ISSN 2185-159X

International Journal of
Environmental and Rural Development

Volume 11 Number 2

December 2020

International Society of Environmental and Rural Development

International Journal of Environmental and Rural Development

Official Journal of the International Society of Environmental and Rural Development
(*Accessible from J-Stage, EBSCO, Google Scholar, CABI International, etc.*)

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Contents

Research article

Methods for Improving the Performance of Paddy Soil-Used Sediment Microbial Fuel Cells

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Received 5 December 2019 Accepted 1 July 2020 (*Corresponding Author)

Abstract Sediment microbial fuel cells (SMFCs) have received considerable attention for remediating sediment and wastewater while providing electricity. This technology offers many benefits for rural regions, particularly for those in developing counties. SMFCs can treat agricultural wastewater, household sewage, and organic waste while providing electricity to households. However, the performance of SMFCs remains low and must be improved. It has reported that mixing steelmaking slag (SS) with littoral sediment improves SMFC performance. The present study examines the use of SS to potentially improve the performance of a SMFC that uses paddy soil as its fuel (PS-SMFC). Moreover, we examine changes in the performance of a SS-SMFC (the PS-SMFC that the anode chamber is filled with SS) that uses lactic acid bacteria (LAB) and BN strain of Bacillus subtilis (BNB) solution-mixed paddy soil as its fuel. In laboratory experiments, paddy soil was poured into the SS layer (the anode chamber) of a SS-SMFC. LAB or BNB were added to the SS-SMFC anode by mixing a bacteria solution with the paddy soil. The SMFC performance was evaluated by measuring the polarization (current–voltage relation) and power density. The power density of the SS-SMFC was observed to be 152 mW.m^{-2}, which is approximately twice than that observed without using SS (80 mW.m^{-2}, as reported in previous studies). This shows that the performance of a paddy soil-used SMFC increases after mixing SS with the paddy soil. Furthermore, the SS-SMFC power density increased from 66 to 191 mW.m^{-2} after adding BNB and to 247 mW.m^{-2} after adding LAB. Thus, adding LAB or BNB to paddy soil is shown to improve SMFC performance. In comparison with BNB, LAB has greater potential for increasing SMFC performance.

Keywords sediment microbial fuel cell, performance, paddy soil, steelmaking slag, lactic acid bacteria, BN strain *B. subtilis*

INTRODUCTION

Recently, sediment microbial fuel cells (SMFCs) have received considerable attention for improving sediment and water quality. Numerous studies have reported that when using SMFCs, the amount and variations in the state of the organic matter present in sediment-applied SMFCs decrease and the redox potential of the sediment increases (Sacco et al., 2012; Sajana et al., 2013; Touch et al., 2014). Furthermore, SMFCs have been proven to be effective in preventing the deterioration of water quality due to ion diffusion from sediment (Touch et al., 2017a) and improving the benthic habitat environment in highly reduced sediment (Touch et al., 2018a). Moreover, Touch et al. (2017b) showed that using SMFCs is effective for removing hydrogen sulfide from sediment and fixing phosphate in them; they showed that the oxidation of reduced substances at the SMFC anode plays an important role in improving the sediment quality and the benthic habitat environment. As such, SMFCs were employed into the sediment deposited near a sewage outlet (Touch et al., 2018b) and an oyster farm (Touch et al., 2018c) to improve the quality of the sediment and water.

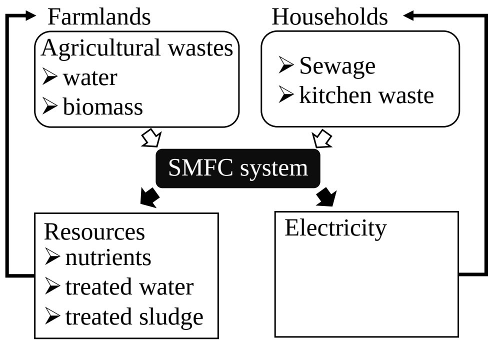

Fig. 1 Benefits of using SMFCs in rural regions

The achievements reported in previous studies suggested that SMFCs offer many benefits for rural regions, particularly those in developing counties. For example, SMFCs can treat agricultural wastewater, household sewage, and organic waste while providing electricity to households and recycled resources to farmlands (Fig. 1). However, the performance of SMFCs remains low and must be improved. Kouzuma et al. (2014) reported the maximum power and short-circuit current densities of SMFCs in rice paddy fields are only 80 $mW.m^{-2}$ and 550 $mA.m^{-2}$, respectively (based on the projected anode area). Many methods have been proposed for improving the SMFC performance, such as adding mediators to the sediment (Lovley et al., 2004) and the activation of organisms on electrode (Wang et al., 2009). It has been showed that adding steelmaking slag (SS) to littoral sediment could improve the SMFC performance (Nishimura et al., 2018). In the present study, we focus on using SS to improve the performance of a SMFC that uses paddy soil as its fuel (PS-SMFC); further, we examine the applicability of lactic acid bacteria (LAB) and the BN strain of *Bacillus subtilis* (BNB) to improve the performance of a SS-SMFC (the PS-SMFC that the anode chamber is filled with SS).

OBJECTIVE

The first objective of this study was to examine the changes in the performance (current and power) of a PS-SMFC after adding SS to the anode chamber, i.e., the performance of SS-SMFC. The second objective of this study was to examine the applicability of LAB and BNB to improve the performance of SS-SMFC.

METHODOLOGY

Experimental Device and Materials

The experimental device comprised a cylindrical bottle with an inner diameter and height of 120 mm and 150 mm, respectively. The bottle was filled with SS (diameter range of 5–40 mm) to a depth of 20 mm, and the anode electrode was placed on the SS layer. Then, 20 mm of the SS layer was placed on the anode electrode. The wet paddy soil was mixed with deionized water in a soil-to-water weight ratio of 1:2; subsequently, the mixture was slowly poured into the bottle until it reached a height of 50 mm from the bottom of the bottle. Finally, tap water was poured over the soil layer, and the cathode electrode was submerged near the surface of the water (Fig. 2a).

The paddy soil was collected from a rice filed (Ebina, Kanagawa, Japan) during the agricultural off-season. Approximately 150 mm of the surface soil was collected and transported to the laboratory. The paddy soil was mixed with deionized water to facilitate its easy pouring into the SS layer. Solutions of LAB or BNB were used instead of the aforementioned deionized water to examine their effects. Either 50-g Natto or 75-g yogurt (commercial products) was mixed with 3-L tap water and fermented for 7 days at ambient temperature. Then, the supernatant was extracted and mixed with the paddy soil.

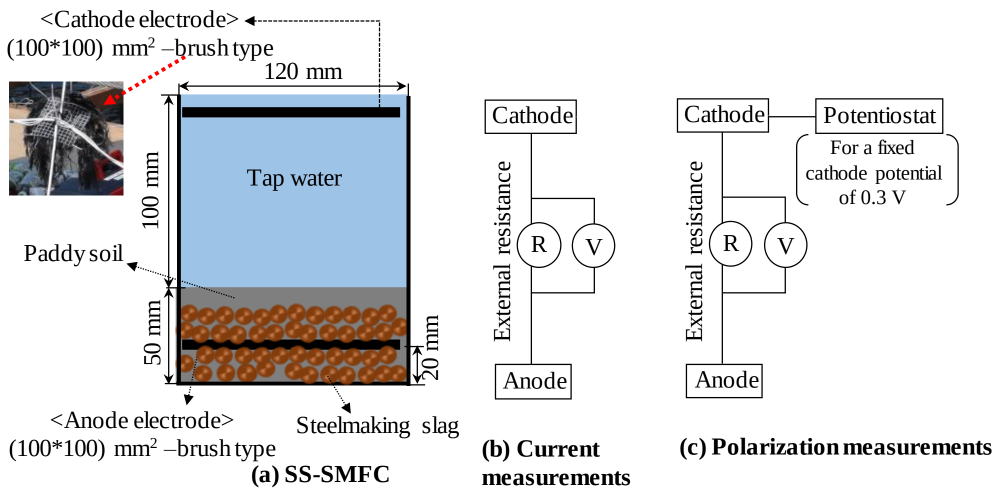

Fig. 2 Experimental device and measurement methods

The electrode material used was carbon cloth (News Company, PL200-E), which was heated at 500 °C for 1 h to improve its performance before being used as the electrode material according to Nagatsu et al. (2014). The heated carbon cloth, with a surface area of 10000 mm^2 (100-mm width and 100-mm long), was separated into carbon fibers to make the brush-type anode or cathode (Fig. 2a). Plastic-coated copper wire was used for all the connections in the SS-SMFC and operating circuits.

Operations and Measurements

The experiments were conducted by following the operations and measurements as shown in Fig. 3. All SS-SMFCs were put into an open circuit (without electrical current flow) mode until their voltages stabilized (~7 days), after which the polarization was measured using the circuit shown in Fig. 2b. An external resistance was loaded between the anode and cathode and varied over 2.2 Ω–10 kΩ. The cell voltage was recorded 1 min after each external resistance was loaded. The recorded voltage was used to calculate the current according to the Ohm's law, namely, $I = U/R_{ex}$, where U [V] is the voltage, I [A] is the current, and R_{ex} [Ω] is the external resistance; further, the power P was calculated according to $P = IU$. The current and power densities were obtained by dividing these values by the surface area of the electrode, i.e., 0.01 m^2. To understand the long-term performance of SS-SMFCs, an external resistance of 20 Ω was loaded between the anode and the cathode electrodes (Fig. 2b), after the polarization measurement.

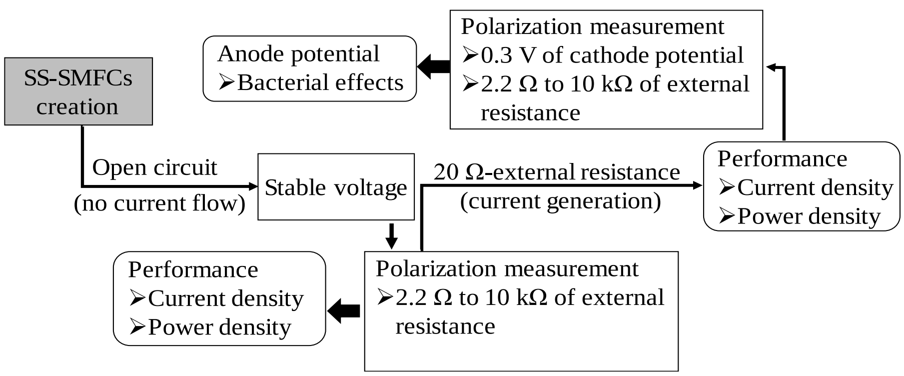

Fig. 3 Operation conditions and measurements during experiments

To calculate the circuit current, the voltage across the external resistance was measured every 30 min using a voltmeter (Graphtec, midi LOGGER GL840-M). After long-term current generation, the SS-SMFCs were put into an open circuit mode again until their voltages stabilized. To evaluate the effects of LAB or BNB in the SS-SMFCs, the polarization was measured by fixing the cathode potential at 0.3 V versus Ag/AgCl using a potentiostat (Hokuto, HB-151B) (Fig. 2c). This value was sourced from the study conducted by Nagama et al. (2018), who noted that the potential of sea water is approximately 0.3 V. After fixing the cathode potential, an external resistance was loaded between the anode and cathode and varied over 2.2 Ω–10 kΩ. The cell voltage was recorded 1 min after loading each external resistance.

RESULTS AND DISCUSSION

Improved Performance of Paddy Soil-Used SMFCs by Steelmaking Slag

Fig. 4 shows the polarization curves of the SS-SMFCs before they generate electrical current. As shown in Fig. 4a, the maximum power and current densities of the SS-SMFCs were approximately 150 $mW.m^{-2}$ and 1600 $mA.m^{-2}$, respectively. Kouzuma et al. (2014) reported the maximum power and short-circuit current densities of SMFCs in rice paddy fields were only 80 $mW.m^{-2}$ and 550 $mA.m^{-2}$, respectively. Comparison with the two latter shows that the performance of a PS-SMFC increases when SS is used in the anode chamber of the PS-SMFC.

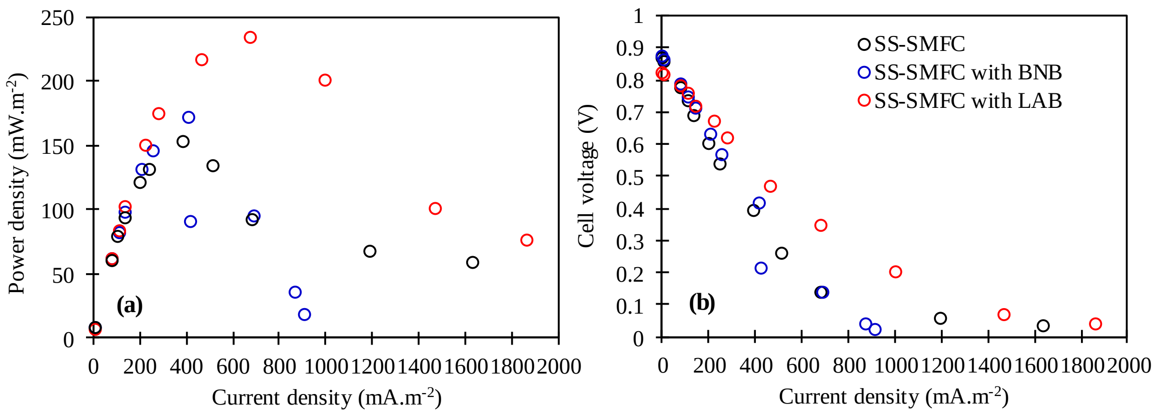

Fig. 4 Polarization curves of SS-SMFCs before generating electrical current

The results of the present study agree well with those of Nishimura et al. (2018), who suggested that mixing SS with littoral sediment increases SMFC performance. They argued that the reduction of iron compounds in the SS and its dissolution could make sediment into a higher reduced condition. Furthermore, the SS might play an important role in supporting electron transfer in the sediment. Our results suggest that mixing SS with either littoral sediment or paddy soil can improve SMFC performance.

Effects of Lactic Acid Bacteria (LAB) and BN stain of *Bacillus subtilis* (BNB) in SS-SMFCs

Fig. 4 (the polarization without fixing the cathode potential) shows that the differences in the power and current densities of a SS-SMFC with and without BNB were unclear; this occurs because the SMFC performance depends on the performance of the cathode and anode electrodes. Thus, we must fix the cathode electrode at the same potential to obtain a better understanding the anode electrode performance, i.e., the effects of either LAB or BNB in the SS-SMFC anode.

Fig. 5 depicts the polarization curves for a fixed cathode potential of 0.3 V. The maximum power density was 66 $mW.m^{-2}$ in the case of using paddy soil alone; it increased to 190 $mW.m^{-2}$ (a threefold increase) after adding BNB to the paddy soil and to 247 $mW.m^{-2}$ (an increase of 3.74 times) after adding LAB (Fig. 5a). This suggests that adding either BNB or LAB improves SS-SMFC performance, with LAB improving the performance more. A Similar conclusion is reached by comparing the current density of each SS-SMFC (Fig. 5).

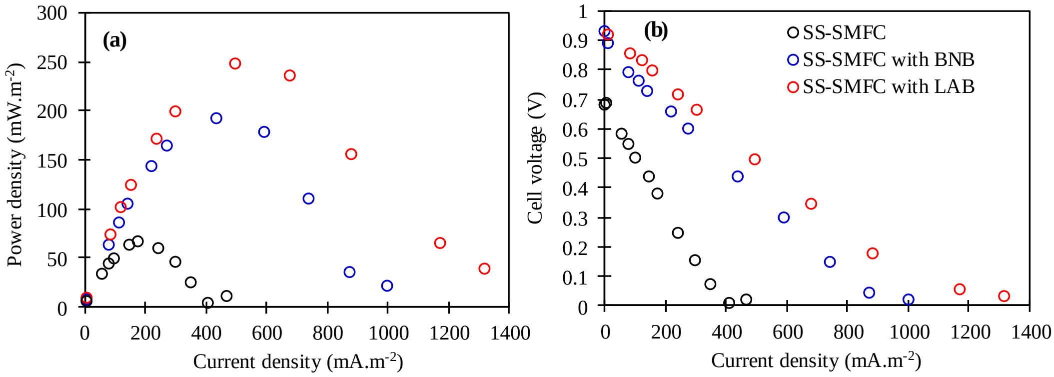

Fig. 5 Polarization curves for a fixed cathode potential of 0.3 V

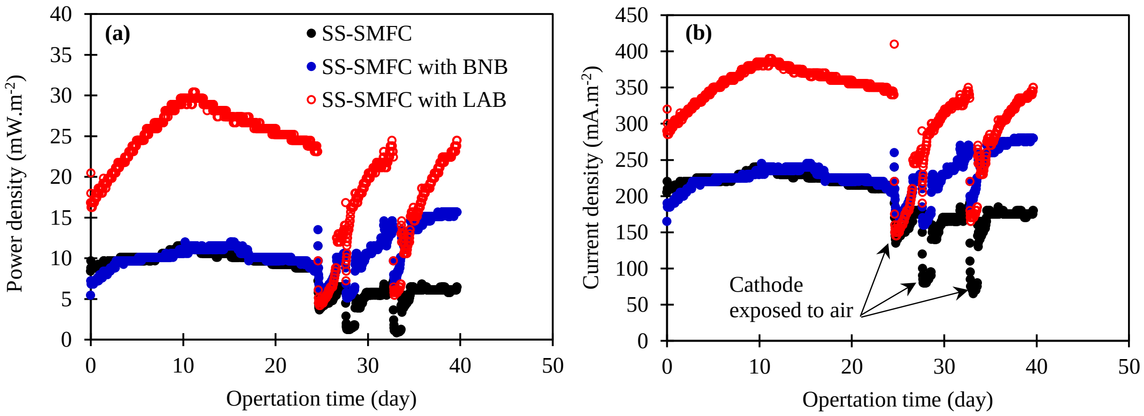

Fig. 6 Long-term variations of power and current densities of SS-SMFCs

A SMFC experiences various potential losses that decrease the cell voltage during electricity generation (Touch et al., 2019). In other words, the cell voltage of a SMFC with higher performance is less reduced for a given generated current. For a current density of 400 $mA.m^{-2}$, Fig. 5b shows that the cell voltage decreased by approximately 0.70, 0.45, and 0.35 V for the basic SS-SMFC, SS-SMFC with BNB, and SS-SMFC with LAB, respectively. From this, it can be said that adding either BNB or LAB can improve the SS-SMFC performance. The improvement may be partly due to the enhanced electron transfer to the anode and the accelerated decomposition of organic matter by the bacteria; unfortunately, those reasons could not be examined in the present study.

In addition, having continuously generated electrical current for 40 days, the power densities were 7, 16, and 25 $mW.m^{-2}$ for the basic SS-SMFC, SS-SMFC with BNB, and SS-SMFC with LAB, respectively (Fig. 6a), and the current densities were 180, 280, and 350 $mA.m^{-2}$, respectively (Fig. 6b). These results suggest that the bacteria will continue to affect the SS-SMFCs during long-term operations.

CONCLUSION

In this study, laboratory experiments were conducted to examine changes in the performance of the PS-SMFC when using SS in the anode chamber and the applicability of LAB and BNB for improving SS-SMFC performance. A twofold increase in the power density was observed, suggesting that the utilization of SS in the anode chamber improves the PS-SMFC performance. Furthermore, the power density increased by 2.9 times after adding BNB and 3.7 times after adding LAB to paddy soil, thereby indicating that adding either LAB or BNB improves the SS-SMFC performance; further, adding LAB was shown to increase the SS-SMFC performance more. It was considered that these bacteria enhance the electron transfer to the anode and accelerate the decomposition of organic matter.

ACKNOWLEDGEMENTS

The authors gratefully acknowledge the students of the Rural Environmental Engineering Laboratory, Tokyo University of Agriculture, for their efforts in collecting data.

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Research article

Risk Assessment of Pesticide Use in Chinese kale Cultivation of GAP and Conventional Practice by EIQ in North-East Thailand

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Received 10 September 2019 Accepted 21 July 2020 (*Corresponding Author)

Abstract This study reports the pesticide application and environmental impact in Chinese kale cultivation under Good Agricultural Practice (GAP) and conventional practice in North-East, Thailand. The Environmental Impact Quotient (EIQ) model was applied in this study. The data were collected by using semi-structured interviews and observation. GAP farmers (farmers in GAP's system) and conventional cultivation farmers (non-GAP farmers) were purposive selected, 10 per each group with a total of 20 farmers. Data from farmer interviews on pesticides application, type of substances, application rates, frequency, and plot size were used in the EIQ Field Use equation to assess environmental risks between the two practices. The criteria are EIQ Field Use; <25 = very low risk <50 = low risk 50-99 = moderate risk 100-199 = high risk and> 200 = very high risk. The results showed that 15 active ingredients in pesticide were found in GAP farms and 19 active ingredients in pesticide use were found in non-GAP farms. The GAP Chinese kale has a lower level of impact on environmental risks than the conventional one (Average EIQ Field Use: GAP = 87.4, non-GAP = 136.87). This data indicates that the GAP system could reduce the risk of pesticides in the environment of commercial vegetable-growing village.

Keywords environmental impact quotient, pesticide risk, good agricultural practice

INTRODUCTION

The increasing rate of pesticides application poses enormous challenges to manage the associated risks to people and ecosystems (Schreinemachers et al., 2017; Harnpicharnchai et al., 2013). In conventional agricultural practice, the application of pesticides is a common practice among vegetable grower due to the prevalent pest and disease problems. Pesticides are products that improved agricultural productivity, although their inherent toxicity and misuse have led to various adverse effects on important ecosystems and human health (Páez et al., 2013). Although nowadays consumers are increasingly concerned about food safety and looking for safer food (Schreinemachers et al., 2012). To reduce potential food hazards and increase the good image of Thai horticultural products abroad, the Thai government introduced public standards of Good Agricultural Practice (GAP). This has been shown that the application of pesticides in a GAP system is a production strategy that ensures sustainability and competitiveness. An environmentfriendly agricultural production and a contribution to the health of workers, consumers and other stakeholders in the food chain, facilitate trade and international opportunities (Páez et al., 2013).

