7661,7662,7663,8960,8961,8962,8963,8964,10257,10258,10259,10262,10263,10266,10268,10270,10272,10274,10729,10735,10736, R-020955,R-021018,R-021090-A,Yezin-1,Yezin-6,Yezin-10,MAS-1,Pai Kyar Lwi
Highly susceptible (HS)	5	33	4135,4141,4142,4144,4145,4148,4151,4152,4153,4155,4161,4163,4164,4169,4170,4172,4173,4176,4177,4194,4196,4197,4199,7353,7365,7366,7376,7614,7620,7621,7623,7624,7628,7629,7630,7631,7632,7635,7650,7660,7664,7665,7666,7667,10260,10261,10264,10265,10267,10269,10271,10273,10730,10731,10732,10733,10734,R-021040,Yezin-11,Yezin-14,Yezin-5,Yezin-7,Yezin-9

Table 5. Relation of germplasm and resistance against multiple diseases

No.	Germplasm accession	MYMV	CLS	powdery
1.	4145	HR	R	HS
2.	4188	HS	HR	R
3.	4189	HS	HR	R
4.	7639	HR	MR	S
5.	7643	MR	MR	S
6.	8964	R	MR	S
7.	10266	HR	MR	HS
8.	10271	MR	MR	HS
9.	10733	HR	MR	HS
10.	10734	HR	MR	HS
11.	10735	R	MR	S
12.	10736	HR	MR	S
13.	Yezin-11	HR	MR	HS
14.	Yezin-14	R	MR	HS

spreader rows (Yezin-9) showed MYMV incidence under field conditions in pre-monsoon season (2018) Figure 1 (a).

The data on severity score for CLS on 5 randomly selected plants in each germplasm was recorded at before maturity stage in 2018 monsoon season. The severity of disease was recorded using an arbitrary scale 1-5 in terms of leaf coverage by the cercospora leaf spot (Park, 1978) where 1 = highly resistant, 2 = resistant, 3 = moderately resistant, 4 = susceptible and 5 = highly susceptible in Figure 1 (b).

Powdery mildew was scored on 0-5 scale as recommended by Reddy et al. (1994) in 2017 post-monsoon season. The severity of disease was recorded at the time of before harvesting using an arbitrary scale 0-5 in terms of leaf coverage where 0 = highly resistant (R0), 1 = highly resistant (R1), 2 = resistant (R2), 3 = moderately resistant (MS), 4 = susceptible (S) and 5 = highly susceptible (HS) in Table 1.

Results and discussion

Mungbean yellow mosaic virus disease reaction

In 2018 pre-monsoon season, identification of 196 mung bean germplasm accessions under natural field condition against MYMV was carried out and the results are presented in Table 2. Based on the disease reaction, eight accession (4145, 7639, 10266, 10269, 10733, 10734,10736, Yezin-11), three accessions (8964, 10735,Yezin-14) and two accessions (7643, 10271) showed highly resistant (HR), resistant (R) and moderately resistant (MR) reaction, respectively. The remaining of total 3, 12 and 168 accessions exhibited as moderately susceptible (MS) and susceptible (S), and highly susceptible (HS) reaction. It suggested that the degree of resistant against MYMY among the accessions was varied. It might not only be due to the genetic background of the accessions but also the strains of MYMV vectors infected in Mung bean during the experiment. Thus it is needed to identify the strains of MYMV vectors.

The findings of present observation were in close agreement with numerous other evaluation of disease screening. Mohan et al., 2014 identified 120 mungbean germplasm accessions and out of 15 and 18 accessions were resistant and moderately resistant, respectively. Previous researchers were observed to find out resistant sources of mungbean germplasm for the breeding program (Oo et al., 2008; Iqbal et al., 2011; Mohan et al., 2014; Munawwar wt al., 2014; Gopi et al., 2016; Deepa et al., 2017 and Mondol et al, 2017).

Cercospora leaf spot disease reaction (CLS)

The results presented in Table 3 confirmed significant groups among tested mung bean germplasm on the basis of disease reaction against cercospora leaf disease. Out of 196 mung bean germplasms, 3 accessions (4188, 4189, 7656) and 32 accessions (4138, 4144, 4145, 4150, 4170, 4182, 4184, 4193, 4197, 4198, 4199, 7350, 7358, 7359, 7361, 7364, 7375, 7377, 7380, 7614, 7641, 7648, 7657, 7662, 8961, 8962, 8963, 10257, 10260, 10265, R-020954, R-021090-B) were recognized as highly resistant (HR) and resistant (R), respectively. However, other 84 accessions, 49 accessions and 28 accessions were categorized into moderately resistant (MR), susceptible (S) and highly susceptible (HS). These research findings are very similar to other studies for resistant sources against cercospora leaf spot diseases (Marrapa et al., 2008; Yadav et al., 2014a; 2014b; Bhaskar, 2017).