The long-term strategies to manage risks in the GAP system, farmers can pesticide to control weeds, pests, and diseases following the principles of Integrated Pest Management (IPM) because Good Agricultural Practice will be decided on interventions following consideration of all possible methods and their short and long-term effects on-farm productivity and environmental implications in order to minimize the use of agrochemicals, in particular, promote IPM (FAO, 2004). However, some growers and pest management practitioners did take into account the effect of the pesticides on the applicator or beneficial natural enemies such as predatory mites when making pesticide recommendations, but no formal method was available to assist them in making environmentally based pesticide choices. Because there is no easy method to assess pesticide impacts, each individual had to rely primarily on their own judgment to make these decisions (Kovach et al.1992).

The Environmental Impact Quotient (EIQ) is a formula created to provide growers with data regarding the environmental and health impacts of their pesticide options, so they can make better informed decisions regarding their pesticide selection. (Cornell University, 2018) The formula helps to calculate the environmental impact of most common fruit and vegetable pesticides (insecticides, acaricides, fungicides and herbicides) used in commercial agriculture. The values obtained from these calculations can be used to compare different pesticides and pest management programs to ultimately determine which program or pesticide is likely to have the lower environmental impact. The method addresses a majority of the environmental concerns that are encountered in agricultural systems including farm worker, consumer, wildlife, health and safety (Kovach et al., 1992). Since 2000, the EIQ has been used in several IPM projects in Asia for different purposes ranging from impact assessment to pesticide selection (FAO, 2008).

Chinese kale is one of the main vegetable growing in Khon Kaen province in North-East, Thailand and is one of the major vegetable consumed in the region (National Bureau of Agricultural Commodity and Food Standards, 2016). The vegetable is also susceptible to a substantial number of arthropod pests and plant diseases, which farmers need a lot of pesticides to prevent crop damage. For the commercial vegetable village in this study area, GAP farmers have used pesticides less than non-GAP farmers because they were supported to pesticides used in accordance with IPM. However, there are no indicators that GAP can reduce the risk of pesticides used. Therefore, the EIQ impact assessment will show the risk levels of both Chinese kale cultivation (GAP and non-GAP). This will be answered that whether GAP compliance can reduce the risk of pesticides on environmental and health impacts or not. Moreover, it is expected that the results of the study can also be used to help governmental agencies to implement better GAP programs in this region.

OBJECTIVE

To assess pesticide risk and environmental impact in Chinese kale cultivation among GAP and conventional practices.

METHODOLOGY

Data Collection

The commercial vegetable growing village in Muang District, Khon Kaen Province, Thailand was purposively selected as a study site in this research. This village is a large vegetable production in the area which farmers continue to grow vegetables for more than 30 years as it is the main source of their incomes. At the same time, this village is one of the pilot GAP vegetable production areas by the government. Since it is a voluntary scheme, there are both GAP farmers and non-GAP farmers in the village. In this study, Chinese kale plots were purposively collected from 10 GAP and 10 non-GAP plots, as their farms scattered across the village. Pesticide application data were collected by using a semi-structure interview and making observations, during January to October 2018. Data of pesticide compound, common name, active ingredient, % active ingredient, rate of application, frequency of application and plot size were collected from sample plots.

Risk Assessment of Pesticide used by EIQ

The EIQ value for a particular active ingredient is calculated according to a formula that includes parameters of toxicity (dermal, chronic, bird, bee, fish, and beneficial arthropod), soil half-life, systemicity, leaching potential, and plant surface half-life are considered. The formula for determining the EIQ value of individual pesticides is listed below and is the average of the farm worker, consumer, and ecological components. The EIQ Equation as in Eq.(1) (Kovach et al., 1992).

$$EIQ=\{C[(DT*5)+(DT*P)]+[(C*((S+P)/2)*SY)+(L)]+[(F*R)+(D*((S+P)/2)*3)+(Z*P*3)+(B*P*5)]\}/3 \quad (1)$$

Where DT = dermal toxicity, C = chronic toxicity, SY = systemicity, F = fish toxicity, L = leaching potential, R = surface loss potential, D = bird toxicity, S = soil half-life, Z = bee toxicity, B = beneficial arthropod toxicity, P = plant surface half-life.

Field Use EIQ is calculated by multiplying the table EIQ value for a specific chemical by the percentage of active ingredient in the formulation and its dosage rate per hectare, as in Eq. (2)

$$\text{Field Use EIQ} = \text{EIQ value} \times \%\ \text{active ingredient} \times \text{Dosage rate} \quad (2)$$

The risk level according to the EIQ Field Use Rating Levels; when EIQ Field Use less than 25 = very low risk, less than 50 = low risk, 50-99 = moderate risk, 100-199 = high risk, over than 200 = very high risk (Cornell University, 2018).

RESULTS AND DISCUSSION

Pesticide Applied in Chinese Kale Cultivation

In each crop production, different frequencies of different types of pesticides were found applied in both GAP and non-GAP plots. The insecticides that commonly applied in all production cycle in both plots indicating that insect damage in Chinese kale production in this area was critical and approaches to reduce the infestation of insect must be seriously taken in to account. The types of pesticides applied by farmers (GAP and non-GAP) were not different because most farmers buy pesticides at the agro-chemicals shops in the village. For example, imidacloprid was commonly used for control worms and aphids because this product is inexpensive, and easy to obtain from shops in the village. In the rainy season, during the high pest epidemics, farmers will use pesticides with higher toxicity levels, such as tolfenpyrad, profenofos and cypermethrin. However, considering number of chemicals used, GAP farmers used less than non-GAP farmers (Table 1).

Based on a survey of pest control in the field, GAP farmers tried to use integrated pest management methods, which were bio pesticide such as azadirachtin, *Baciluss thuringiensis*, *Trichoderma harzianum* and *Steinernema sp.* Moreover, they also applied insect net for protection against pests with government support, which non-GAP farmers do not have. This may be the reason of fewer number of pesticides applied by GAP farmers and also indicate the important of intervention form government agencies in terms of production and reducing pesticide application. However, factors affecting farmers' decision to apply pesticides include labor, market motivation, disease and insect outbreaks, and size of vegetable plots.

Risk Assessment of Pesticide Applied in Chinese Kale Cultivation

The EIQ Field Use values were calculated by using data of pesticide applied in farmlands. The results of calculated EIQ Field Use for assessing pesticide risk revealed that EIQ Field Use (n =10) of GAP farmers was in the range of 28-131 and the average EIQ Field Use values is 87.42 (Rating level=moderate risk). Although the EIQ Field Use (n =10) of non-GAP farmers was in the range 30–393 and the average EIQ Field Use values is 136.87 (Rating levl= high risk). This data shown in Table 2.

Table 1 Pesticide application of GAP and non-GAP farmers in Chinese kale plots

Pesticides	Type	%Active ingredient	Application rate per 20 L water		Frequency of application per crop	
			GAP	non-GAP	GAP	non-GAP
abamectin	I	1.8%W/V EC	20-30 ml	20-30 ml	3-6	3-6
acetamiprid	I	20% SP	5 g	5 g	2	2
alachlor	H	48%W/V EC	150 ml	100-175 ml	1	1
carbaryl	I	85%WP	20 g	30 g	1	3
chlorfenapyr	I	10%W/V EC	40 ml	40 ml	1	1
chlorantraniliprole	I	5.17%W/V SC	40 ml	-	2	-
chlorpyrifos+cypermethrin	I	50%+5%W/V EC	-	20 ml	-	6
cypermethrin	I	35%W/V EC	10-20 ml	10-30 ml	1-6	3
diazinon	I	60% W/V EC	-	40 ml	-	1
dichlorvos	I	50%W/V EC	40 ml	10-60 ml	3	2-6
dinotefuran	I	10% WP	-	10-15 g	-	1-4
emamectin benzoate	I	5% WG	-	10 g	-	2
haloxyfop-p- methyl	H	10.8%W/V EC	50 ml	50 ml	1	1
imidacloprid	I	70% WG	5 g	10 g	2	2
indoxacarb	I	15%W/V EC	-	10 ml	-	1
mancozeb	F	85%WP	50 g	40 g	1	6
oxadiazon	H	25%W/V EC	100 ml	100 ml	1	1
profenofos	I	50%W/V EC	20 ml	10 ml	3	4
spinetoram	I	12% W/V SC	15 ml	10 ml	3	4
tolfenpyrad	I	16% EC	20 ml	40 ml	1	1-5

Remark: Collected samples (N=20) from 10 GAP and 10 non- GAP farmers interviews in March to May 2018 of Muang District Khon Kaen Province Thailand. I= Insecticide, H=Herbicide, F= Fungicide, Application rate per 400 m² plot size.

Table 2 EIQ Field Use of GAP and non-GAP Chinese kale cultivation

Type of Chinese kale cultivation	EIQ Field Use (Min-Max)	Average EIQ Field Use	S.D.	Risk rating
GAP (N=10)	28-131	87.42	31.38	Moderate risk
non-GAP (N=10)	30-393	136.87	115.76	High risk

Remark: when EIQ Field Use less than 25 = Very low risk, less than 50 = Low risk, 50-99 = Moderate risk, 100-199 = High risk, over than 200 = Very high risk (Cornell University, 2018).

The numbers of GAP and non-GAP Chinese kale farms classified by EIQ Field Use rating are presented in Fig.1. The result of calculated EIQ Field Use risk assessment of pesticide application revealed that in 10 GAP farms there are4 farms with high risk levels (40%), 5 farms with moderate risk levels (50%) and 1 farm with low risk levels (10%). Within the 10 non-GAP farms, there are 3 very high risk levels (30%), 2 farms with high risk levels (20%), 4 farms with moderate risk levels (40%), and 1 farm with low risk levels (10%).

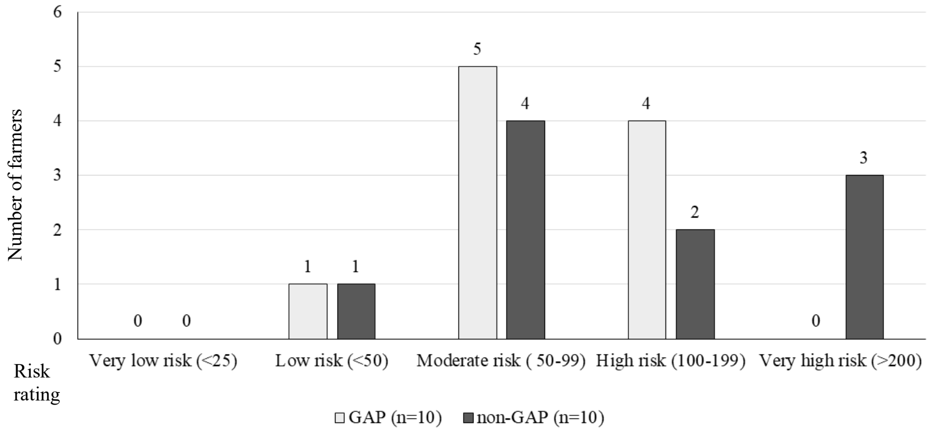

Fig.1 Number of GAP and non-GAP Chinese kale farms classified by EIQ Field Use rating

CONCLUSION

GAP Chinese kale cultivation has a lower level of impact on environmental risks than that of conventional one (Average EIQ Field Use: GAP = 87.4, non-GAP = 136.87). This data indicates that the GAP system could reduce the risk of pesticides application in the environment of commercial vegetable-growing village.

ACKNOWLEDGEMENTS

This study was funded by The Agricultural Research Development Agency (Public Organization) Bangkok, Thailand. The authors would like to thank the Office of Agricultural Research and Development Region 3, Department of Agriculture, Ministry of Agriculture and Cooperatives, Thailand for participating in this research.

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Research article

Farmers' Perceptions on Soil Degradation and their Criteria to Adopt Soil and Water Conservation Strategies in Ovche Pole Region in North Macedonia

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Received 22 January 2020 Accepted 11 September 2020 (*Corresponding Author)

Abstract Ovche Pole is a region in Macedonia where the main economic activity of people is agriculture. Moderate-continental-sub-Mediterranean climatic conditions are prevalent in the area. However, based on the data for average annual precipitations (P) and potential evapotranspiration (PET), the region has aridity index of 0.64, thus it is classified as dry sub-humid and vulnerable to desertification. The region is dominated by agriculture land which takes 62% of total area, followed by forests and pastures that takes 22.55% and 14% respectively. Vertisols are the dominant soil type, taking 51.24% of total area in the region. Climatic conditions, together with the unsustainable agricultural practices highly influence the process of land degradation, especially soil degradation in the region. The key for success of any land restoration activity is the involvement of local communities. Understanding the farmers' perceptions on this issue is crucial for development and implementation of sustainable resource management strategies. Therefore, the objectives of this study are to: (i) assess farmers' perceptions on different types of soil degradation and (ii) examine farmers' perception and motivation for adopting new SWC practices. A semi-structured questionnaire was developed and distributed to farmers to gather primary data. Out of total population of 375 registered farmers, following convenience sampling method, 102 farmers took a part in the questionnaire survey. Secondary data on climate/weather, land use, soils, demography was obtained from published or unpublished sources. The results of the study show that farmers could observe different soil degradation process on their land. Most of the farmers perceived decline in soil moisture retention as most intense and most significant problem. For majority of interviewed farmers, the main criteria to adopt SWC are the increased financial benefits and gains from the new measure and financial incentives provided by government institutions.

Keywords farmers' perceptions, questionnaire survey, soil degradation, soil and water conservation

INTRODUCTION

The Land Degradation Assessment in Drylands (LADA) project (2011) reported that "Soil degradation occurs as a result of adverse changes in the soil biological, chemical, physical and/or hydrological properties. Such changes can increase the vulnerability of the soil to further degradation". Although, soil degradation is influenced by local environmental conditions such as climate, topography, soil type etc., farmers with their land management practices can exacerbate degradation processes too. Therefore, adoption of SWC measure is required to prevent or revers degradation of natural resources. However, achieving success in SWC programs is difficult because many constrains play a role. Deciding to adopt SWC measures is complicated process influenced by many factors such as the agro- ecological conditions, socioeconomic and cultural characteristics of the farmers' population (Calatrava et al., 2011; Pulido and Bocco, 2014). Decision to adopt SWC measures driven by intrinsic factors can promote long lasting behavioral change, while decisions made only because of extrinsic motivation factors, such as financial incentives provide less stable changes. Understanding the motivation factors that influence farmers to implement new SWC will help policymakers to design more effective SWC strategies and manage conservation programs more successfully. Top-down oriented projects in general are not so successful; Development organizations focus more on participatory methods emphasizing the importance of beneficiaries' commitment and engagement in activities (Kessler, 2006).

OBJECTIVE

The objectives of this research are (i) to assess farmers' perceptions of different types of soil degradation and (ii) to examine farmers' perception and motivation for adopting new SWC practices.

METHODOLOGY

Study Area Description

The region of Ovche Pole is a plain located in the east central part of Macedonia and takes an area of 649 km^2 (Fig. 1). Administratively, the region is divided into two municipal units, Sveti Nikole and Lozovo. According the last census municipalities together had population of 21.355 people (State Statistical Office, 2002). Highest point is on 856 m above sea level, however the average elevation of the region is between 200 and 400 meters. Three characteristically different landscape types can be distinguished in the region. Agricultural flatland landscape on saline ground takes the flat areas up to elevation of 350 m. specific for this area is the presence of halomorphic soils. Lowland rolling agricultural landscape, which are the areas found up to elevation of 500 m.a.s.l. represented by hills with mild slopes. The third specific landscape type is the lowland rolling agricultural landscape with wind hedges. Specific for this area is the presence of man-made corridors of trees and shrubs that protect the agriculture land from the prevailing winds (Melovski et al., 2015).

Fig. 1 Geographical position of the research area (in red borders of the right picture)

The climate in the region is modified warm continental with Mediterranean influence (Zikov, 1995; Filipovski et al., 1996). Specific for this region is the occurrence of strong winds coming from the north-west, north, south-east direction present most of the time of the year. Analysis of climatic data for the period between 1950 and 2000 showed that the average annual precipitation is 471.1 mm and the average annual evapotranspiration is 734.4 mm, with an aridity index of 0.64. According to the UNCCD this classifies the region as dry sub-humid and vulnerable of desertification (Blinkov et al., 2005; Miladinovc et al., 2006). The region is dominated by vast areas under arable fields and croplands. Although, agriculture land takes 40 183 ha (62 % of the total land), much of the arable land is not irrigated (Fig. 2). Forests cover 14 619 ha (22.5%) of which 2/3 are degraded, whereas 9134.38 ha (14%) are pastures (CORINE LC/LC, 2012). Vertisols are the dominant soil type in the region, almost entirely distributed in areas where agriculture is intensively practiced. This soil type is distributed on 33 422 ha or 51.24 % of the land (MASIS). Farmers mainly produce grains such as wheat and barley, however there are areas where tobacco, alfalfa, melons, and vegetables are cultivated.

Fig. 2 Agriculture landscape in the research area

Data Collection and Analysis

The study was conducted from 7th of September to 7th of October 2019. Semi-structured questionnaire was developed and distributed to farmers to gather primary data. Using convenience sampling method, 102 farmers took a part in the questionnaire survey, out of a population of 375 registered farmers (MAFWM, 2019). The interviews with the farmers were done at any place they were met, usually in the field, local bars and shops in the villages or in their homes. Part of the questions were designed in a 5-point liker-type scale, ranging from "strongly not agree" to "strongly agree", however some information were gathered through ranking questions. The question statements were put in simple language, however in case when person could not understand some part additional explanation were given to them. The questionnaire was designed to have three sections. The first sections, contained questions related to socioeconomic characteristic of farmers as well as the land management practices. Second section, captured farmers' perceptions on soil degradation. Questions in the third section captured farmers' perceptions on SWC and their drivers of motivation to adopt new SWC measures. Simple descriptive statistics such us frequency distribution and percentage were used to interpret and present data. Secondary data on climate/weather, land use, soils, demography was obtained from published or unpublished sources. The number of registered farmers was provided by The Ministry of Agriculture, Forestry and Water Management (MAFWM). Data on land use/land cover was obtained from the CORINE Land Cover (CLC2012) data set from 2012, program coordinated by European Environmental Agency (EEA). Data from The Macedonian Soil Information System (MASIS) was used to analyze characteristics and distribution of the soil in the research area.

RESULTS AND DISCUSSION

Farmers' Perceptions on Soil Degradation Processes

Questionnaire results showed that 89% of the respondents noticed some negative changes related to soil quality. Table 1 outlines farmers' perceptions on the degree of intensity of soil degradation processes on their land. The farmers could choose one response on an intensity scale with five levels of degree ranging from no presence of soil degradation to extreme intensity of soil degradation. The results showed that water logging and salinization and/or alkalinisation were not present at all for

91% and 82% of the farmers, respectively. However, majority of farmers reported some degree of degradation, for the other investigated soil degradation processes. Decline of soil moisture retention was perceived as most insensitively present problem; 77% of the farmers reported strong and 6% extreme degree of this type of soil degradation. For loss of fertility and loss of soil structure, majority of the respondents' answers ranged between light, moderate and strong. Regarding, loss of topsoil and erosion 46% of the farmers reported light intensity, 31% reported no presence and 20% moderate intensity. However, for loss of life and biodiversity the results showed two tendencies in the response. A group of 39% of respondents that did not notice this problem and a group of 32% reports strong intensity of loss of soil life and biodiversity.

Regarding the perception for the time of beginning of these issues, 12% of respondents answered that the soil degradation issues started in the past 5 years, 35% said in the past 10 years, 25% in the past 15 years, 15% said in the past 20 years and 13% told they don't know. In addition, 69% of farmers said that now they use more fertilizers compared to the past 10 years. Farmers were asked to rank the soil degradation processes by the degree of significance for their farming activities. The results from the data analysis are visually presented in Fig. 3. The sample group gave consistent answers when ranked the 1st and 2nd most significant soil degradation issues. Decline in soil moisture retention capacity was ranked as the most significant problem by 89% of the respondents. The loss of soil fertility was ranked 2nd most significant issue by 75% of farmers. Loss of soil structure and loss of topsoil and erosion were ranked 3rd and 4th most significant issues, respectively. Loss of life and soil biodiversity was ranked 5th most significant issue. These results can be explained if we have in mind the climatic conditions and properties of Vertisols-the dominant soil type in the region.

Table 1 Farmers' perception on soil degradation intensity degree

Type of degradation	Intensity of soil degradation process				
	Not present	Light	Moderate	Strong	Extreme
Loss of topsoil and erosion.	31%	46%	20%	3%	0%
Loss of soil fertility	3%	17%	44%	34%	2%
Loss of soil structure	4%	24%	48%	24%	1%
Water logging of soil	91%	7%	1%	1%	0%
Loss of life and soil biodiversity	39%	14%	9%	32%	6%
Salinization and/or alkalinisation	82%	16%	2%	0%	0%
Decline in soil moisture retention	4%	4%	2%	77%	13%

Own Source: Data provided by questionnaire survey, 2019

The World Soil Resource Report (2015) notes that "the physical properties and the soil moisture regime of Vertisols represent serious management constraints. The heavy soil texture and domination of expanding clay minerals result in a narrow soil moisture range between moisture stress and water excess" (IUSS Working Group WRB, 2015). According to Alvaro-Fuentes et al. (2008) "Soil organic matter (SOM) is a key factor in semiarid agrosystem production" (Álvaro-Fuentes et al., 2008). In their study on effects of soil organic matter on soil productivity, Bauer and Black (1994) concluded that loss of fertility explained loss of productivity due to a depletion of soil organic matter.

Soil and Water Conservation Practices among Farmers

The results from the questionnaire showed that 77% of the farmers practice some measure for SWC conservation and 23% did not. Fig. 4 shows information on the different SWC practices implemented by farmers. Farmers practice only traditional conservation measure such as manuring, crop rotation and fallow. Except drip irrigation which is integrated by 5% of respondents, no other new technologies or practices are implemented. The involvement of government institutions or other organization to support and encourage farmers in implementation of SWC is absent. The results of the survey showed that 96% of farmers are not familiar with government programs aimed to support SWC. In addition, 98% of farmers have never been contacted by any institution or organization on SWC and issues related with soil degradation.

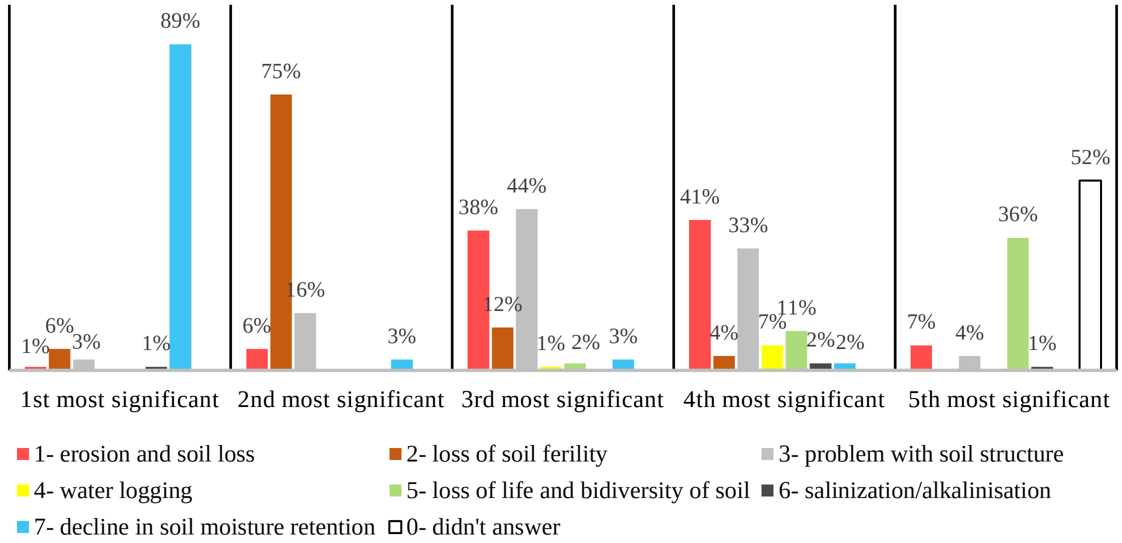

Fig. 3 Ranking of soil degradation issues by significance

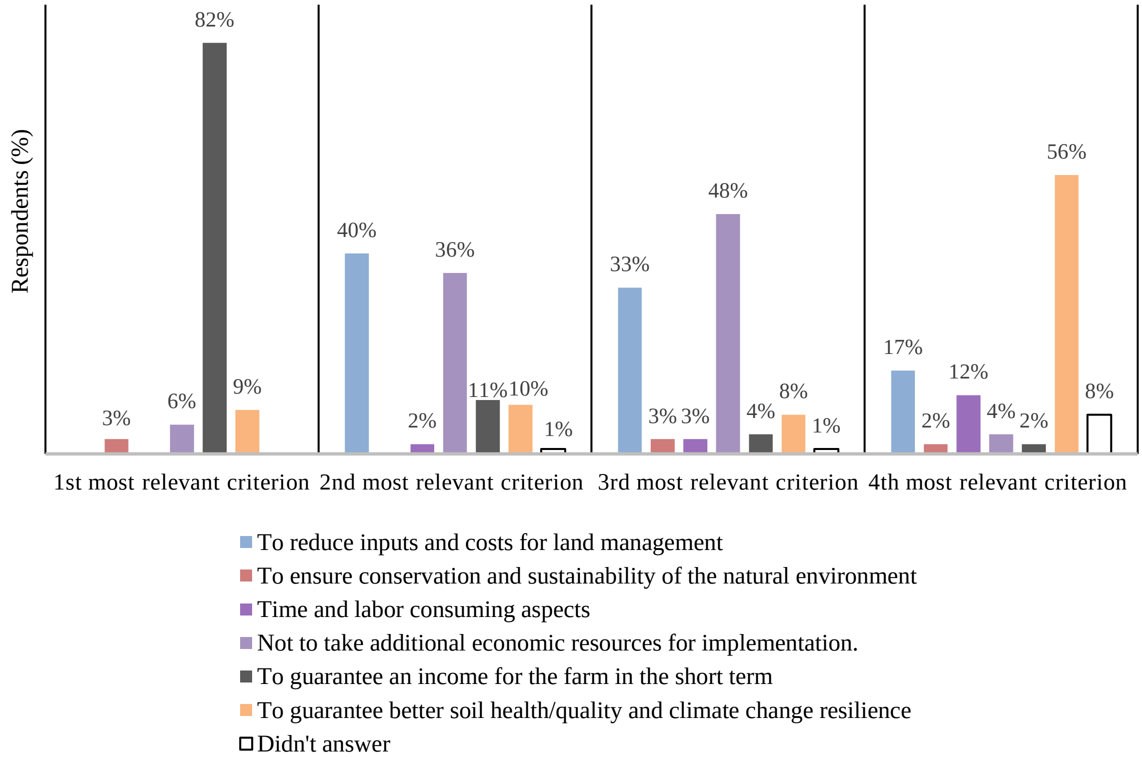

Fig. 4 Distribution of different soil and water conservation practices among farmers

Farmers' Motivation for Adopting New Soil and Water Conservation Practices

On the question if there is an interest in adoption of SWC measures among farmers, 61% answered affirmative, 19% said that there is no interest and 20% did not know how to answer. Perception of existing a future risk can be a driver for behavioral change, in this case adoption of SWC measure.

Therefore, farmers were asked if they believe that soil degradation issues would increase, stay same or decrease in future. Out of all, 95% answered that the soil degradation processes will increase in future and only 3% and 2% believed that issues will stay same and decrease, respectively. In this study respondents were asked to rank relevant criteria expected when adopting new SWC measure. The results presented in Fig. 5 show that the three most relevant criteria are related to the economic benefits of the farmers. Better soil quality and climate change resilience is on the fourth place of importance.

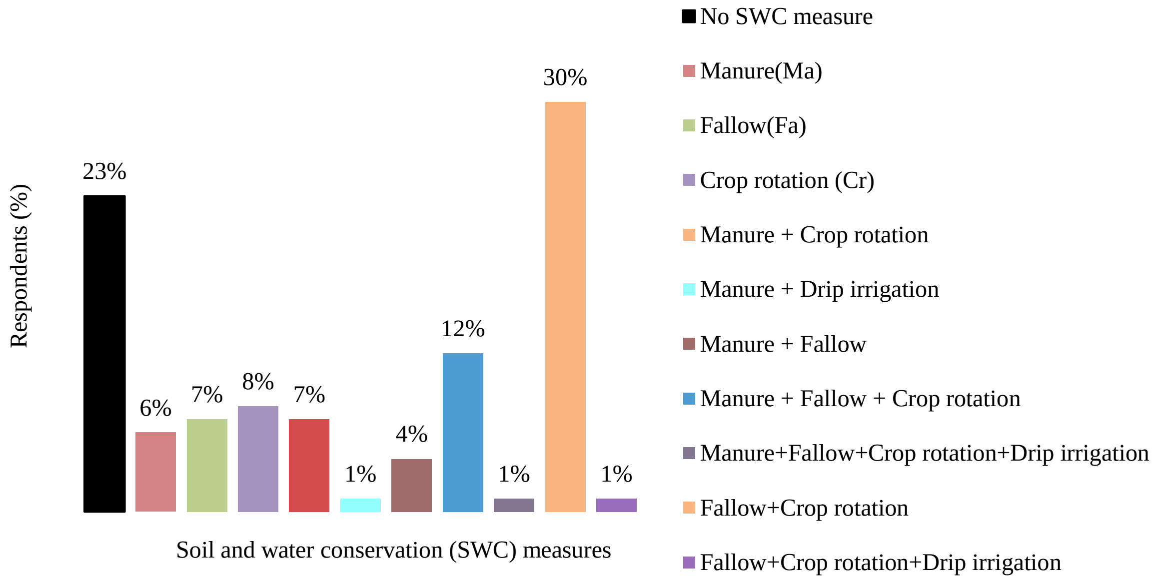

Fig. 5 Farmers' ranking of relevant criteria for adoption of SWC measure

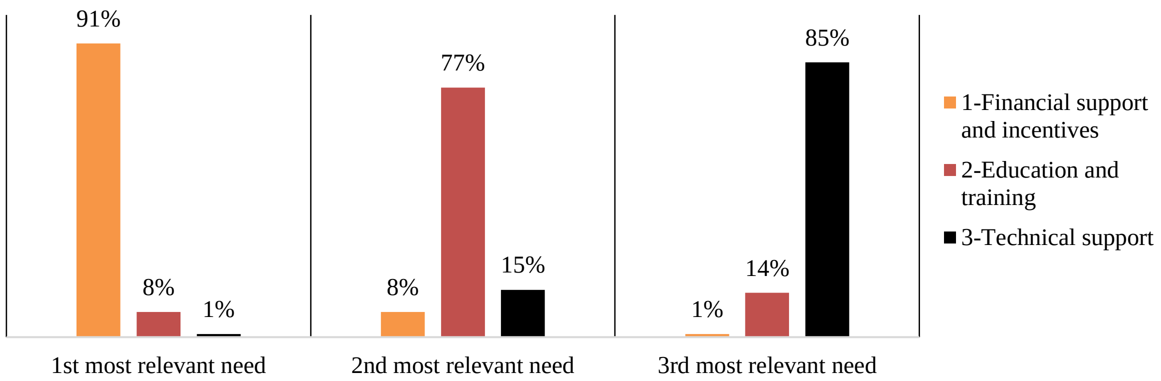

Fig. 6 Ranking of relevant need for adoption of SWC measure

To extract information on what farmers need to adopt new soil and water conservation measure they were asked to rank among: education and training, technical support and financial incentives. Participants in the survey ranked financial support and incentives as most relevant need for adoption of new SWC measure, technical support was ranked 2nd whereas education and training 3th most relevant need for adoption of new SWC measure. The results are presented in Fig. 6 of this manuscript. A study that compared results of independent research projects in five developing countries showed that factors that motivates farmers are always context-specific and generalization is not possible. However, in general profitability and financial benefits are common factors that influence farmers to adopt SWC measures (de Graaff et al, 2008). Other authors had similar conclusion that resource conservation should be accompanied by short-term economic benefits for farmers (Pulido and Bocco, 2014). However Calatrava et al. (2011) in their study on policy measures for agricultural soil conservation in semi-arid Mediterranean areas noted that “stakeholders stated that the most important and effective measure is to provide technical education and information to farmers to convince them of the benefits of conservation practice."

CONCLUSION

General perception among the participants in the study is that biggest issues come from the decline in soil moisture retention, decline of soil fertility, soil structure and soil erosion. Soil degradation is induced as a result of combination of factors such as climatic conditions in the region and the properties of the dominant soil type, however problems are exaggerated by the land management practices. Although, 76% of the farmers of Ovche Pole region implement one or more SWC measure, most farmers execute only some traditional and very basic land management practices, new SWC practices have been rarely or not adopted at all. Extending of the traditional measures and introduction of new practices is needed, however this would require education, technical and financial support for farmers. Results of this study point out that SWC needs to be followed by short-term financial benefits through improved production and reduced costs, which are primary interest of farmers. Therefore, as a way to promote and encourage conservation agriculture, government must provide direct or indirect subsidies for farmers that implement SWC measures. In addition, institutions should provide financial support and incentives for farmers in the initial phase of implementation so they can overcome the initial investment constrains that they usually face. So far, the engagement of relevant government or non-governmental agencies to support farmers in adoption of new SWC strategies is very low. Therefore, development of capacity of institutions and organizations to conduct SWC programs and support farmers to implement measures on their land is needed. Commitment should be on a long term and project interventions need to have longer project cycle. Establishment of research and demonstration sites where farmers can directly see the benefits of SWC and be trained should be considered as appropriate strategy for long term results. Local solutions and innovations, as well as farmer-to farmer knowledge dissemination should be encouraged.

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Research article

Combination of Entomopathogenic Fungi with Essential Oil for Controlling Bean Fly, *Ophiomyia phaseoli* Tryon (Agromyzidae: Diptera)

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Received 6 March 2020 Accepted 12 October 2020 (*Corresponding Author)

Abstract The objective of this study was to evaluate the compatibility of entomopathogenic fungi with repellants to control bean fly, *Ophiomyia phaseoli* Tryon (Agromyzidae: Diptera). Nine isolates of entomopathogenic fungi belonging to 3 genera and 5 species were screened for pathogenicity against bean fly. The results found that *Beauveria bassiana* isolate Bff and *Metarhizium anisopliae* isolate Mff caused 100% mortality to both its larval and adult stages. The repellency of 7 essential oil was also evaluated against adult bean fly in the laboratory. The results showed significant differences in repellency among essential oil and concentrations. Essential oil extract from pomelo peeling was the strongest repellant followed by eucalyptus and sweet basil. However, essential oil extract from camphor was the weakest repellant. On the other hand, these seven essential oils (pomelo, zingiber, citronella grass, eucalyptus, camphor, kaffir lime and sweet basil) at a concentration of 0.1% had no effect on the viability of conidia, but at higher concentrations it was found that citronella grass and zingiber reduced viability of *B. bassiana*. The results on the effect of essential oils on colony growth showed the same tendency as the one on the viability of conidia.

Keywords bean fly, entomopathogenic fungi, essential oil, repellent

INTRODUCTION

Phaseolus vulgaris L., French bean is a herbaceous annual plant in the Fabaceae family, it grows to between 20-60 cm high; and twining, climbing vines up to 2-5m long. The stems of bushy types are rather slender, pubescent with many branches (Chávez-Servia et al., 2016). In twinning types, the stems are prostrate for most of their length and rise toward the end. The leaves, borne on long green petioles, are green or purple in colour and trifoliate. Leaflets are 6-15 cm long and 3-11 cm broad. The inflorescences are axillary or terminal, 15-35 cm long racemes. The flowers are arranged in pairs or solitary along the rachis, white to purple and typically papillonaceous. Once pollinated, each flower gives rise to one pod. Pods are slender, green, yellow, black or purple in colour, sometimes striped (Caproni et al., 2019) . They can be cylindrical or flat, straight or curved, 1-1.5 cm wide and up to 20 cm in length. The pods may contain 4 to 12 seeds. The seeds are 0.5-2 cm long, kidney-shaped and highly variable in colour depending on the variety: white, red, green, tan, purple, gray or black.

French bean is a major plant of Royal Project Foundation for the growers of organic vegetable system in Thailand. However, the problem of French bean plantation is bean fly, *Ophiomyia phaseoli* Tryon)Agromyzidae: Diptera) (Ojwang et al., 2010) .They lay eggs in the leaf tissue or directly on the stem. Early signs of attack are egg laying punctures on the primary leaves which tend to be concentrated around the leaf base (Letourneau, 1994). Eggs hatch into small white maggots which migrate down the stem to the root zone where they pupate into brown puparia. Severe damage is indicated by wilting and dying of seedlings. The attack disrupts nutrient transportation, causing the tap root to die (Ssekandi et al., 2016). The plant attempts to recover by forming adventitious roots above the damaged area (Ojwang et al., 2010). Young seedlings under stress wilt and die within a short time. Older and more vigorous plants may tolerate the damage but become stunted and will have reduced yield. Control strategies for grower to use were as follow: application of botanical pesticides, natural enemies, sticky trap and also chemical seed dressing with systemic insecticides. *Plutachis* sp. Eulophid, *Biosteres* sp. *Pteromalid* sp. nematode and *Oecophylla smaragdina* Fabricius were effective against bean fly by 52% but bean fly still serious pest of French bean plantation (Jaramillo et al., 2013).

OBJECTIVES

The objectives of this study were: firstly to screen promising entomopathogenic fungi against bean fly and secondly to evaluate plant-based insect repellants and their compatibility with the entomopathogenic fungi in controlling bean fly.

MATERIALS AND METHODS

Selection of Entomopathogenic Fungi from Collection

Nine isolates of entomopathogenic fungi consisting of 3 different genera and 5 different species were selected from Agricultural Technology Research Institute, Rajamangala University of Technology Lanna, Lampang 52000, Thailand. These were screened for their efficacy against bean fly under laboratory condition.

Selection of Plants as Repellants Against Bean Fly

Selection of plants that have potential to repel bean fly was conducted according to the literature reviewed that hinted on the plants that have essential oils that repel invertebrates (Showler, 2017 and Abtew *et al.*, 2015). Extraction of essential oil was done using the Steam-distilled method (Mcguinness, 2003). After that, Study on the efficacy of essential oil that repel bean fly at difference concentration was conducted. Moreover, study on effect of essential oil to germination of entomopathogenic fungi and study effect of essential oil to growth of entomopathogenic fungi was also conducted (Liu, 2012).

Efficacy of Formulation of Entomopathogenic Fungi Combine with Repellant

This was conducted with the aim to produce an efficient formulation of entomopathogenic fungi for controlling bean fly. The formulation was produced by mixing 20% of entomopathogenic fungi + 1% of Tween 80 at a concentration of 10% + 1% of Glycerin + 5% vegetable oil + 3% Propylene glycol (Malee, 2015). This was then applied on French bean leaves to assess the spore viability and efficacy of formulation of entomopathogenic fungi against bean fly. The experiments were carried out in 3 treatments: formulation 1 (*Beauveria bassiana*), formulation 2 (*Metarhizium anisopliae*) and control. Suspension was directly sprayed on to the bean fly.

RESULTS AND DISCUSSION

Efficacy of Entomopathogenic Fungi to Infected Bean Fly

Nine isolates of entomopathogenic fungi belonging to *M. anisopliae*, *B. bassiana Isaria fumosoroseus*, *Isaria tenuipes* and *Isaria farinosus* were selected for this study. The results for pathogenicities of 9 isolates of these entomopathogenic fungi showed high virulence against larval and adult stage of bean fly. It was observed that *B. bassiana* isolate Bff and *M. anisopliae* isolate Mff caused 100% mortality to both larval and adult stages of bean fly as shown in Table 1. This was a very impressive result and is in agreement with several studies (Letourneau, 1994). The other advantage of these entomopathogenic fungi is that they offer endophytic advantages as well to the planted when they are inoculated (Mantzoukas and Eliopoulos, 2020).

Table 1 Percent mortality of entomopathogenic fungi to bean fly (larval stages)

Entomopathogenic fungi*	Isolates	Percent mortality
Metarhizium anisopliae	Ma.4849	80.00
	Ma.7965	93.33
	Mff	100.0
Beauveria bassiana	Bb.5335	80.00
	Bb.4591	80.00
	Bff	100.0
Isaria fumosoroseus	Pfu.2507	60.00
Isaria tenuipes	Pt.6073	46.67
Isaria farinosus	If 2549	40.00

**Fungus isolates from Agricultural Technology Research Institute, Rajamangala University of Technology Lanna, Lampang*

Efficacy of Plants as Repellants Against Bean Fly

The repellency of 7 essential oil was evaluated against adult bean fly in the laboratory. The results showed significant differences in the repellency among essential oils in different concentrations. Essential oil extract from peel of pomelo was the strongest repellent followed by eucalyptus and sweet basil. Essential oil extract from camphor was observed to be the weakest repellent as indicated in Fig. 1. In addition, the seven essential oils (pomelo, zingiber, citronella grass, eucalyptus, camphor, kaffir lime and sweet basil) a concentration of 0.1% had no effect on the viability of conidia, but in higher concentrations, it was observed that citronella grass and zingiber reduced viability of *B. bassiana*. The results on the effect of essential oils on colony growth showed the same tendency as shown in the viability of conidia (Fig. 2). These results did not deviate much from other studies (Liu, 2012). Compatibility of these EPFs is known to be of paramount effect on their effectiveness and hence cannot be omitted (Neves et al., 2001).