Powdery mildew disease

During post-monsoon season (2017), powdery mildew disease is seriously infected and severity of disease was recorded at the time of before harvest using an arbitrary scale. The rating scale of disease reaction is presented in table 4. Among 196 mung bean germplasm accessions, no accession was found to be highly resistant (R0) (R1) reaction. Only 3 accessions (4188, 4189, 7358) were grouped as resistant (R2). The remaining 24, 106 and 33 accessions were exhibited moderately susceptible (MS) and susceptible (S), and highly susceptible (HS) reaction. Identification of resistant sources and genetic studies for modes of inheritance has reported for the plant breeder needs of mung bean breeding program (Yohe and Poehlman, 1975; Fernandez and Shanmugasundaram, 1988; Hartman et al., 1993; Reddy et al., 1994a; Reddy et al., 1994b; Reddy, 2009; Sorajjapinun et al., 2005; Kasettranan et al., 2009 Ramakrishnan and Savithramma (2014) and Yadav et al., 2014) and they suggested that there are different mechanisms or genes conferring resistance to powdery mildew disease.

Resistance of germplasm against multiple diseases

Some of mung bean germplasm accessions that linked with multiple diseases are presented in Table 5. Two accessions (4188 and 4189) out of 198 accessions exhibited to be multiple diseases resistant against cercospora leaf spot and powdery mildew diseases. Although, other accessions (4145, 7639, 7643, 8964, 10266, 10271, 10733, 10734, 10735, 10736, Yezin-11, Yezin-14) showed resistant to MYMV and cercospora leaf spot and they were not resistant to powdery mildew disease.

In the present investigation, infestation and severity of diseases (powdery mildew, MYMV, CLS) vary with different growing seasons of study area (Department of Agricultural Research,Yezin, Naypyitaw). Among infected diseases, only powdery mildew disease was found during post-monsoon (2017), the incidence of MYMV was more severe in pre-monsoon season (2018) and CLS disease was more apparent in monsoon (2018) season under natural condition. Although the severe incidence of different diseases was observed in each growing season, some accessions of mung bean germplasm responded differently for resistance to a particular disease.

Conclusion

The results of this study describes the infection time of major diseases on mung bean such as MYMV, CLS and powdery mildew are significantly different among the tested germplasm and mainly relating with environmental condition. And individual resistant sources of these diseases are not resistant to all major diseases. Although some accessions are resistant and moderately resistant to these three major diseases, most of other resistant sources can resist only one or two type of diseases. Therefore, the selected resistant sources from this study program should be used as donor parents for the breeding program to develop new varieties after the investigation on yield performance and phenology of resistant sources of germplasm accessions.

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Photo Records

Opening speech delivered by U Aye Maung Sein, Nay Pyi Taw Council member, Nay Pyi Taw

Opening remarks delivered by Mr Xavier Bouan, Senior Technical Adviser, FAO

Words of acknowledgement and objectives of the Workshop by Dr Nang Hseng Hom, Rector, Yezin Agricultural University

Group photo of honorable guest and speakers

Chair by Dr Myint Thaung on the section of Concept of Climate Change and CSA

Presentation by speaker

Presentation by the speakers on climate smart agriculture related topic

Question and answer by the participants and speakers

Group discussion and presentation by participants

Award the certificate of participation to the speakers

Closing remarks by Mr Xavier Bouan, Senior Technical Adviser, FAO and Dr Mie Mie Aung, Professor, Yezin Agricultural University

ANNEX 1.