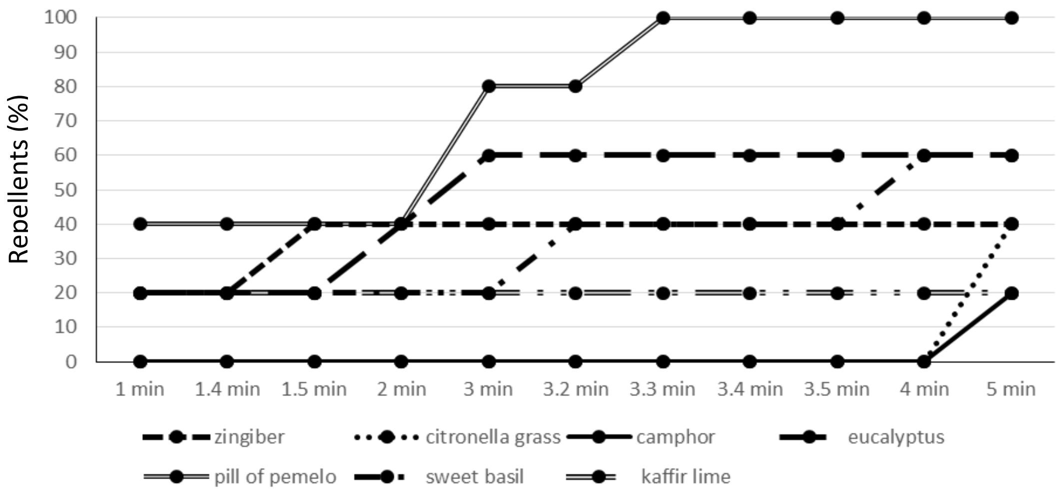

Fig. 1 Percent efficacy of plants as repellents against bean fly

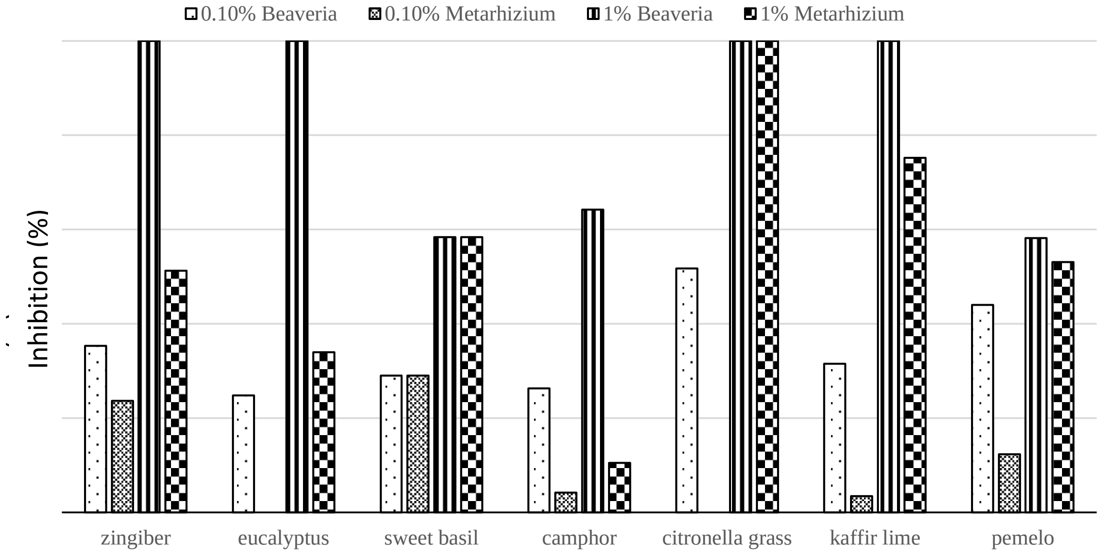

Fig. 2 Percent inhibition of plant repellent to *Beauveria* spp. and *Metarhizium* spp.

Efficacy of Formulation of Entomopathogenic Fungi Combine with Repellent

Concerning the potentiality of formulation of entomopathogenic fungi in combination with essential oils against bean fly, it was observed that when entomopathogenic fungi combine with essential oil there was increased effectiveness in controlling bean fly. This is an interesting finding as they would complement without adverse effects. Ali et al (2018) also worked with eucalyptus and entomopathogenic fungi observed remarkable potential in their compatibility and the resultant efficacy.

CONCLUSIONS

Out of 9 isolates, 2 isolates i.e., *B. bassiana* isolate Bff and *M. anisopliae* isolate Mff showed the highest mortality against both larval and adult stages of bean fly. Formulation of entomopathogenic fungi took time to ablate from French bean leave which was very impressive. Essential oil extract from peel of pomelo was a stronger repellent followed by eucalyptus and sweet basil. However, essential oil extract from camphor was a weaker repellent. It was also observed that a concentration of 0.1% had no effect on the viability of conidia, but at higher concentrations it was found that citronella grass and zingiber reduced viability of *B. bassiana*. The results on the effect of essential oils on colony growth showed the same tendency as the one on the viability of conidia. Entomopathogenic fungi combined with essential oil had high potential in controlling bean fly.

ACKNOWLEDGEMENTS

This research was funded by Highland Research and Development Institute (Public Organization).

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Research article

Agronomic and Yield Performances of Three Rice Cultivars (*Oryza sativa* L.) under Water Regimes in Dry Season

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Abstract Rice *(Oryza sativa.* L*)* is widely cultivated in Cambodia, but it consumes considerably more water than any other crops. In the context of water scarcity due to global climate change, rice cultivation in Cambodia has been worsened by the effect of drought. Development of a cultivation technique to minimize yield loss under drought stress or/and limited water resource in rice production is of great strategic value. Therefore, the present study aims to investigate growth and yield performances of three rice genotypes, namely CAR 14, CAR 15 and CAR 16 under different water regimes including drought (at flowering stage), alternative wet and dry (AWD), and flooded conditions. The experiment was conducted from January to October 2019, at the Tonle Bati Agricultural Development Center, located in Bati District, Takeo Province, Cambodia. The soil is clay loam and is classified as Toul Samrong (Soil Classification for Rice Production in Cambodia). Two-way ANOVA was utilized to determine interaction between the genotypes and the water regimes. As a result, the genotype-water regime interaction was detected for grain yield. Water regimes affected grain filling percentage and yield, whereas rice genotypes affected plant height, 50% flowering days, 100% flowering days, number of unfertile grains, grain yield, and 1000 grain weight. Nevertheless, plant density, panicle length, and straw biomass were not affected by either of the factors. In any water regimes, CAR16 grew the tallest at 94.4 cm and blossomed 2 to 4 days later than any other cultivars. In contrast, CAR 15 had the highest yield, observed in permanent flooding and in AWD. Although 27% of irrigation water was saved in AWD, permanent flooding produced more yield. In short, drought conditions affected total yield. Despite that, Car 15 was observed to be more suitable for any water regimes.

Keywords Rice cultivars, AWD, drought, rice yield, straw biomass

INTRODUCTION

Rice belongs to the genus *Oryza sativa* L. and is known as a remarkable semi-aquatic plant which has been cultivated in tropical and subtropical regions for about 10,000 years (IRRI, 2013; Sivapalan, 2015). Maintaining proper water level in paddy fields is critical for rice production, but rice plants will die or suffer yield loss when the water is too deep (Eckardt, 2017). International Rice Research Institute (2013) reported that rice alone provides food for nearly half of the world population that has increased remarkably. Irrigated rice accounts for 55% of the world's harvested rice area and increases by 25% in the next 20 years. Inadequate irrigation causes agronomic problems for intensive rice cultivation (Sivapalan, 2015). It is reported that drought adversely affects rice production by limiting growth and reducing yield by 25.4%, posing a serious threat to global food security (Zhang et al., 2018). The problem is even exacerbated when the demand for clean water is not fulfilled because competition between irrigation and household use has formed.

In Cambodia, rice is grown in both wet and dry seasons depending on availability of water sources. However, prolonged drought has been considered one of the main affecting factors that limit annual rice planting areas. In 2015, severe drought occurred in the country, resulting in dire water shortages and affecting several million people, while in 2012, thousands of hectares of rice fields were destroyed (Climate Change Adaptation, 2019). In response, new rice varieties are studied and bred in hopes of producing drought tolerability. As a result, several varieties such as CAR 14, CAR 15 and CAR 16 have been released, but they are not yet widely available. Besides that, recognizing their effectiveness is still unclear (CARDI, 2019). To address these issues, a proper irrigation technique is required to maintain the yield although drought-tolerant rice varieties are used. A promising solution to rice cultivation with water scarcity is alternative wetting and drying (AWD) designed to irrigate paddy fields when needed, to save water. Large numbers of research results show that AMD significantly reduced water use while maintaining yield (Howell et al., 2015). Therefore, testing different irrigation methods may be beneficial for sustainable rice production within the country.

OBJECTIVE

The research aims to investigate growth and yield performances of the three rice genotypes under different water regimes classified as drought (at flowering stage), alternative wetting and drying irrigation (AWD), and flooded conditions, known as flooding in three rice varieties: CAR 14, CAR 15 and CAR 16.

METHODOLOGY

The experiment was conducted at the Tonle Bati Agricultural Development Center, located in Bati District, Takeo Province, Cambodia, starting from January to October 2019. Three rice cultivars were planted on clay loam, classified as Toul Samroang based on the Cambodian soil classification for rice production. Those cultivars were CAR 14, CAR 15, and CAR 16, and they were planted under three different water regimes designed for drought conditions at flower stage, alternative wetting and drying irrigation (AWD), and flooded conditions, known as flooding. The experimental plots were neatly prepared, bunded, and lined in polythene plastic at the depth of 30 cm. Rice seeds were broadcasted at rates of 125 kg ha^{-1}, with urea and DAP fertilizer applied at rates of 50 kg ha^{-1} each after land preparation and at 100 kg ha^{-1} at the vegetable stage.

In drought conditions, the water level was maintained at 5.0 cm above the ground, but the plots were completely drained at the flowering stage. Draining activities were repeated in case of rain to ensure no water was left in the field. In AWD, PVC tubes were placed in the plots at 40 cm underground and at 20 cm above the ground. The tubes were 40.0 cm in length and 15.0 cm in diameter, perforated with 0.5 cm diameter holes spaced 2.0 cm apart and covered in cloth to prevent clogging. The water level in the AWD plots was maintained at 5.0 cm above the ground and repetitive irrigation was needed when it decreased 5.0 cm below the ground. This practice was discontinued at the flowering stage. In flooding, the paddy fields were kept submerged at 3.0 - 5.0 cm above the ground and then at 5.0 - 7.0 cm until the booting stage. At milking stage, the plots were completely drained.

Three months after planting, the plant height was measured from 10 randomly selected plants within each plot, while plant density was evaluated from 3 random locations within each plot using a 1.0-m^{-2} frame area. In addition, 50% and 100% flowering was evaluated by counting the number of days required from planting to half-full and full blossom. In each plot, panicle length and the number of grains per panicle were measured from 10 randomly selected plants and rice yield from 3 locations using a 4.0-m^{-2} square frame area. Manual threshing was done to collect grains for drying and weighing to calculate the rice yield in all treatments. Then the straw biomass left was dried using an oven at 80^{0}C for 48 hours. Grain weight was measured based on 1000-grain quantity (Tian et al., 2017). Firstly, grains were dried to reach 14^{0}C. Then 1000 grains from each plot samples were randomly taken and weighed. Afterwards, grains were split into categories, full or imperfect, and then counted for comparison.

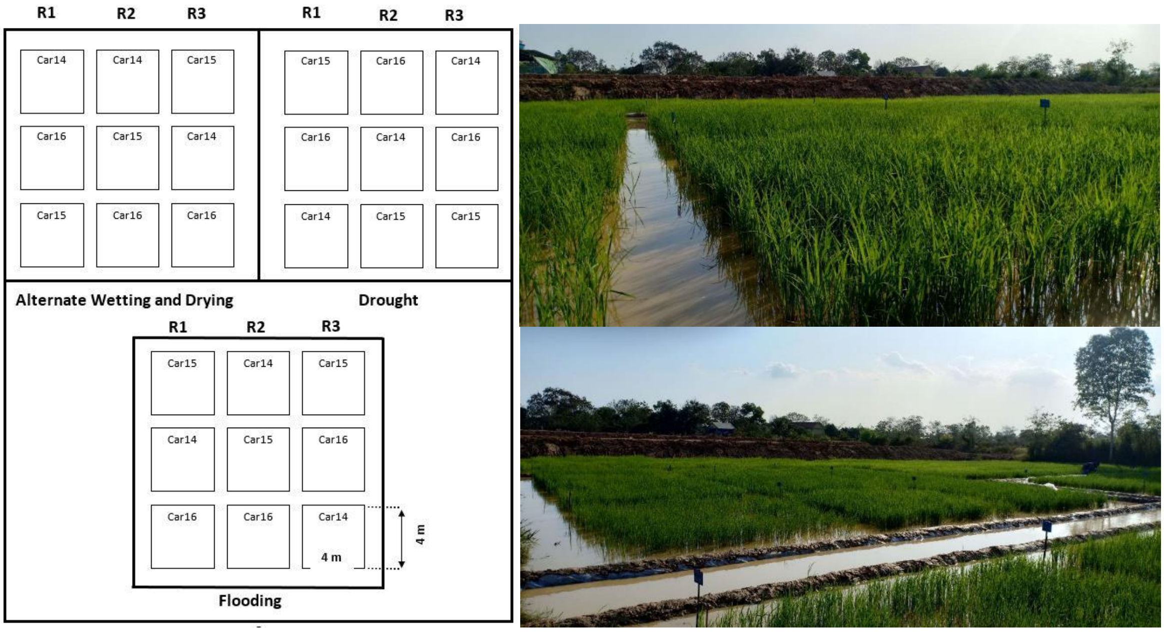

Fig. 1 Experimental plots arranged in RCBD and placed under three water regimes

The experiment arranged for this study was a randomized complete block design comprising three rice cultivars grown in three different water regimes. This combination constituted 6 treatments replicated three times, generating 27 plots. Each plot was 4.0 m by 4.0 m and had spacing of 1.0 m. Two-way ANOVA was performed to determine the interaction between the varieties and the water regime used. Statistical differences were stated by using LSD-test with an error of 5%.

RESULTS AND DISCUSSION

Plant height and Plant density

No significant interactions between the varieties and the water regimes were observed for plant height (P=0.086). The water regimes (p=0.200) also had no effects on plant height, but there were significant differences among the varieties (p<0.001). CAR 16 varieties had significantly higher stems, when compared to CAR 14 and CAR 15, regardless of irrigation techniques. In contrast, CAR 14 had the shortest stems. In addition, the plant height was significantly greater in AWD than in flooding and drought conditions. In Flooding, the plant height for CAR 14, CAR 15, and CAR 16 was 91.0, 90.6, and 96.8 cm, respectively. In AWD, they were 93.5, 91.7, and 98.1 cm, respectively. In drought, the plant stems for different rice cultivars were the shortest, averaging less than 93.0 cm. In short, drought affected rice growth, stunting the stems. Regarding plant density, there were no interactions between the varieties and the water regimes. In addition, no significant differences were found among the two factors. Regardless of the varieties and the irrigation technique used, the plant density ranged from 61 to 73 plants m^{-2}.

Flowering Stage

Days to flowering were counted in this experiment starting from the day of sowing until 50% and 100% blossom. However, no signification interactions between the varieties and the water regimes were observed. Different water regimes also had no significant effects on flowering days, but there were significant differences among the varieties, which means that different rice cultivars started to blossom at different days. It was observed that CAR 14 started to flower faster, when compared to other varieties. In addition, CAR 16 produced flowers at the slowest pace. In all regimes, CAR 14 began to flower 50% at day 64 after planting, followed by CAR 15 and CAR 16 that produced 50%

blossom at days 67 and 68. Full blossom was observed 2 days after 50% flowering. In short, drought did not have effects on flowering dates, and but different varieties did.

Panicle Length

In the experiment, the panicle length of the different varieties was measured at harvest time. There were no significant interactions between the varieties and the water regimes used. In addition, neither of the two factors affected the panicle. These mean that the tested varieties had similar panicle length. Regardless of the water regimes used, the panicle length was observed to lie within the range of 24.8 to 25.9 mm

Table 1 Comparison of vegetative and reproductive growth in three seed varieties planted in three water regimes (Different alphabets mean statistical difference at 5% error)

Water Regime (WR)	Seed variety (SV)	Plant height (cm)	Plant density (plants/m^2)	50% flowering days	100% flowering days	Panicle length (cm)
Drought	Car 14	89.1 cd	64.3	64.7 c	66.7 c	24.8
	Car 15	92.3 b	61.2	67.0 b	69.0 b	25.3
	Car 16	92.9 a	64.9	68.0 a	70.0 a	24.9
AWD	Car 14	89.1 d	65.9	65.0 c	68.0 c	25.9
	Car 15	91.7 bc	66.6	67.0 b	69.0 b	25.6
	Car 16	93.5 b	65.0	68.0 a	70.0 a	25.8
Flooding	Car 14	91.0 bcd	70.9	64.7 c	67.5 c	24.9
	Car 15	90.6 bcd	68.0	67.3 ab	70.0 ab	24.9
	Car 16	96.8 b	73.6	68.0 a	70.3 a	25.0
SE		19.87	4.81	N/A	N/A	2.1
F-test probabilities						
WR		*0.200*	*0.054*	*0.721*	*0.831*	*0.113*
SV		*<0.001****	*0.6167*	*<0.001****	*<0.001****	*0.990*
WR x SV		0.08630	0.76040	0.52150	0.52450	0.965

**Significantly different p at 0.05; **significantly different p at 0.01; and ***significantly different p at 0.001*

Table 2 Comparison of vegetative and reproductive growth in three seed varieties planted in three water regimes (Different alphabets mean statistical difference at 5% error)

Water Regime (WR)	Seed variety (SV)	Yield (Ton/ha)	1000-grain weight (g)	Straw biomass (Ton/ha)	Harvest index (%)	Water used (m^3 ha^{-1})
Drought	Car 14	2.47 e	25.0 c	6.80	26.8	4,824
	Car 15	2.96 cde	28.4 ab	6.98	29.8	
	Car 16	2.62 de	29.8 a	6.90	30.7	
AWD	Car 14	3.12 bcde	24.8 c	5.94	35.1	4,968
	Car 15	4.00 a	27.9 b	7.85	33.9	
	Car 16	2.72 de	28.9 ab	5.51	32.9	
Flooding	Car 14	3.45 abc	25.6 c	8.80	28.2	6,768
	Car 15	3.70 ab	28.8 ab	7.92	31.8	
	Car 16	3.18 bcd	30.0 a	7.85	29.0	
SE		*0.42*	*7.80*	0.72	2.18	N/A
F-test probabilities						
WR		*<0.001****	*0.175*	*0.066*	*0.093*	
SV		*<0.001****	*<0.001****	*0.527*	*0.730*	
WR x SV		*0.021**	*0.980*	*0.517*	*0.807*	

**Significant different p at 0.05; **significant different p at 0.01; and ***significantly different p at 0.001*

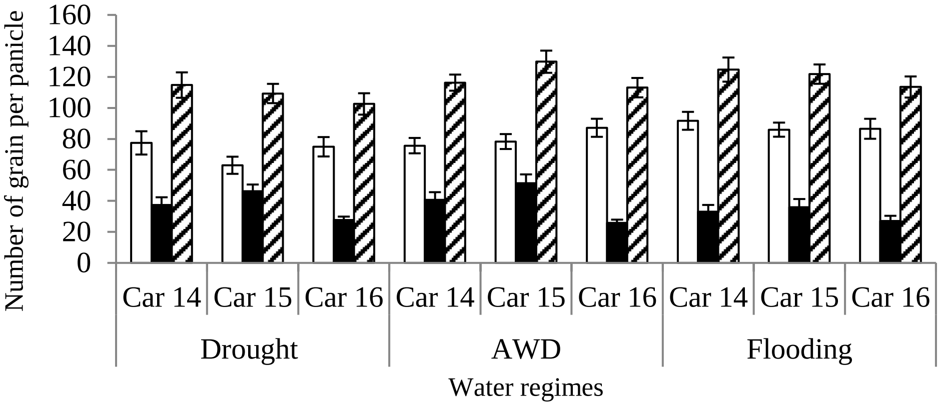

Fig. 2 Comparison of full and imperfect grains for each rice cultivars grown in different water regimes (mean ± SD; n = 30).

Weight in 1000 Rice Grains

After harvest, the grain was sun-dried until they arrived at 14% moisture. Then, 1000 grains were repeatedly taken from the different varieties, weighed and compared. Statistically, no interactions between the varieties and the water regimes were observed (p=0.980). Significant differences in 1000-grain weight were not detected among the water regimes (p=0.175). However, there were significant differences in the weight among the varieties (p<0.001). Regardless of the irrigation conditions, 1000-grain weight was similar between CAR 15 and CAR 16 but was the lowest in CAR 14. On average, 1000 grains of CAR 15 and CAR 16 weighed 28 to 30 g, whereas the same amount of CAR 14 weighed only 25 g.

Number of Panicle Grains

Effects of drought were detected based on separation of full and imperfect grains. No interactions between the varieties and the water regimes were observed for imperfect grains (p=0.377) and for full grains (0.360). Significant differences in imperfect grains were found among the varieties used (p<0.001), but not the water regimes (p=0.081). In contrast, full grains were significantly affected by the water regimes (p=0.001), not by the varieties (p=0.222). Among the varieties planted, CAR 14 had greater numbers of full grains in AWD and drought, compared to other varieties. Likewise, CAR 16 was seen to have more full grains in flooding. Both of these varieties had few imperfect grams than CAR 15 did. Regarding the total grain number, CAR 15 had the most and CAR 16 had the least, while CAR 14 was in the middle.

Rice Yield, Straw Biomass, Harvest Index, and Water Use

Significant interactions between the varieties and the water regimes were observed in rice yield (p=0.021), and these two factors also affected the yield (p<0.001). It can be seen that the yield harvested in the drought treatment was significantly lower than in other treatments, regardless of the varieties used. Similar rice yield was obtained both in AWD and flooding treatments. In drought condition, the yield for the three varieties was less than 3 tons ha^{-1}. Drought reduced the yield was reduced by 28 % for CAR 14, 20% for CAR 15, and 17% for CAR 16. The result was similar in the studies by Zhang et al. (2018), which identified the effect of drought by 25.4%. Besides that, the rice yield of CAR 14 and CAR 15 was lower in this study than in the report by CARDI (2018a & 2018b).

Straw biomass was also collected from all treatments for comparison and for calculating harvest index. Significant interaction between the varieties and water regimes was not observed (p=0.517), nor were there significant differences in straw biomass (p=0.066; p=0.527). It was found that drought had no effects on biomass that varied from 5.5 to 8.8 tons ha^{-1} among all treatments. Significant interaction between the varieties and water regimes were not detected for the harvest index (p=0.093). There were also no significant differences among the two factors (p=0.730; p=0.807). In all treatments, the harvest index averaged 31%. Regarding the water use, it can be seen that the flooding treatment consumed considerably more water than other treatments, while the amount of water used in the drought condition and AWD was quite similar. In this research, the amount of water consumed was 4,824 for drought, 4,968 for AWD and 6,768 m^3 ha^{-1} for flooding. When compared, flooding consumed 26.6% more water than AWD, but the rice yield between these treatments was not much different. Likewise, CGIAR (2014) also mentioned in a report and Kumar and Rajitha (2019) in their studies that using AWD could save water up to 25%.

CONCLUSION

In this research, three different rice cultivars CAR 14, CAR 15, and CAR 16 were planted in three different water regimes, namely drought, AWD, and flooding, to find out their effects on rice growth and yield, as well as aiming to select the most suitable varieties. In the results, CAR 16 produced the greatest plant length among the experimented cultivars, but began to flower a bit late, when compared to other varieties. However, they had similar panicle length. CAR 15 and CAR 16 produced higher yield, regardless of the water regimes although the straw biomass and harvest index among the treatment were not different. In conclusion, drought conditions tend to affect total rice yield, while flooding and AWD were more favorable for rice plants. For drought tolerance, CAR 15 and 16 should be selected for cultivation. For flooded conditions, all of the varieties were suitable and for AWD, CAR 14 and CAR 15 were better.

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Research article

Applicability of Tank Model in Mid-Sized Catchments in Eastern Uganda

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Received 27 January 2020 Accepted 29 October 2020 (*Corresponding Author)

Abstract Long-term stream discharge data is indispensable in irrigation and drainage design. However, in Uganda, this data is poor and insufficient, limiting irrigation system design. Conversely, the rainfall monitoring network is denser than the river flow monitoring network. Therefore, we attempt to build a model that calculates river discharge from input of rainfall. In this study, the lumped parameter Tank Model was applied. The model was applied to the Namatala River catchment (155 km^2) in Eastern Uganda. The study sought to ascertain the applicability of a lumped parameter model to a mid-sized catchment. Specifically, the objectives were: 1) To calibrate the numerical values of Tank Model parameters, 2) To verify the Tank Model parameters. This Tank Model required daily rainfall, evapotranspiration and river discharge data during calibration. Data for years 2015 and 2016 was used for calibration and validation respectively. During calibration, Monte Carlo simulation was used to find the numerical values of 16 Tank Model parameters. The best performing calibration parameter set had Nash-Sutcliffe (*NS*) efficiencies of 0.608 and 0.257 in calibration and validation respectively. However, among the 2015 calibration parameter sets, the one with a calibration *NS* of 0.502 performed best in validation (*NS* = 0.526). Equifinality was observed during parameter calibration. By using Tank Model, simulated discharge was divided into its surface runoff, interflow and base flow components. Tank Model was adaptable to Namatala River catchment.

Keywords Equifinality, lumped model, Monte Carlo simulation, parameter, Tank Model

INTRODUCTION

To buttress the vulnerable agricultural systems in Uganda, the government plans to promote irrigation (MWE, 2013). Irrigation and drainage planning requires long-term observed hydro-meteorological data. However, Uganda has a scarcity of this data. Numerous Ugandan rivers are ungauged, and worse, only about 33% of installed water level gauging stations are operational (MWE, 2013). Comparatively, the state of rainfall monitoring is better than that of the hydrological monitoring. Further, Kobayashi et al. (2018) explored the accuracy of satellite rainfall observations and found their detection accuracy to be acceptable. Satellite observed rainfall data is therefore a promising source of rainfall data.

Since rainfall data is more readily available, it is attempted to build a hydrological model to calculate river discharge from inputs of rainfall. Tank Model (Sugawara, 1995) and TOPMODEL (Beven and Kirkby, 1979), are some of the successful hydrological models. Okiria et al. (2019) applied the semi-distributed TOPMODEL to the Atari River catchment in Eastern Uganda. In this study, an attempt will be made to represent the hydrological response of the Namatala River catchment (NRc) using Tank Model. Whereas TOPMODEL is semi-distributed, and has fewer parameters, it is comparatively complex, and separates the predicted hydrograph into only two components, i.e., surface runoff and subsurface flow. On the other hand, Tank Model is simpler and separates the predicted hydrograph into four components, *i.e*., surface runoff, inter flow, sub-base flow and base flow. A weakness of Tank Model is that it is a lumped parameter model, with many unknown parameters (16 parameters for a 4-tank Tank Model). Because it is lumped, it cannot represent the heterogeneity in catchment characteristics. And due to the many unknown parameters, a more pronounced equifinality is expected. This equifinality might be caused by the interdependence among parameters reported in Beven (1997).

Whereas Tank Model has been successful in the continuously wet soils in humid sub-tropical climates (Suryoputro et al., 2017; Xiong et al., 2009), its behaviour in tropical climates, with soils that undergo both wet and dry periods, is not widely documented. Onyutha (2016) applied Tank Model to the Blue Nile Basin in Ethiopia. In East Africa, Tank Model was applied to a catchment in Rwanda (JICA, 2014). To date, the authors have not found published evidence of the application of Tank Model in Uganda. Therefore, the novelty of this study is to pioneer the development of Tank Model for a catchment in Eastern Uganda.

Before hydrological models are applied to ungauged catchments, they require calibration and validation. Model calibration involves the determination of unknown parameters and their predictive performance. On the other hand, validation involves testing the predictive performance of the calibrated parameters in a period other than that of calibration. Being one of the well gauged catchments in Uganda, the NRc was chosen for the calibration of Tank Model.

The lumped parameter model assumption of a catchment scale homogeneous hydrological response is likely to fail for medium to large catchments. Therefore, the purpose of the study is to ascertain the applicability of a lumped parameter model (Tank Model) to mid-sized catchments in Eastern Uganda. The specific objectives are: 1) Calibration of Tank Model parameters; and 2) Validation of the model parameters. In so doing, we strive to build a Tank Model that successfully predicts daily stream discharge from inputs of daily rainfall and evapotranspiration.

METHODOLOGY

Study Area

The study area is the Namatala River catchment (NRc), a headwater catchment of Mt. Elgon in Eastern Uganda, with a drainage area of 155 km^2 at the stream gauging station. Its topography is comprised of mountainous areas from where the Namatala River originates and flows to the relatively flat plains. From ASTER GDEM, the difference in height between the lowest and the highest point is 1,262 m. Of the 155 km^2, 73% is agriculture, 24% is forest, 2% is built up areas and 1% is rangeland.

Under the Project on Irrigation Scheme Development in Central and Eastern Uganda (PISD) (JICA, 2017), hydro-meteorological monitoring equipment were set up in the NRc, *viz*., a mid-stream rain-gauge to detect catchment rainfall, a downstream meteorological station to measure evapotranspiration parameters and a water level logger at a control section of the Namatala River.

Tank Model Concept

One version of Tank Model comprises of four tanks laid out vertically in series, so named tanks 1, 2, 3 and 4. Rainfall is added to the topmost tank while evapotranspiration is subtracted from it. If tank 1 is empty, evapotranspiration is deducted from tank 2. If both tanks 1 and 2 are empty, then evapotranspiration is subtracted from tank 3 and so on. The storage tanks have side outlets, from which runoff flows. Side outlets of tanks 1,2,3 and 4 release surface runoff, interflow, sub-base flow and base flow respectively. Tanks 1,2 and 3 have bottom outlets as well, through which infiltration to a lower tank occurs. Tank Model is calibrated to determine the value of 16 unknown parameters, namely; A_1 (coefficient of top side out let of tank 1), A_2 (coefficient of lower side outlet of tank 1), B_1 (coefficient of side outlet of tank 2), C_1 (coefficient of side outlet of tank 3), D_1 (coefficient of side outlet of tank 4), A_0 (coefficient of bottom outlet of tank 1), B_0 (coefficient of bottom outlet of tank 2), C_0 (coefficient of bottom outlet of tank 3), AH_1 (height of top side outlet of tank 1), AH_2 (height of lower side outlet of tank 1), BH (height of side outlet of tank 2), CH (height of side outlet of tank 3), SA_0 (initial height of water in tank 1), SB_0 (initial height of water in tank 2), SC_0 (initial height of water in tank 3) and SD_0 (initial height of water in tank 4), as in Fig. 2. The simulated river discharge is the sum of runoff from all the side outlets. Details of Tank Model are in Sugawara (1995).

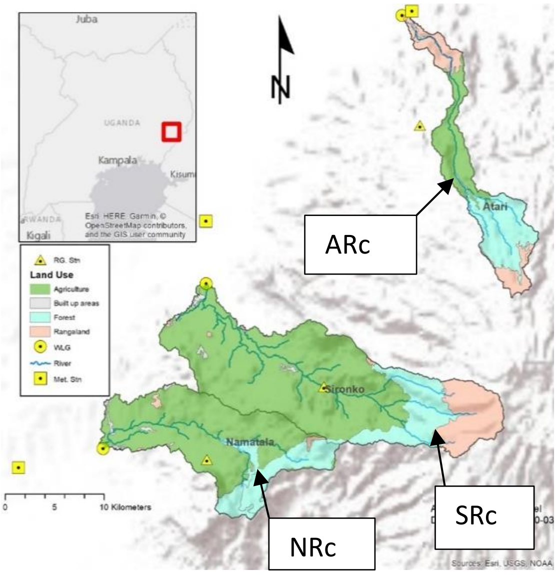

Fig. 1 Location of Namatala River catchment (NRc) relative to Atari River catchment (ARc) and Sironko River catchment (SRc)

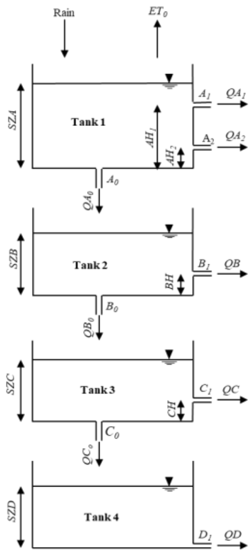

Fig. 2 Schematic of Tank Model

Computational Procedure of Tank Model

Evaluation of tank 1:

$$SA_t = SZA_t + R_t - ET_{0t} \tag{1}$$

SA_t is water depth in the tank during calculation (mm), SZA_t is water depth in the tank at the start and end of each time step calculation (mm), R is observed rainfall (mm/day), ET_{0t} is potential evapotranspiration (mm/day), and the subscript t is the time step of calculation (day).

$$QA_{xt} = \begin{cases} A_x \times (SZA - AH_x) \\ 0 \;\; for\; SZA < AH_x \end{cases} \tag{2}$$

QA_{xt} is runoff from side outlet (mm/day), A_x is discharge co-efficient of side outlet, AH_x is height of side outlet (mm), and subscript x is side outlet under consideration (1 or 2).

$$QA_{0t} = A_0 \times SA_t \tag{3}$$

QA_{0t} is infiltration from tank 1 to tank 2 (mm/day), A_0 is discharge co-efficient of tank 1 bottom outlet.

$$SZA_t = SA_t - QA_{1t} - QA_{2t} - QA_{0t} \tag{4}$$

Evaluation of tank 2:

$$SB_0 = \begin{cases} SZB_0 + QA_{0t} - ET_{0t} & \text{for day 1, and an empty tank 1} \\ SZB_0 + QA_{0t} & \text{for day 1 and non} - \text{empty tank 1} \end{cases} \quad (5)$$

SB_0 is water depth in the tank during calculation (mm), SZB_0 is water depth in the tank at the start and end of each time step calculation (mm).

$$SB_t = \begin{cases} SZB_t + QA_{0t} - ET_{0t} & \text{after day 1, and an empty tank 1} \\ SZB_t + QA_{0t} & \text{after day 1 and non} - \text{empty tank 1} \end{cases} \quad (6)$$

SB_t is water depth in tank during calculation (mm), SZB_t is water depth in the tank at the start and end of calculation (mm).

$$QB_{1t} = \begin{cases} B_1 \times (SB_t - BH) \\ 0 \ \text{ for } SB_t < BH \end{cases} \quad (7)$$

QB_{1t} is runoff from tank 2 side outlet (mm/day), B_1 is discharge co-efficient of tank 2 side outlet, BH is height of tank 2 side outlet (mm).

$$QB_{0t} = B_0 \times SB_t \quad (8)$$

QB_{0t} is infiltration (mm/day) from tank 2 to tank 3, B_0 is discharge coefficient of tank 2 bottom outlet.

$$SZB_t = SB_t - QB_{1t} - QB_{0t} \quad (9)$$

The calculations for tanks 3 and 4 follow the same logic as the calculations for tank 2. Also, these conditions must be met: $A_0 > B_0 > C_0$ and $0 > C > 1$ where C is discharge coefficient.

Evaluation of Parameter Predictive Power

Nash and Sutcliffe efficiency (*NS*), (Nash and Sutcliffe, 1970) and Root Mean Square Error (*RMSE*) are the indices for evaluating model efficiency as in Okiria et al. (2019).

Novel Concept for Managing Competing Parameter Sets

Calibration of model parameters is an uncertain process with uncertainty increasing with increasing number of unknown parameters. The Generalised Likelihood Uncertainty Estimation (GLUE) framework was developed to eliminate competing parameter sets (Beven, 1997). To augment this concept, the authors suggested another method to manage uncertainty, *i.e.*: 1) Use the competing parameter sets to simulate the hydrograph for a period outside the calibration period (verification of competing parameter sets). The parameters that perform poorly in validation are then rejected; 2) Plot hydrograph components predicted using non-rejected parameter sets and choose the most likely hydrograph based on the depiction of the shape of the base flow component, which is supposed to be fairly constant. The authors attempted to use 1) and 2) in combination, to eliminate competing parameter sets.

Data Requirement

The input data for Tank Model is rainfall (*R*), river discharge (*Q*) and evapotranspiration (ET_0).

Table 1 Tank Model input data

Purpose	Period	*R* (mm)	ET_0 (mm)	*Q* (mm)
Calibration	2015-Feb-27 to Oct-22 (238 days)	1,376	866	517
Validation	2016-Apr-27 to Dec-31(249 days)	1,004	921	467

RESULTS AND DISCUSSION

Like findings by Beven (1997), competing parameter sets were observed, making it impossible to identify with certainty the optimum parameter set for Tank Model.

Table 2 shows two parameter sets from the calibration in 2015 as well as their calibration and validation performances. During calibration, the best performing parameter set had an *NS* value of 0.608. However, during validation, its predictive power reduced to an *NS* of 0.257. On the other hand, the parameter set with the calibration *NS* of 0.502 had the best performance during validation, with a validation *NS* of 0.526. The difference between calibration and validation *NS* values could be evidence that parameter sets are dependent on rainfall characteristics as reported in Okiria *et al*. (2019). It can also be attributed to the obscurity in setting the initial condition during validation. Figure 3 shows the best performing Tank Model parameters. Based on the new method to manage uncertainty, the parameter set with calibration and validation *NS* of 0.608 and 0.257 respectively is preferred since it has a very good calibration *NS* and a sufficient validation *NS*, and it also yields a reasonable base flow curve – the classification of *NS* as good or sufficient is in Foglia et al. (2009).

Fig. 4 shows the observed and simulated hydrographs for 2015 during calibration while Fig.6 shows the observed and simulated hydrographs for 2016 during validation of 2015 parameters. In 2015, the trend of the simulated hydrograph was quite similar to that of the observed hydrograph. However, in 2016, the trends between observed and simulated hydrographs were less similar. The dissimilarity in 2016 could be attributed to input data error or in an ability of the model to accurately represent the rainfall-runoff response of 2016. In both years, majority of the peak discharges were underestimated. This could be attributed to under estimation of catchment rainfall and or the over estimation of evapotranspiration.

In Fig. 5 the components of the simulated hydrograph for 2015 during calibration are shown while Fig.7 shows the components of the simulated hydrograph for 2016 during validation by 2015 calibration parameters. The simulated discharge was separated into its surface runoff, inter flow, sub-surface flow and base flow components. Surface runoff was dominant during the rainy period while base flow was the dominant component in the dry period. In addition, base flow was generally stable and showed delayed response to rainfall.

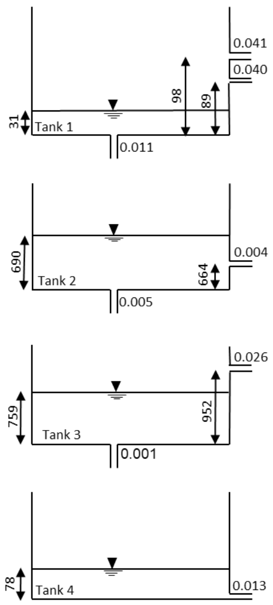

Fig. 3 Best performing parameters for Namatala River catchment (NRc) calibrated in 2015

Table 2 Best parameter set from calibration in 2015 and their validation performance in 2016

A_1	A_2	A_0	B_1	B_0	C_1	C_0	D_1	$SA_{initial}$	$SB_{initial}$	$SC_{initial}$	$SD_{initial}$	AH_1	AH_2	BH	CH	NS_c	$RMSE_c$	NS_v	$RMSE_v$
0.041	0.040	0.011	0.004	0.005	0.026	0.001	0.013	31	690	759	78	98	89	664	952	0.608	1.141	0.257	1.387
0.028	0.008	0.010	0.002	0.006	0.069	0.004	0.005	124	100	528	51	63	7	55	502	0.502	1.285	0.526	1.108

Note: NS_c and $RMSE_c$ are NS and RMSE values respectively during calibration, and NS_v and $RMSE_v$ are NS and RMSE values respectively during validation

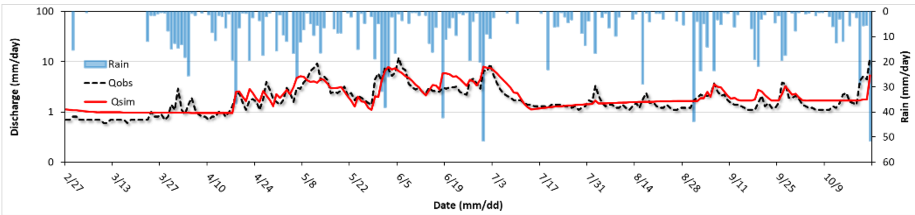

Fig. 4 Observed and simulated hydrograph for best parameter of 2015

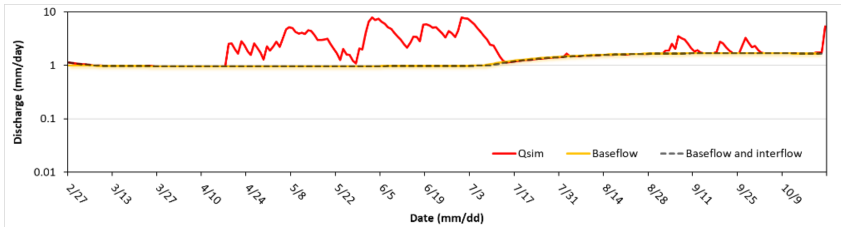

Fig. 5 Hydrograph components for 2015 during calibration

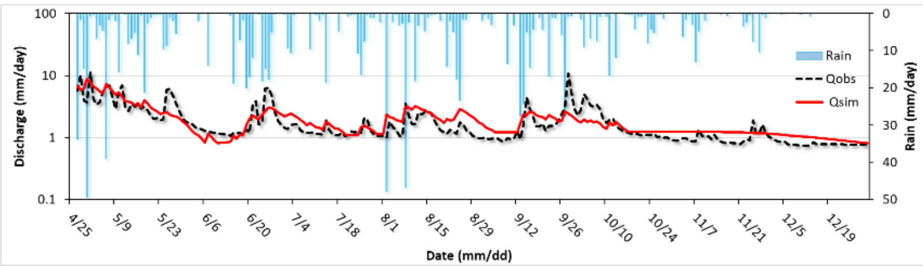

Fig. 6 2016 Observed and simulated hydrograph using 2015 parameters

Note: Q_{obs} is observed discharge, Q_{sim} is simulated discharge

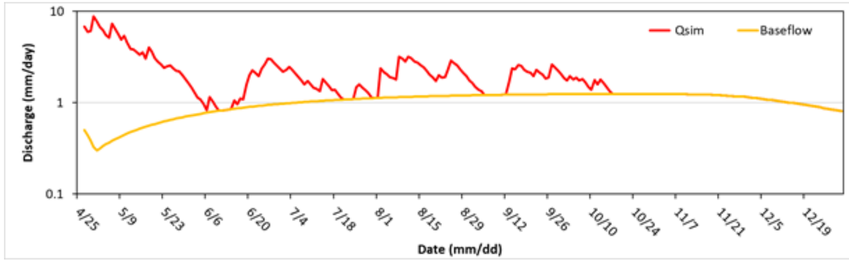

Fig. 7 2016 Hydrograph components during validation by 2015

CONCLUSION

Tank Model was successfully applied to the Namatala River catchment to simulate its rainfall-runoff process. However, due to equifinality, the model should be applied with caution. In addition, more research needs to be done to better understand the shortcomings of the model. Acquisition of finer spatial resolution input data is recommended. Studies on other catchments in Eastern Uganda could be useful in confirming the applicability of lumped parameter models.

ACKNOWLEDGEMENTS

The study was done during graduate studies at Tokyo University of Agriculture, Tokyo, Japan, courtesy of scholarship from Japan International Co-operation Agency (JICA), Japan. It goes without thanking NTC-International Co., Ltd for the opportunity to advance my career.

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Research article

Effect of Excavated Small Drainage Channels on Desalinization in Northeastern Thailand

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Received 27 January 2020 Accepted 29 October 2020 (*Corresponding Author)

Abstract Salt-affected soil is a serious problem in Thailand, and most of this soil is found in the northeastern part of Thailand. The total area of saline land in Northeast Thailand is 2.85 million ha, which accounts for about 17% of this area (Land Development Department,2011). The objective of this study is to evaluate the effect of desalinization by digging drainage channels in salt-affected fields during rainfall. The study was conducted on a high salinity field in Khon Kaen, Thailand. In April 2019, the main drainage channel of a depth of 1 m, was excavated across the center of the field in the south-to-north direction. Additionally, side ditches were installed along the circumference of the west part of the field. We constructed drainage channels to promote field drainage and effectively induce salt leaching with rainfall. Field observations were conducted eight times, especially in the rainy season, from August 2018 to September 2019. Soil apparent electricity conductivity (EC_a) was measured using an electromagnetic induction meter in three distinct depth ranges, i.e., 0.375 m, 0.75 m, and 1.5 m, from the soil surface. Soil salinity was represented as contour maps based on spatially interpolated data and spatial distribution and temporal changes were analyzed. The soil EC_a in the field gradually increased from upstream to downstream. Moreover, it was higher near the surface and lower deep underground. By comparing the soil salinity observed in the later part of the rainy season in both the years, EC_a was observed to have decreased by 20% from August 2018 to September 2019. The EC_a values at depths of 0.375 m and 0.75 m in the west part of the field, which had side ditches, were significantly lower than those in the east part of the field two months after the drainage channels were constructed. However, a contrary result was obtained after a heavy flood. These results indicate that drainage channels contribute to salt leaching with rainfall. Our results suggested that excavating drainage channels could effectively reduce soil salinity during the rainy season under good drainage conditions.