Agenda for the Workshop on "Promoting Climate Smart Agriculture in Myanmar"

Diamond Jubilee Hall, Yezin Agricultural University

Time	Title	Person
08:30–09:00	Registration	
Opening Session		
09:00–09:10	Opening speech	U Aye Maung Sein, Nay Pyi Taw Council member
09:10-09:20	Opening remarks	Mr Xavier Bouan, Senior Technical Adviser, FAO
09:20-09:30	Words of acknowledgement and objectives of the workshop	Dr Nang Hseng Hom, Rector, Yezin Agricultural University
09:30-09:40	Photo session	Participants
09:40-10:15	**Refreshment**	
Paper presentations and discussions (10 minutes presentations)		
1. Concept of climate change and cSA (Chair-person - Dr Myint Thaung)		
10:15-10:35	Sustainable cropland and forest management in priority agro-ecosystems: Promoting climate-smart agriculture in Myanmar	Jitendra Jaiswal and Khin San Nwe
10:35-10:45	Farmers' practices and understanding of climate-smart agriculture in the Pyin Oo Lwin district of Myanmar	San Hla Htwe
10:45-10:55	Methane emission from different rice paddy fields as affected by water management	Khin Mar Htay, Kyaw Myaing and Chaw Su
10:55-11:05	Evaluation of different rates of organic manure and water management practices on methane emission from rice production	Ei Phyu Win, Kyaw Kyaw Win, Kyaw Ngwe, Than Da Min
11:05-11:20	Open discussion	
2. Resistance to climatic stress (Chair-person – Mr Xavier Bouan, FAO)		
11:20-11:30	Effect of cutting position in cut stem transplant method, climate resilient practices implemented in Deepwater area in Bago region	Yu Mon, Mie Mie Aung, Nyo Mar Htwe, Thanda Min and Yoshinori Yamamoto
11:30-11:40	Screening MAGIC *Indica* population for their cold stress tolerance at the seedling stage	Su Latt Phyu, Jose E. Hernandez, Rakesh Kumar Singh, Pompe C. Sta Cruz, Teresita H. Borromeo
11:40-11:50	Root characteristics of rice (*Oryza sativa* L.) associated with tolerance to complete flooding in greenhouse condition	Myat Moe Hlaing, Nina M. Cadiz, Abdelbagi M. Ismail
11:50-12:00	Impact assessment on agricultural production and coping strategies to flood in Kambalu township, Sagaing region	San San Myint and Yu Yu Tun
12:00-12:10	Influence of temperature and relative humidity on pollen germination and spikelet sterility in improved rice varieties	Saw Bo Day Shar, Than Myint Htun, Nyo Mar Htwe, Aung Naing Oo, Soe Win, Mie Mie Aung

12:25-13:25	**Lunch break**	
3. Forestry/agroforestry and disease, pest and nutrient management (Chair-person – U Ngwe Thee)		
13:25-13:35	Review methodology of Myanmar initial FRL submitted to UNFCCC	Myat Su Mon, Khine Zaw Wynn, Nay Lin Tun
13:35-13:45	The potential of agroforestry as a climate CSA practice for enhancing local livelihood opportunities in central dry zone, Myanmar: A case study in Pakokku district	Phyu Phyu Thinn, Idd Idd Shwe Sin, Myo Min Latt
13:45-13:55	Distribution, habitat association and species composition of tiger beetles (Coleoptera: Cicindelidae) in Myanmar	Moe Hnin Phyu, Thi Tar Oo and Michio Hori
13:55-14:05	Comparison of forage crop performance in three selective grass cultivars	Ei Thandar Ko, Kyaw Kyaw Win, Myint Yee and Phyu Thaw Tun
14:05-14:15	Assessment of farmers attitude on the use of farmyard manure and chemical fertilizers or cotton production in dry zone	Khin Khin Mu, Kyaw Ngwe, Than Da Min, Aung Naing Oo and Swe Swe Mar
14:15-14:25	Identification for sources of resistance against major diseases of mungbean germplasm under natural field condition	Kyaw Swar Win, Soe Win, Than Myint Htun, Nang Kyu Kyu Win and Mie Mie Aung
14:25-14:45	Open discussion	
Group Exercise and Presentation		
14:45-14:55	Group division (4 groups) and clarification of the tasks	Jitendra and Khin San Nwe
14:55-15:10	**Refreshment**	
15:10-15:55	**Group Discussions:** **Group 1 and 3:** How to promote CSA in Myanmar (issues/challenges, opportunities, recommendations). **Group 2 and 4:** How to make CSA center effective (key roles and responsibilities of the center, key organizations to be involved in TSG and their main roles, recommendations for sustainability of the CSA center)	All participants
15:55-16:15	Presentations by 4 groups and discussions/Q&A	All participants
Closing Session		
16:15-16:20	Closing remarks	FAO
16:20-16:30	Words of thanks	YAU, Rector

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