Keywords saline soil, desalinization, leaching, drainage, electric conductivity

INTRODUCTION

Soil salinization is a major global problem limiting crop productivity. Urgency exists to prevent and improve soil salinization for sustainable agriculture. Salt-affected soils are found in more than 100 countries and typically occur in arid and semi-arid regions (Rengasamy, 2006). The Food and Agriculture Organization (FAO) estimated that globally the total area of salt-affected soils is 831 million ha. Salt-affected soils have also been developing in monsoon zones in South and Southeast Asia. Thailand is one of the countries where improving saline soil is an urgent need.

Salt-affected soil is a serious problem in Thailand, and most of this soil is found in the northeastern part of Thailand. The total area of saline land in Northeast Thailand is 2.85 million ha, which accounts for about 17% of this area (Land Development Department,2011). The potential source of salt in this area is halite in the Maha Sarakham Formation (Wongsomsak, 1986). Apart from its geographical environment, human activities such as deforestation associated with agricultural development and traditional salt making have contributed to accelerating soil salinization (Arunin et al., 2015; Löffler et al., 1988). People in this area are impoverished because of low agricultural productivity resulting from infertile land and salt-affected soil. To combat this problem, the mechanism of reducing soil salinization was elucidated, and studies using various approaches to mitigate soil salinity have been attempted from more than 30 years (Miura et al., 1991; Patcharapreecha et al., 1990). However, the people in this area are still suffering from salt-affected soil. In other words, these desalinization approaches do not have widespread application. Some farmers abandoned their farmlands and gave up farming because with salt-affected soil being formed opportunities to expand farmlands did not exist. To enhance agricultural development and encourage the agricultural community, ameliorating salt-affected soil and develop them for farmlands are necessary.

One of the common strategies for combating salt-affected soil is leaching salts from upper to lower soil depths (Qadir et al., 2000). To effectively facilitate the leaching process, an open or subsurface drainage system is commonly adopted (Ritzema, 2016). This approach is generally considered to decrease the saline groundwater table and removes leaching water from the soil profile. However, installing a drainage system to control salinity is a costly proposition (Datta et al., 2000) and raises concerns about high salinity drainage water. In this study, a conceptual model of the Cascading Salt Using System (CSUS) (Kume et al., 2019a, 2019b) has been considered. This model focuses on water and salt flow and proposes to reconsider salt as a useful resource. In this system, different types of crop cultivation are practiced considering feasible salinity levels. For instance, rice paddies can be cultivated upstream and halophilic crops can be cultivated downstream where the salt concentration is higher. Moreover, table salt can be made from high salinity discharge water that is observed at the lowest downstream level. Production of halophilic crops and salt are expected to raise farmers' income.

This study is the first step of the CSUS project to decrease soil salinity in a large salt-affected field by excavating small drainage channels. Open drainage channels that are currently installed in the field considered in this study are not aimed towards completely removing salts from the field and mitigating soil salinity for low salt-affected levels. These drainage channels are not large; therefore, they are inexpensive and easy to install for farmers. The objective of this study is to evaluate the effect of desalinization by digging small drainage channels.

METHODOLOGY

Study Area

The study was conducted in a high saline soil field in Ban Phai district (16°03′ N, 102°69′ E), Khon Kaen (Fig. 1). This area experiences a tropical savanna climate (Köppen climate classification *Aw*) with marked alternation of the rainy season (from May to October) and dry season (from November to April). The range of annual precipitation is from 1,100 mm to 1,500 mm, and the mean annual temperature is 27°C. The overview of the field under consideration in this study is shown in Fig. 2. This field with an area of approximately 0.8 ha has no vegetation because of high soil salinity; however, the upper area of the field is used for rice cultivation in the rainy season. For improving the saline soil in the field, a strategy to install small drainage channels was adopted by the Land Development Department. The drainage channels are expected to promote field drainage and induce salt leaching with rainfall. In April 2019, a main drainage channel with a 1-m depth was excavated across the center of the field in the south-to-north direction. Additionally, side ditches with a depth of 1 m were installed along the circumference of the west part of the field. The gradient of the drainage channels was approximately 2.5 / 1000. The water flow is in the direction of the arrow in Fig. 2. The drainage ultimately runs downstream through the hume pipe under the road lying on the north side of the field. Daily precipitation data (Fig.3) in the urban area in Khon Kaen was obtained from the Japan Meteorological Agency website.

Field Survey

Soil salinity was measured using an electromagnetic induction meter, EM38-MK2 (Geonics Limited), which measured apparent soil electrical conductivity (EC_a) in units of millisiemens per meter (mS/m). This instrument has two receiver coils, each of which, are separated by 1 m and 0.5 m from the transmitter providing data from effective depth ranges of 1.5 m and 0.75 m, respectively, when positioned in the vertical dipole orientation, and 0.75 m and 0.375 m respectively, when positioned in the horizontal dipole orientation. We measured soil salinity in vertical and horizontal dipole orientation in 1-m intercoil spacing as well as in horizontal dipole orientation in 0.5-m intercoil spacing, thereby obtaining three distinct depth ranges of data, i.e., 0.375 m, 0.75 m and 1.5 m, from the soil surface. The measurement interval was about 10 m. Field observations were conducted eight times, especially in the rainy season, from August 2018 to September 2019 and three times in the dry season, i.e., February, March, and December 2019.

Fig. 1 Location of the study area

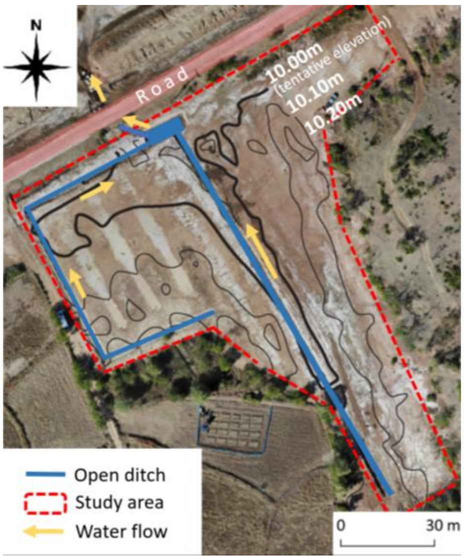

Fig. 2 Overview of the study area

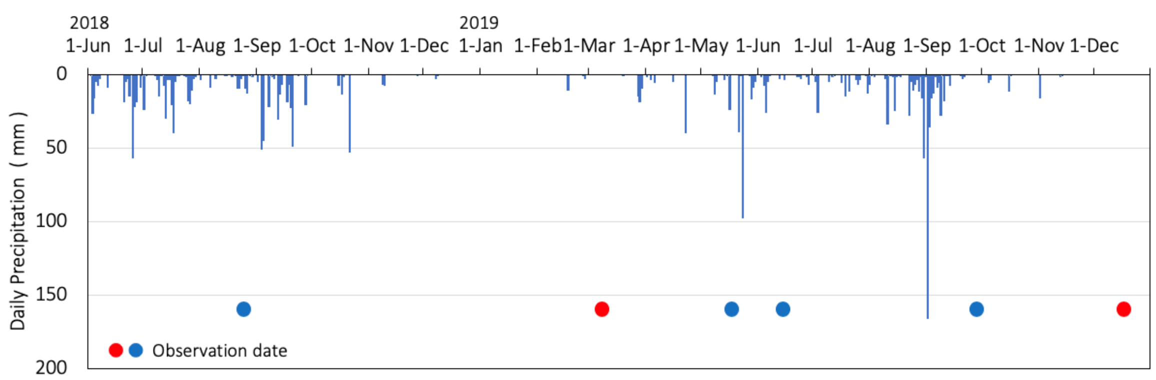

Fig. 3 Daily precipitation in Khon Kaen

Data Analysis

The soil EC_a data obtained from EM38-MK2 in the field were used as a database for mapping the distribution of the field soil salinity. They were interpolated using the Inverse Distance Weighted method with 1-m intervals and represented as contour maps to analyze spatial and temporal distributions. Because EC_a measured using EM38-MK2 affects soil moisture, data under similar groundwater level conditions were used for comparing soil salinity changes. The observation dates of the data used for this analysis are shown in Fig. 3 in blue (in the rainy season) and red (in the dry season) dots. Moreover, averages of field EC_a were calculated based on the interpolated data.

RESULTS AND DISCUSSION

Spatial Distribution and Temporal Changes of Soil Salinity in the Field

Soil salinity in the field was represented as contour maps. Fig. 4 shows field soil salinity at a depth range of 0.75 m in August 2018 as well as September 2019 before and after excavating the drainage channels. The soil EC_a gradually increased from upstream to downstream in the field associated with water flow. Identical results were obtained at the other measurement dates as well as the other two depths, i.e., 0.375 m and 1.5 m. Comparison of both the figures showed that the soil EC_a in September 2019 was lower than that in August 2018 in the entire field. Table 1 shows the average EC_a in the field at three different depth under similar groundwater level conditions in the rainy season. The soil EC_a has a tendency to be higher near the soil surface and lower deep underground. In the rainy season in 2019, the soil EC_a gradually decreased from the early part of the rainy season in May to the end of the rainy season September. The specific decrease was from 1398 mS/m to1290 mS/m, 1367 mS/m to 1205 mS/m, and from 1106 mS/m to 944 mS/m at the depths of 0.375 m, 0.75 m, and 1.5 m, respectively. The total rainfall in this period was 655.4 mm. Leaching is considered to have progressed during rainfall.

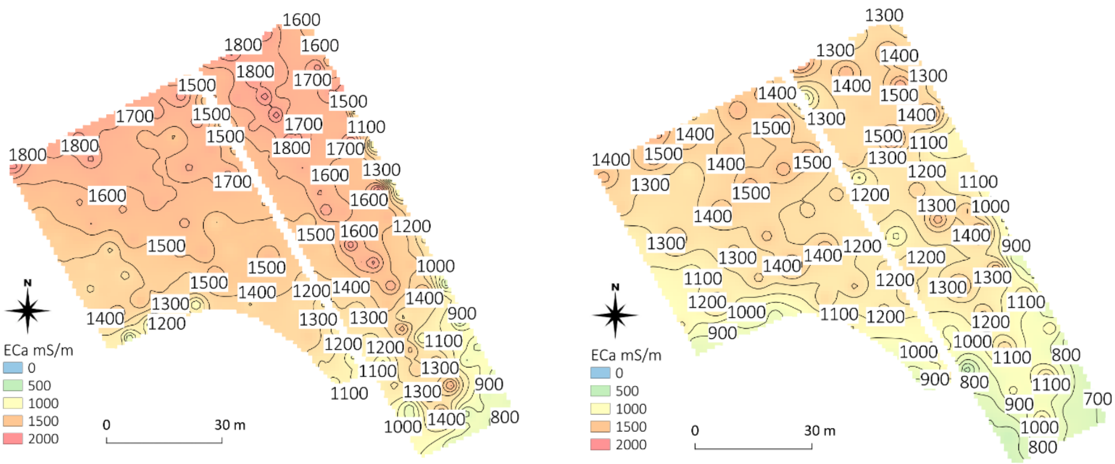

Fig. 4 Distribution of soil salinity in the field at a depth of 0.75 m before the installation of drainage (left) and after the installation of drainage (right) in the rainy season

Moreover, the soil EC_a decreased after excavated drainage channels. The soil EC_a in September 2019 was 20% lower than that in August 2018, even though both these periods were the later part of the rainy season. This result indicates that installing drainage channels promotes salt leaching by rainfall in the rainy season.

Additionally, soil salinity was compared before and after excavating drainage channels in the dry season. Fig.5 shows field soil salinity at a depth range of 0.75 m in March 2019 as well as December 2019 before and after excavating the drainage channels. The averages of the soil EC_a in the dry season are also shown in Table 1. After installing drainage, the soil EC_a in December 2019 was lower than that in March 2019, before installing drainage. Additionally, Fig. 5 clearly shows that the soil EC_a decreases after excavating the drainage channels. Miura, K., and Subhasaram, T. (1991) indicated that accumulation of salt on the soil surface in the dry season was associated with the elevation of the groundwater table to a critical level at the end of the rainy season and continuity of capillary pores above the groundwater level. In this study, comparing the soil EC_a under similar groundwater level conditions, this continuity of capillary pores should be prevented due to the groundwater level after excavating the drainage channels was relatively lower than before that. This result agrees with the earlier result in the rainy season and supports the assumption that drainage channels effectively function as a desalinization method.

Table 1 Averages of field EC_a (mS/m) at three depths

Depth (m)	Rainy season				Dry season	
	August 2018	May 2019	June 2019	September 2019	March 2019	December 2019
0.375	-	1398	1277	1290	1133	944
0.75	1470	1367	1286	1205	1109	954
1.5	1155	1106	1077	944	947	840

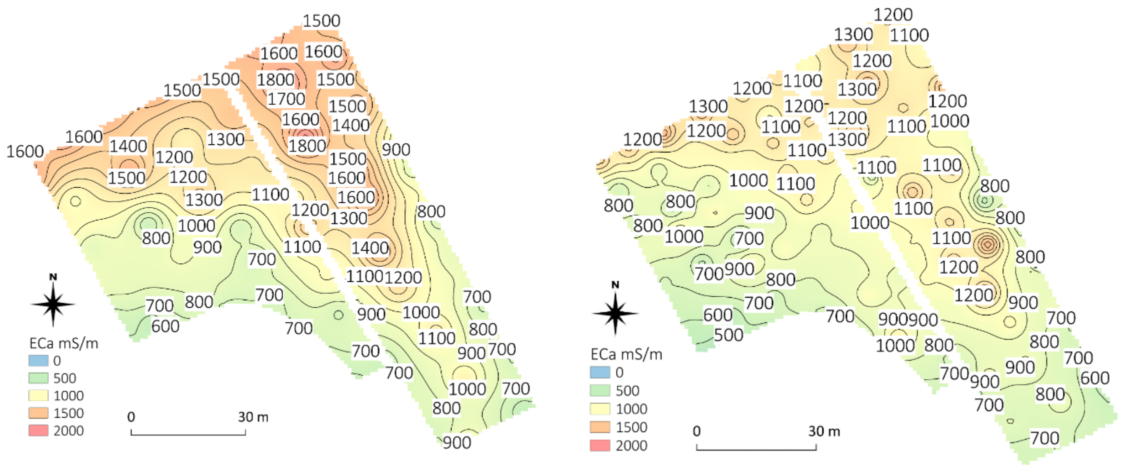

Fig. 5 Distribution of soil salinity in the field at a depth of 0.75 m before installing drainage (left) and after installing drainage (right) in the dry season

Comparison of Salinity Changes under Different Drainage Intensity

In the field under consideration in this study, the intention of drainage channels is different between the west and east parts of the field. The west part of the field is surrounded by a side ditch; therefore, drainage and leaching efficiency in the west part are expected to be better than those in the east part of the field. To compare the desalinization effect on both the sides, we compared the soil EC_a in the west part to that in the east part of the field. Fig. 6 shows the average soil EC_a at a depth of 0.75 m in the west and east parts of the field. The error bars show the standard deviation. The average of the soil EC_a before the introduction of drainage was higher in the west part of the field than that in the east part of the field, i.e., 1498 mS/m and 1442 mS/m, respectively. However, the soil EC_a was lower in the west part than that in the east part of the field two months after the drainage installation, i.e., June 2019. The average field EC_a was 1205 mS/m and 1340 mS/m in the west and the east part of the field, respectively. Moreover, significant difference (Mann-Whitney U test; $p < 0.01$) with the same result was obtained at a depth of 0.375 m, while no significant difference between the west and the east parts of the field was observed at a depth of 1.5 m. This result indicates that intensive drainage enhanced salt leaching in the west part of the field. However, in September 2019, the soil EC_a in the west part was higher than in the east part of the field. Before measurement in September 2019, this area experienced heavy flooding, and some parts of the drainage system were broken; therefore, excess water in the field could not be immediately removed. This may have caused higher salinity in the west part of the field in September 2019. In December 2019 after the flood, the same tendency was observed as that before the flood even though it was the dry season.

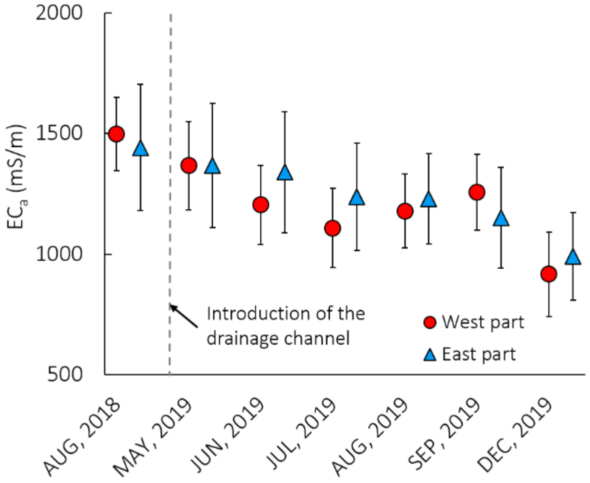

Fig. 6 Averages of the soil EC_a in the west and the east part of the field at a depth of 0.75 m

Fig. 7 Divided five areas depend on the distance from drainage channels

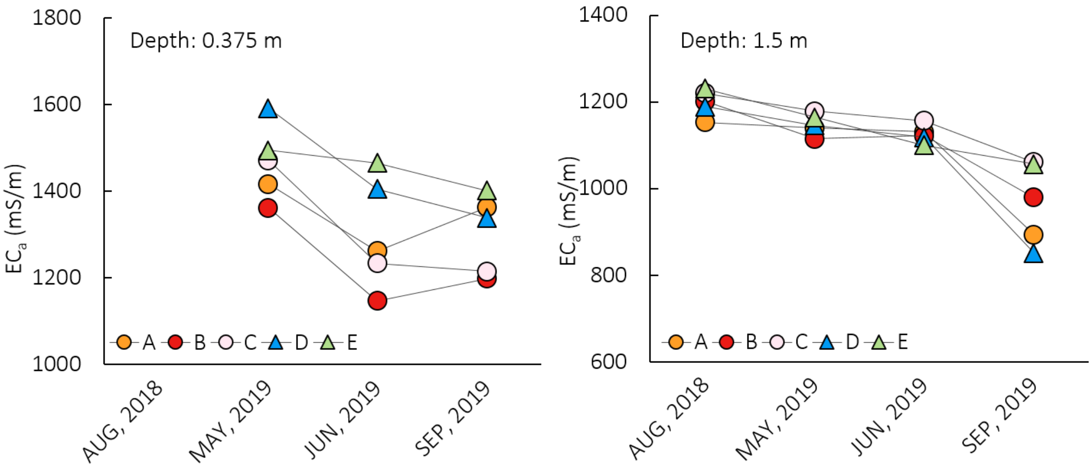

Fig. 8 Changes of the average EC_a in five areas in the rainy season

Subsequently, we compared the soil EC_a near the drainage channels and far from them to conduct a detailed examination of the field salinity changes. The field was divided into five areas (Fig. 7) based on the distance from the drainage channels, i.e., the area 0-10 m from the main drainage channel in the west part of the field (area A), the area 0-10 m from the side ditch in the west part of the field (area B), the middle area of the west part of the field (area C), the area 0-10 m from the main drainage channel in the east part of the filed (area D), and the area 10-25 m from the main drainage channel in the east part of the field (area E). We compared the values of the soil EC_a in the five areas at three depths during the rainy season under a similar groundwater level condition. Fig. 8 shows the average soil EC_a in each of the five areas at depths of 0.375 m and 1.5 m as an example. The soil EC_a generally decreased in all the areas and at all the depths from August 2018 to June 2019. However, in September 2019, after the flood, the soil EC_a suddenly increased in areas A and B at a depth of 0.375 m, while it slightly decreased in area C, which was surrounded by A and B,. This result indicates that salt was supplied from the soil surface layer in C to the A and B areas. Alternatively, this may suggest that salt reaccumulated from the drainage water after the flood. Conversely, at a depth of 1.5 m, the soil EC_a in areas A, B, and D near the drainage channel, considerably decreased in September 2019 in contrast with small changes before that. The drainage and leaching effect was considered to be less at a depth of 1.5 m because the groundwater level was over 1.5 m in the ordinarily rainy season, but the depth of the excavated drainage channels was 1.0 m. However, the groundwater level in the field was low in July and August 2019 because low rainfall was experience during this period. Therefore, a large amount of rainfall caused by the flood infiltrated deep underground in an instant and this made the salt leach away, especially from near the drainage channel and deep underground. These results indicate that drainage channels contribute to salt leaching during rainfall and drainage systems operating in a satisfactory manner are important for desalinization.

CONCLUSION

We evaluated the effect of small drainage channels during rainfall on desalinization in the high salinity field in Khon Kaen, Thailand by measuring field soil EC_a using an electromagnetic induction meter. After analyzing the spatial distribution and temporal changes of the field soil salinity, we found the following results. The soil EC_a gradually increased in the field from upstream to downstream. The soil EC_a was higher near the surface and lower deep underground. In 2019, the soil EC_a gradually decreased from the early part rainy season to the end of the rainy season. By comparing the soil salinity before and after excavating the drainage channels in the same season, the soil EC_a was observed to have decreased after drainage installation. Moreover, the soil EC_a in the west part of the field, where drainage was more intensive, was significantly lower than that in the east part of the field two months after the drainage channels were constructed. However, later in the rainy season in 2019, the value of the soil EC_a in the west part of the field was higher than that in the east part of the field. The drainage channels were considered to have not worked well after the heavy flood. The same holds true of the result obtained by comparing the EC_a changes based on the distance of the drainage channels. Our results suggest that the excavated drainage channels can effectively reduce soil salinity during the rainy season. Overall, the desalinization effect could be observed in the field soil EC_a throughout the year. Additionally, desalinization is assumed to continue to progress by repairing the drainage channels.

It was estimated that heavy flood in September 2019 would be equivalent to once in 50 years scale from local interviews. Due to such heavy flood, several collapses of the channel slope, sedimentation in the channel, and damage to the Hume concrete pipe at the most downstream point occurred. In order to restore the drainage function and leaching effect, it is necessary to repair them urgently.

ACKNOWLEDGEMENT

This work was supported by Grant-in-Aid for Scientific Research (KAKENHI; No.17H04630) (B) from the Japan Society for the Promotion of Science (JSPS) and The Mitsui & Co. Environment Fund (Grant No. R17-0039).

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Research article

Farmer’s Perception of Ecosystem Services for Lowland Rice Cropping Systems in Battambang Province, Northwest of Cambodia

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Received 25 January 2020 Accepted 2 November 2020 (*Corresponding Author)

Abstract Rice is significant in Cambodian food security. The main cultivated area is in central plain and floodplain of Tonle Sap Lake (TSL). TSL provides importantly both provisioning and regulating services to rice cultivations in its floodplain such natural flood for irrigation, soil fertility from sediment and aquatics animals specifically fish and snakes which regulated and improve the rice cropping system naturally. However, changes of the Mekong River (flood pulse) and climate change impact on changes of rice cropping systems (RCS) observed recently. The objective of the study aims at carrying out farmer’s perception on ecosystem services (ES) in comparison with two sites of Low-water-land (LWL) and middle-water-land (MWL) in Sangkae district, Battambang province. An agrarian system analysis and diagnosis method applied for whole implementation with 120 rice farmers for this survey. Flood-pulse of TSL have change to lower and lower which led some part of floodplain became infertility, so farmers have changed their traditional rice cropping systems (floating rice and long-term rice) to high-yield rice; shifted from traditional techniques to modern systems by adopting new innovations, inputs and technology, chemical fertiliser and modern machineries. Nevertheless, from our study, the new rice cropping systems seem to be less sustainable, inadequate use of new technologies or inputs in the study areas. Rice cropping systems in MWL is more profitable than LML site. Farmers in both sites are aware of the ecosystem services provided by TSL, but not all of them perceived the same importance among the RCS because of agroecosystem differentiation. The poor farmers, who lived in and closer to the TSL basin relied the most on traditional rice; floating and long-term rice, were vulnerable to food insecurity and insufficient household’s income, changes of the ecosystem services in their regions. They reported the ES are more importance to their RCS than other medium and large farmers. Adaptive RCS and irrigation system should promote corresponding to the dynamic changes, ecosystems of Tonle Sap Lake.

Keywords rice cropping system, agrarian system and diagnosis, ecosystem services, perception, economic analysis, Tonle Sap Lake

INTRODUCTION

Tonle Sap lake (TSL) is known as a complex ecosystem, which provides a substantial hydrological, biological, nutritional, cultural value and the productive operations as natural floodwater reservoir in the lower Mekong region offering flood protection and assuring dry season flow to the Mekong Delta (Arias et al., 2014; Kummu et al., 2014). The TSL floodplain system plays a critical role not only in providing necessary water resources and other environmental services for the entire country, but it also represents a global biodiversity hotspot supporting the remarkable productions of fishery and agriculture, mainly rice (Keskinen et al., 2013).

The lowland areas are largely cultivated in TSL floodplain, which accounts for almost 90% of the total rice cultivation fields as well as for 77% of total rice production (Chea, 2015; MAFF, 2016). Particularly RCS are enormously dependent on the natural resources provisioning. Battambang province is the major producer of rice called "rice bowl" located in northwest of Cambodia, where more than 70% of the population depend on agriculture as their main job and almost half of them cultivate rice (provincial department of planning, 2016). However, the extreme flooding occurred which damaged more than one tenth of rice cultivated area in 2011 in the country, but the total areas of rice affected by these floods reached more than 30% in this province, while damages in Sangkae district itself represented 70% of the total cultivated area (Kamoshita and Ouk, 2015). With these changes especially flood pulse of TSL, farmers have changed their RCS by adapting new innovations and technologies in the purpose of increasing their rice production. In floodplain areas of TSL, floating rice (FR) or long-term rice (LTR) areas dramatically shifted to high-yield rice, particularly EWSR and/or RR practices (Keskinen et al., 2013).

OBJECTIVES

The overall objective of this study aims at understanding farmer's perception on ecosystem services (ES) in comparison with two sites of LWL and MWL in Sangkae district, Battambang province with respect to recent dynamics in TSL floodplain ecosystems.

Based on the interactions of these changes of TSL ecosystem sand RCS, the study discusses on the advantages and disadvantages of the changes in RCS as well as to document the perception of ES of TSL affecting the livelihood of households in different agroecosystems. Moreover, there are still lack of scientific studies on such topic from Cambodia which would deeply analyse the changes of agricultural land-use systems of RCS in the floodplains in/around TSL whereas the ES of TSL altered by the changes of its flood pulse. The study proposes to conduct a research on these interactions between ES of TSL and RCS in lowland area in Battambang province.

The limitation of the study did not access to measure economic comparation neither between *RCS in both MWL and MWL, nor the* household's livelihood diversity provided by provisioning and regulating services of ES from TSL

METHODOLOGY

Agrarian System Overview

The study was adopted agrarian system concept in order to achieve the objective of the study. This is an all-encompassing concept, capable of making sense of agricultural and livelihood activities at a regional scale in a way that accounts for both ecological and socio-economic dimensions (Cochet, 2012). The historical changes study helps to identify and understand the main dynamics of differentiation among farming families and thus help define current farming systems (Barral et al., 2012).

Sample Selection and Data Collection

120 rice producing farmers (60 farmers from each site) were randomly selected in both different agro-ecological systems in Sangkae district. Baset, Oumuni and Rorkar in Middle-water-land (MWL) site, Samdach, Svay Sar, and Boeng Tuem from low-water-land (LWL) site.

Data Analyses

SPSS version 20 (Social Package for Social Sciences) was performed by specific tools basically descriptive statistic, such as frequencies, means and standard deviations. Likert scale, a psychometric response scale primarily used in questionnaires to obtain participant's preferences or degree of agreement with a statement or set of statements, was also used. The order scaling was set as 4 levels scoring from 1 to 4 which represents from ―Strongly agree‖ to ―Disagree‖ (1=strongly agree, 2=agree, 3= somewhat disagree, 4= disagree) while the scoring from 1 to 6 representing from ―Strongly decrease‖ to ―Don't know‖ (1=strongly decrease, 2=somewhat decrease, 3=the same, 4=strongly increase, 5=somewhat increase and 6=don't know), and other scoring for awareness was from 1 to 4 (1=strongly aware, 2=aware, 3=somewhat aware, 4=not aware).

Study Area

The study was conducted at floodplain areas in Sangkae districts of Battambang province. The Fig**.** 1 visualised the layout and location in red of TSL in Cambodia. The hydrological regime of this province supports an unnoticeable support to national economic development contribution of Cambodia by providing a wide range of ecosystems such as high biodiversity and productivity, mainly fish, plant communities, and wildlife. Almost half of the Cambodian population uses resources of TSL (Arias et al., 2014).

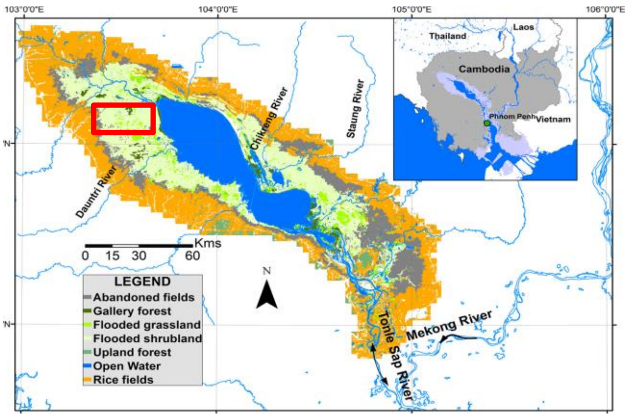
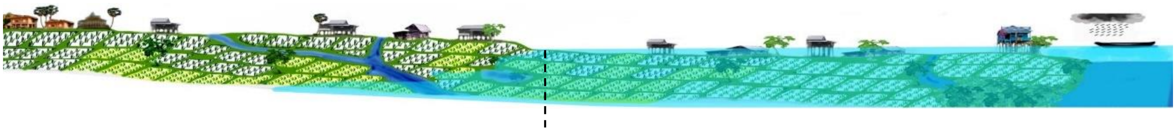


Fig. 1 Map of Cambodia and study area (Arias et al. 2014)

Two Ago-ecological zones of the Sangkae distinct were selected for this study (Fig. 2), the This area from 0 -1 m unless there is flooding. Agricultural land is cultivated RCS such as long-term rice (LTR), early season rice (ESR), and dry season rice (DSR). There are not many fruit trees or vegetable grown in this area. There are available supplementary irrigation systems in this zone, which suitable for cultivating short-term RCS.



Zone 2: Middle-water- land or middle field | Zone 1: Low-water-land or low field

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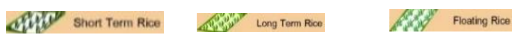

Fig. 2 Landscape during wet season (November - April)

RESULTS AND DISCUSSION

Rice Cropping Practices in Two-zones

Fig. 3 shows rice cropping systems cultivated in low-water land and middle-water land. Only floating rice (FL) is existing in LWL while there is no any farmers in MWL cultivated this rice cropping system.

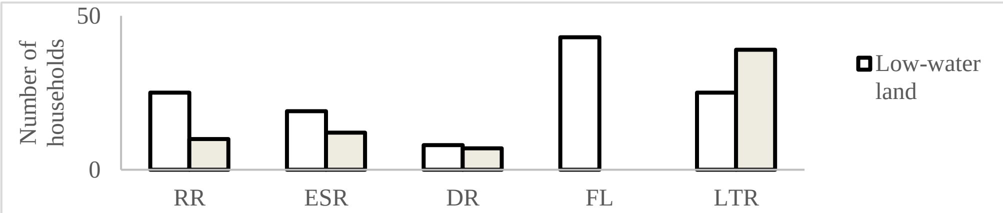

Fig. 3 Rice cropping systems in different agroecology

As a result, majority of farmers (>60%) in both sides have adopted this innovation by changing their old RCS, which practised with traditional techniques and mainly relied on natural resources provisioning, to the new RCS which confirmed by keskinen (2013). Farmers have low adaptive capacity while the climate and ES (flood pulse) variability have occurred in their areas which similar to the studies rainfed upland in Cambodia (Yusf and Francisco, 2009). Insufficient supplementary irrigation systems and depending on unreliable rainfalls and floodwater from TSL led to low productivity improvement while they have shifted to cultivate high-yield RCS in their areas which consistent with Sophea's study (2012).

Farmer's Perceptions of Ecosystem Services

Most of the farmers in both areas have similar perceptions of ES such as floodwater, wildlife, fish and forest. They perceived that those ES dramatically declined and changed. The amount of fish was indicated by more than 50% of farmers in the MWL as strongly decrease while 60% in the LWL. On the contrary, among the interviewed farmers had a different opinion of floodwater. They have mentioned that floodwater was strongly increased which more than 5% of them in both areas perceived while more than 2% of farmers in the MWL was found somewhat increase as shown in Fig. 4.

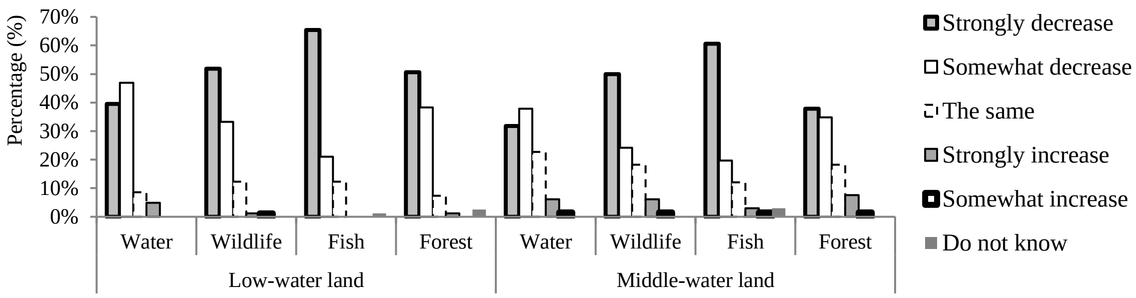

Fig. 4 Farmer's perceptions of ES changed in TSL

FR cropping system was, traditional system, required low cost of production compared to high-yield RCS. Additionally, farmers exercised this RCS with lower labour and cost of inputs, farmers did not apply chemical fertilisers and obtained approximately 900kg/ha. Farmers practice FR for mainly household's consumption which similar to Sarkkula et al. (2003), who stated that FR is significant for the poorest households on floodplain area due to its cost-efficiency. Therefore, the study found that farmers perceive that ES from TSL not only the water for their RCS, but also provided other fishy research for their livelihood system. The result of analysis indicated that the farmers in LWL valued the ES more importantly to the resources from TLS rather than the farmers in MWL site. From this over-view, the study assumes that farmers who lived in and closer to the TSL basin are aware of and depended directly on the ES of TSL.

Farmer's Awareness of Ecosystem Services

Farmers provided different information of awareness evaluation as shown in Fig. 5. The respondents in the LWL is higher than who in the MWL, 80% of farmers in the LWL aware the ES in their RCS annually while 60% in the MWL. In contrast, 40% of farmers in the MWL are not aware ES while 20% in the LWL. Additionally, farmers provided their level of awareness on four specific ES such as water, wildlife, fish, and forest contributed in their RCS.

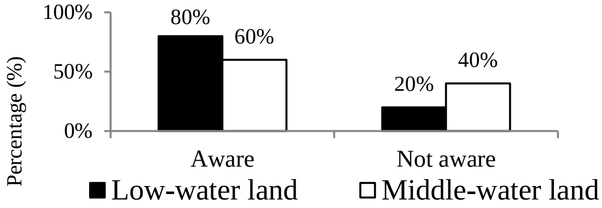

Fig. 5 Farmer's awareness of ES for rice cropping systems in both sites

The Importance of Ecosystem Services

Figure 6 shows the farmer's perceptions of the importance of ES in TSL for their RCS. As the results, more than 80% of local farmers show that the ES are necessary for their RCS particularly floodwater. Meanwhile, 7% of farmers in LWL mentioned not all of the ES are important while 2% of farmers in the MWL also mentioned. Additionally, among those farmers,10% of farmers in LWL and 17% in the MWL, also did not know whether these ES are important or not.

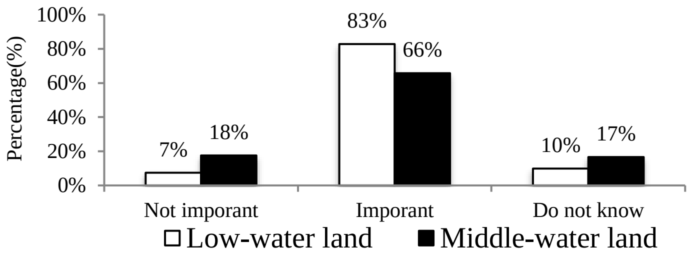

Fig. 6 Farmers' perceptions of the importance of ES for rice cropping systems

Most of the households in the both agro-ecosystems were aware of a wide range of ES provisioning from TSL for their RCS such as freshwater, wildlife, flooded forest, and fish. This awareness was higher among the farmers from LWL with 80%, compared to 60% in MWL, respectively. However, both values were lower compare to 90% observed in Nigeria (Zhang et al., 2016). It explicitly explained that farmers in the LWL might be closely interacted and depended on the ES from TSL for their RCS while farmers in the MWL did not which relatively similar to a study conducted in Philippines (Lasco et al. 2016) and main areas of European grasslands (Lamargue et al. 2011).

Correspondents in the LWL were more likely to be aware the causes of changing while farmers in the MWL were not widely aware. The linkages between their livelihood and ES in TSL also might highlight their different perceptions of ES. Due to the LWL located very closed to TSL, most of them actively and directly relied on those ES which led them to well recognising the causes of changes.

CONCLUSION

Land-use systems in floodplain of Tonle Sap Lake (TSL) were changed resulting particularly in vast deforestation and replacing traditional rice varieties practices in past decades, then to modern rice cropping systems mainly for the household's improvement and Cambodian country's economy. Such changes also affected the TSL'ES and profitability of particular systems. ES variation affected the households' livelihood particularly the poorest households in the floodplains. Changing of the RCS provided highly negative impacts on ecosystems in TSL, using high chemical fertilisers, pesticides and herbicides among inputs. Farmers were more vulnerable and prone to high risk for their RCS due to low adaptive capacity, lack of supplementary irrigation systems and explicit reliable sources of metrological information to confront with ES and recent climate change. Majority of farmers in both study sites perceived ES of TSL as important directly to their RCS and other fishery resources provisioning to their livelihood. The more closer people to TSL basin, the more they relied on the ES. However, not all of them perceived that ES provided by TSL are important to them while those ES changed particularly flood pulse which in particularly year their RCS were seriously damaged by flooding. Moreover, they were aware about the changes in freshwater, fish, wildlife, and flooded forest, but farmers in LWL were aware the causes of change of ES higher than farmers in MWL due to their closely interaction between ecosystems in TSL.

ACKNOWLEDGEMENTS

The authors are grateful for supports and cooperation from AFABET scholarship program (2015-2018) funded by EU, the villagers and relevant sectoral department governors/authorities, Ecosystem Service and Land Use Research Center (ECOLAND) at the Royal University of Agriculture (RUA) in Cambodia, Dr. Vladimir Verner, Faculty of Tropical AgriSciences of Czech University of Life Sciences Prague, Czech Republic, and Dr. Kimchhin SOK's Ph.D. project.

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Research article

Improvements in Agricultural Education at Secondary Schools in Nepal: A Case Study in Mustang District

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Received 25 January 2020 Accepted 9 November 2020 (*Corresponding Author)

Abstract The Nepal government introduced Technical Vocational Education to secondary schools nationwide in 2014 as part of its School Sector Reform Plan (running from 2009 through to 2015). The purpose of agricultural education in secondary schools is to develop a workforce to support the nation's agricultural development and alleviate poverty. This case study analyzes the current status of and issues with agricultural education at a secondary school in Nepal's Mustang District. First, the curriculum and syllabi of the Plant Science Stream program were reviewed. Second, the school's teaching activities were analyzed and compared with the teaching methods in use at a Japanese agricultural high school in the Nagano Prefecture. The head of the school and a teacher of agriculture conducted observations and interviews regarding the Japanese high school's teaching practices in September 2017. After observing the Japanese high school, focus group discussions were conducted with five other agriculture teachers at the targeted school in Nepal. The discussions found that the content of the lectures did not adequately explain local farming practices. It was determined that the study program should conduct cultivation trials of local products in the school farm. Students could interview local farmers and observe their crop production, agro-processing, livestock rearing, and natural resource managements. Students could practice farming to use the products for their own consumption or sales at school and local markets. These activities can strengthen students' understanding of agricultural information and techniques. The suggested activities would also allow the teachers to learn what information to include in the lectures and practices to support students' knowledge of farming practices relevant to the local area.

Keywords Nepal, mountain area, rural development, practical education

INTRODUCTION

A quarter of Nepal's total population of 27 million falls below the poverty line. More than 80% of the population lives in rural areas, and 73% are engaged in agriculture. Agriculture accounts for 33% of Nepal's gross domestic product (World Bank, 2017). Nepal's National Strategy Plan (13th three-year plan) aimed to improve living standards and reduce poverty to 18% by 2020 (National Planning Commission, 2013). Furthermore, the Ministry of Agriculture Development (MoAD) (2016) prioritized the strengthening of agricultural education to improve agricultural productivity and reduce poverty. However, public agricultural extension services have been limited to reach the rural farmers due to lack of the budget, infrastructure and qualified extension workers. In addition, the supply driven extension approaches rather than demand driven have been failing to cater the needs of the farmers (Dhital, R.P. 2017). Technical and Vocational Education and Training (TVET) program under the Council of TVET have allocated 175 training centers in different areas of Nepal but they are mainly in urban areas. Agricultural training service are also limited in only 20 training centers (Asian Development Bank, 2015).

In 2013, as a part of Nepal's School Sector Reform Plan (2009-15), the Ministry of Education (MoE) established a technical and vocational education (TVE) program in secondary schools, covering the 9th, 10th, 11th, and 12th grades (MoE, 2009; MoE, 2016). The TVE program includes Plant Science, Animal Science, Civil Engineering, Electrical Engineering, and Computer Engineering. The aim of introducing the TVE program was to promote technical studies and facilitate the development of practical engineers who could contribute to Nepal's economic development and poverty alleviation (MoE, 2016; Santwona Memorial Academy Pvt. Ltd., 2017). The Plant Science Stream program aims to attract students to pursue higher education in the subject who can then work in agricultural organizations or companies and promote the role of local agricultural businesses and farming within the overall economy (MoE Curriculum Development Center, 2015; MoAD, 2016). In 2014, the MoE introduced five TVE program in 99 model schools nationwide (MoE, 2015; Santwona Memorial Academy Pvt. Ltd., 2017). As of 2017, 284 schools had adopted a TVE program in secondary school, including 94 which introduced the Plant Science Stream, the largest among all the programs (MoE, 2018).

The Plant Science Stream in secondary schools is expected to enhance the capacity development of national human resources to promote agricultural and rural development in Nepal. However, there is no study, yet which clarifies the current situation since agricultural education has only recently been introduced in secondary schools.

OBJECTIVE

This study analyzes the current status of agricultural education, focusing on Plant Science Stream in secondary schools in Nepal, and identifies issues and ways to improve the program.

METHODOLOGY

This study employed action research which involved both the researchers and targeted beneficiaries, agricultural teachers in this case, to address the existing issues together (Greenwood and Levin, 1998). Education research has often utilized action research for not only teachers' learning to develop teaching methods and skills but also the solutions of significant problems in classrooms and schools (Gregory S. C. Hine. 2013). A teacher or a group of teachers try to identify the issues in their classes and come up with causes and possible solutions with a concrete action plan to apply to the actual lessons as trials. The trial results are monitored and evaluated to ascertain the effectiveness of the solutions. This process is often repeated until addressing the issues and the findings can be shared with other teaching staff and researchers as a valuable reference for further developments (Greenwood and Levin, 1998; Gregory S. C. Hine. 2013.).

This study tried to identify the issues of the teaching methods and other related environments of the surveyed school through the observation of those in Japan for comparison, and several focus group discussions to identify the issues and necessary action plans to solve them with the researchers' facilitation. A targeted secondary school for this study was selected in a mountainous area where the altitude is around 2,600 m in the Mustang district of Nepal (MP RC, 2017). The school introduced the Plant Science Stream in 2014 when the TVE program had just started in Nepal (MoE, 2016). Observations were conducted in December 2016 and again in August 2017, a survey was first conducted comprising observations of lectures and practices; interviews with teachers on their teaching methods; and reviews of the curriculum, syllabi, and teaching materials in a Plant Science

Stream at the targeted school. A questionnaire survey was conducted with the students to record their background, the agricultural experiences of their family, and their career expectations.

Second, in September 2017, to identify the educational issues, joint observations were conducted in a Japanese agricultural high school in the Nagano Prefecture with the head of the targeted school, an agriculture teacher at that school, an MoE officer, and the researchers. The observation team compared their own education at the targeted schools in Nepal with the education system and teaching practices at the Japanese agricultural high school. Thereafter, in November and December 2017, the teachers led several focus group discussions with five other teachers of agriculture at the targeted school, through the facilitation of the researchers.

Fig. 1 Target area in Nepal

RESULTS AND DISCUSSION

Teachers and Students of the Surveyed School

As of August 2017, the targeted secondary school had seven teachers in charge of agricultural subjects and six teachers for general subjects. The agriculture teachers came from areas that were all located at altitudes much lower than that of the Mustang district. The school had 29 students in the 9th grade, 16 in the 10th grade, 20 in the 11th grade, and 16 in the 12th grade. The 12th-grade students were the first group to join the Plant Science Stream of the targeted secondary school.

Table 1 indicates the results of a questionnaire completed by the 12th-grade students in December 2016, when they were in the 11th grade. The students originated primarily from the same village development committee (VDC) area of the surveyed school and neighboring VDCs. Some students came from areas far away from the school or urban areas. The school offered dormitories, kitchen facilities, and dining rooms for out-of-area students. The parents of 13 out of the 14 respondents were engaged in agriculture. The chief crops cultivated as staple foods were maize, potatoes, buckwheat and legumes. Most families grew vegetables and fruits such as carrots, radishes, cabbages, cauliflowers, apples, walnuts, and potatoes are planted as cash crops in the region to be sold to markets in the urban areas. Certain staple foods were generally grown on farmlands using a seasonal crop rotation system. Vegetables and fruits were generally grown in small fields near homes, or in backyards. Regarding students' plans after graduation, seven students aimed to study agriculture in university and seven students planned to work in agriculture.

Table 1 House business and expected careers of the students (December, 2016)

House business	Agriculture: 13 (Maize, Barley, Wheat, Buckwheat, Potato, Common bean, Wild bean, Carrot, Radish, Cabbage, Cauliflower, Apple, Walnut)/ Non agriculture: 1
Expected career after graduation	Agriculture: 7 (4 males and 3 females) , Study in university: 7 (6 males and 1 female) Expected faculty to be enrolled: Agriculture 6, Other 1

Note: Respondents were 14 (Male: 10, Female: 4) out of 16 students in the 12th grade

Curriculum and Syllabus

The curriculum for the Plant Science Stream at the targeted school included general subjects, such as Nepali, English, Mathematics and Science subjects, as well as agricultural subjects which are shown in Table 2 (MoE CDC, 2015; Higher Secondary Education Board, 2015). Each subject has a syllabus covering the course content including the teaching times, objectives, study outcomes, content of theory and practice, and evaluation criteria and methods. Agricultural subjects encompassed a step-by-step learning process from basic knowledge and techniques required in the 9th grade to more specific and subdivided subjects in the 10th to 12th grades. The curriculum also required 3,100 hours of practical work in four years.

Table 2 Agricultural subjects of Plant Science Stream in the surveyed school

Grade	Subjects
9	Principle of Agronomy / Principles and Practices of Fruit Crop / Plant Protection / Soil and Soil Fertility Management / Extension and Community
10	Vegetable and Medical Plant / Floriculture and Nursery Management / Crop Protection / Farm Management and Marketing / Aquaculture and Fisheries / Industrial Entomology and Mushroom
11	Commercial Fruit Production and Orchard Management / Food Crops Production and Food Security / Participatory Agriculture Extension and Marketing
12	Commercial Vegetable Production and Marketing / Sustainable Integrated Nutrient and Pest management / Commercial mushroom production and marketing

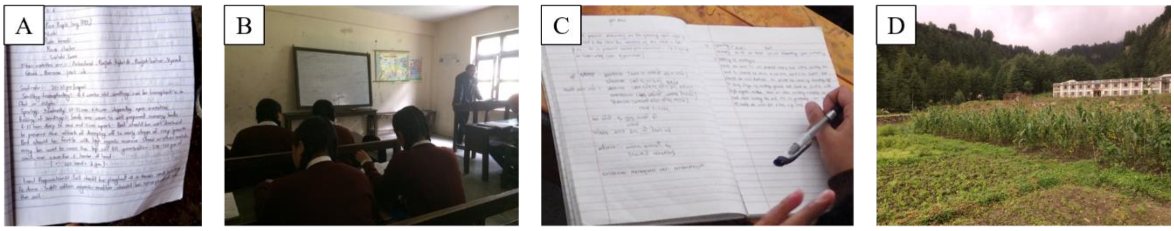
Table 3 Syllabus "Principles and Practices of Fruit Crop Production" in the 9th Grade

[Theory] 1. Introduction: 1.1 Meaning & definition of horticulture and branches. 1.2 Importance & scope of horticulture. 1.3 Types of fruit crops (tropical, subtropical, and temperate) found in Nepal.
2. Climate: 2.1 Environmental factors affecting fruit production. 2.2 Role of climate on fruit distribution.
3. Home garden, 4. Orchard management, 5. Plant growth, 6. Plant growth regulators, 7. Cultivation of fruit crops, 8. Harvesting and post-harvest handling of fruits.
[Practical] 1.1 Identify fruit / plantation crops. 1.2 Identify horticultural tools / equipment. 2.1 Lay-out orchard / tea garden. 2.2 Perform digging and filling of pits and planting of fruits. 2.3 Perform training and pruning of fruit and plantation crop. 3.1 Fertilize / manure fruit trees. 3.2 Prepare Bordeaux mixture / paste. 3.3 Practice cutting / layering / grafting. 4.1 Study the equipment/tools used for preservation. 4.2 Study ripening of banana. 4.3 Perform dehydration and water loss of different fruits. 4.4 Prepare jam / jelly / ketchup / juice / squash / pickles. 4.5 Prepare green coffee.

On completion of the first agricultural course, Principles of Agronomy, which covers the basic knowledge of agronomy and cultivation environments, including plant physiology, soil management, cropping systems, water management, and post-harvest management, students undertook Principles and Practices of Fruit Crop Production which was conducted in the same year. As Table 3 illustrates, the syllabus focused on the basic knowledge of fruit production, and on commercial fruit production and orchard management, which focused more specifically on all kinds of existing Nepalese fruits from tropical, subtropical, and temperate areas. The class included practical and applied knowledge on production skills, farm management, and marketing and distribution systems. Teachers covered tropical and subtropical fruits in lectures, and temperate fruit crops were introduced later. Practical activities offered the experience of identification of fruit crops, the orchard setting, field preparation, fertilization, grafting, pest control, harvesting, and processing (MoE CDC, 2015).

Teaching Methods in Nepal and Japan

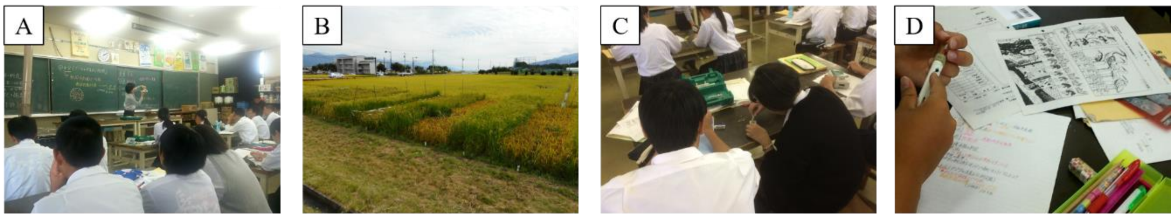
At the surveyed school in Nepal at the time of this study, textbooks or teaching manuals were yet to be created for the Plant Science Stream. Therefore, as Fig. 2 shows, teachers had to prepare teaching notes based on the reference books recommended in the syllabi. Moreover, the students studied later from their lecture notes. In class, the teacher explained the content of the teaching notes orally and by writing on the whiteboard. Additionally, cultivation practice was conducted in the school farm. At the beginning of agricultural education in 2014, one hectare of school farmland had been developed, and cultivation practice was conducted each year.



Teaching note | Lecture | Student's note | School field

Fig. 2 Teaching environments in the surveyed school

On September 5th, 2017, teaching activities in the subject Agriculture and the Environment were observed in a Japanese agricultural high school. As Fig. 3 shows, the teacher first explained in the classroom about rice grain maturity and the appropriate timing of harvesting based on the moisture content of the rice. Second, the teacher guided students to conduct field observations on differences in rice maturity, depending on the varieties. Students sampled the rice stalks with paddy from different varieties to measure the moisture. After returning to the classroom, the students drew diagrams of the rice stalks and measured the moisture of the paddy to prepare a report. The classes covered the entire production process and growing stages of rice, including the preparation of the paddy fields, seeding, transplanting, growth, and harvesting. The theory and practice were interconnected, as Fig. 4 shows.



Demonstration in lecture | Rice production trial | Measuring seed moisture | Report writing

Fig. 3 Integration of teaching methods, lectures, field practices, and teaching material at the Japanese agricultural high school

Issues and Improvement Plan Based on the Focus Group Discussions

(1) Prioritizing local products in lectures and connecting theory with practice:
In the focus group discussion, the teachers suggested focusing more on local agricultural products, although they recognized the importance of knowledge of Nepalese agriculture in tropical, subtropical, and temperate areas. These teachers felt that local farming practices should be integrated into the cultivation practices on the school farm and into the teaching of theory in lectures.

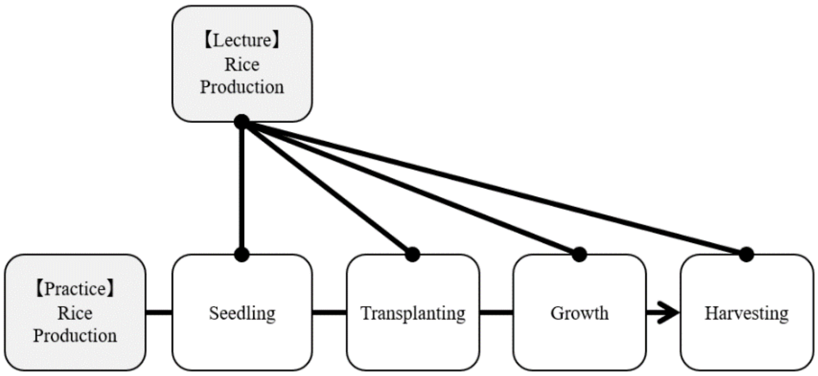


Fig. 4 Integration of the lecture and field practice at the Japanese agricultural high school

The discussion indicated that the teaching content in the lectures and practices did not appear to be integrated. A teacher who had visited Japan emphasized issues based on learning points observed in the Japanese teaching method which connected comparative cultivation trials on rice varieties with lecture contents. These points included observation, measurement of the product's growth and yield components, and report writing relating to the farming practice season by season.

Teacher in charge of Principle of Agronomy in the 9th grade suggested connecting the contents of the lecture and the farming practices with popular local crops such as barley. The field practice could then include a comparison of cultivation among the different varieties of barley. During lectures on germination, for example, the teacher could use the barley cultivation practices to teach the practice of determining germination rate.

Furthermore, the characteristics of plant growth and flowering time could be observed and recorded in the field when the same contents were explained in the lectures. The harvest season could offer the opportunity to observe different maturity timing and to collect yield data for comparisons. The timing of the teaching content in the lectures should thus be matched with the instruction content in the practice activities.

(2) Introducing comparative research:

In the situation at the time of this study, cultivation at school farms was rather limited in offering the experience of farming practices. The teacher in charge of "Industrial Entomology and Mushroom" in the 10th grade also emphasized the necessity of introducing a research context in lectures and practice. The appropriate varieties of mushroom which were easily grown in the school area could be produced in the school farm, allowing for several research topics such as variety comparisons regarding growth and yield. The mushroom beds were available in the agricultural research center in the region and were easy to obtain.

Comparative research could also be introduced to compare apples in different areas. Even if apple trees were not grown in the school farm, the school practice could be conducted on apple farms outside of the school. Teachers and students could visit apple farmers in different areas. The same variety of apple could be collected from different village and the sugar contents of the fruits could be compared.

As a plan for cultivation practices and comparative cultivation trials, the teachers suggested that the school farm be divided into 20 plots for the 9th and 10th grades and another 20 plots for the 11th and 12th grades. In the school farm, crops and vegetables could be cultivated as experimental field practices. Comparative experimental cultivation could provide opportunities for scientific research into different treatments and could also develop knowledge and skills regarding data collection, analysis, and report writing.

It was thus felt that the idea of research should be introduced in lectures and practices. Local products and varieties of each crop, in addition to local cultivation practices, could be used as research targets and prepared for cultivation experiments under the supervision of the agriculture teachers. The experience and knowledge thus gained would later be useful for students, both in higher education and when or if they engage in agriculture.

(3) Learning from farming and processing practices at students' homes and on local farms:
At the time of this study, the families of most students were farmers who cultivated crops, vegetables, and fruits on their own farms or in their home gardens. There were hence many opportunities for students to learn from their own agricultural practices. Additionally, students could learn about natural resources and water management from the real farming practices by local farmers.

Many farmers around the school grew fruit trees, including apple and walnut. The teacher in charge of Principles and Practices of Fruit Crop in the 9th grade suggested that the subject could be linked to the local apple farming and processing which were practiced in the areas around the school and in the neighboring villages. Apples were processed into dry fruit, alcoholic beverages, juice, and jam. It was suggested that these local production processes should be learned through student visits and experienced by the students in the practices in school.

(4) Utilizing the school farm more efficiently and effectively for learning and school management:
The school farm consists of five hectares, including the field and building; however, only one hectare has been used for farming practices since 2014. Thus, the agricultural field could be extended for greater production.

Since apple and walnut are popular as cash crops, it was suggested that the plantations on the school farm be increased for cultivation and research opportunities. These practices could be integrated into the teaching content of the Principles and Practices of Fruit Crop in the 9th grade. Moreover, it was suggested that cauliflower, cabbage, radish, ginger, garlic, onion, and several leaf vegetables be grown as a part of students practice in the school farm. These cultivation practices should then be connected with Vegetable and Medical Plant in the 10th grade and Commercial Vegetable Production and Marketing in the 12th grade.

If apples were to be harvested at the school, agro-processing such as the production of dried apple and apple jam could be practiced in the school kitchen. It was suggested that the learning opportunities arising from existing local processing businesses should be increased by taking students to visit the processers.

More than 20 students who came from the villages or cities far from the school stayed in the school dormitory. The school financially supported the students who stayed at the school dormitory by purchasing food supplies from local markets or farmers. However, it was proposed that if the aforementioned farming activities could be increased, students could produce food for their own consumption. Some harvested and processed products could also be sold in the school or to the local residents. These activities could assist the school management financially, as well as increase learning opportunities regarding farming and business management.

(5) Accumulating the teaching content of lectures and practices:
Since the training and licensing system for teaching agriculture has yet to be established, the subject teachers have not been professionally trained. Most agriculture teachers came from other areas and were not familiar with the farmers' practices and local products grown at an altitude of 2,600 m. The teachers therefore also suggested that each teacher should create teaching notes which could be filed and provided as instructional notes for new teachers. It is important to accumulate teaching knowledge so as to operate efficient schools that incorporate local agriculture.

Relevance of the Results of the Focus Group Discussions

These results identified the issues in agricultural education in the targeted secondary school in Nepal while TVE in secondary school has just been introduced in secondary schools nationwide since 2014. Among five discussion points, the essential issue to be improved is strengthening the links between the educational contents, and regional agriculture and livelihoods with related businesses.

The implementation of the Technical and Vocational Education and Training (TVET) program by Council of TVET has resulted in a low employment rate of graduates largely due to the mismatch between the market needs and program content (ADB, 2015; Bagale, 2018). ADB (2015) argued that the involvement of industry and business is necessary to a market that is responsive in assessing the job market's demand to enhance the employability and productivity of the workforce. Information-sharing between industry and technical institutions is essential to connect the training content with the necessary skills and knowledge of the targeted businesses to close the gap between educational content and learning outcomes which are far from what the market demands (Nepal, 2015; Bagale, 2018).

In the case of the technical education in agriculture (Plant Science Stream) at the surveyed school, a limited connection of the teaching content with local agricultural practices is recognized as the primary issue as argued by the studies cited above. As the TVET experiences indicate, it is a critical situation with a high risk of mismatching between teaching content and the real need for agricultural development in the region. Also, teaching new agricultural techniques, material, equipment, and economic system without understanding local and traditional farming practices runs the risk of the students uncritically adopting those new technologies which sometimes ruin the natural environment and unexpectedly change the socio-economic situation in the region.

The rural people's knowledge and practices on agriculture and natural resources use have been already appropriate and reasonable in many cases. The traditional livelihoods including farming system in developing countries are generally complex and diversified so that rural people can reduce vulnerability and enhance security and ensure long term well-being and sustainability. These traditional rural practices should be appropriately evaluated and outsiders' and rural people's knowledge could combine their strengths and neutralize the weaknesses (Chambers, 1983; Chambers, 1997).

The main purpose of technical education should be to develop the human capacity to improve or optimize the old practices through obtaining the new information, technologies, business strategies, and even lifestyles without environmental and cultural distraction.

Thus, the learning process from real agricultural practices of local farmers could be fundamental for agricultural education. Comparative research can provide the opportunities to enhance the students' capacity for critical thinking with a verification (evaluation) method on the traditional practices and newly introduced techniques. The farming practices through cultivation experiments and crop–fruit–vegetable production in the school farm can not only give meaningful farming skills and learning opportunities of the regional agricultural practices but also trial practices of new techniques and material including seeds and equipment. Crop–fruit–vegetable production for students' consumption in the school can also provide the experiences of processing, storing, and selling the products which enhances the students' knowledge and skills in agricultural management and business development.

The record of research process and outputs including the collected data and students' reports can be accumulated to utilize as teaching materials and learning references. Kanel (2015) emphasizes the importance of the TVE in secondary schools to enhance capacity development of the teaching staff of technical education. The accumulation of the information through the research and practices in and out of the school can be the teaching contents and manual for the teachers. This practical information can be utilized as effective teaching material during the daily lectures in the classes. Combining the theory and practical information based on real farming practices in the daily lectures can synergistically lead to effective and understandable teaching methods in each agricultural subject.

CONCLUSION

This study identified the existing issues and possible action for the improvement of agricultural education in the surveyed secondary school in Nepal through observations of the Japanese school for comparison and discussions by the teachers with researchers' facilitation. The effectiveness of these ideas should be monitored and evaluated through the implementation of the action plan for the improvements.

ACKNOWLEDGEMENTS

This study was conducted under the implementation of JICA partnership project on Enhancement of Agricultural Education in Higher Secondary School in Nepal (2016-2018). We thank Kami-ina

Agricultural High School (Nagano Prefecture, Japan), AST Foundation, and Curriculum Development Center of MoE (Nepal) for their cooperation for the project implementation.

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Research article

Treatment of Wastewater from Dyeing Process of Weaving Workshop in Inle Lake by Using Lotus Stalk and Coconut Shell Charcoal

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Received 30 January 2020 Accepted 12 November 2020 (*Corresponding Author)

Abstract Inle Lake is the second largest natural lake in Myanmar. It has a population of some 150,000 people, many of whom live on floating islands of vegetation. About half of the people who live in Inle Lake work the traditional hand weaving business. It is now facing the environmental degradation of its area due to human activities. Direct discharging of wastewater containing contaminants (especially azo dyes and heavy metals) from dyeing process into its environment impairs the soil and water qualities and causes a series of problems in living beings. In this research, the treatment of wastewater of dyeing process from silk, lotus and cotton hand weaving workshops in Inle lake was performed by sorption technique using local available waste, lotus stalk and coconut shell charcoal as the major sorbent materials. The results obtained from dyed wastewater treatment using activated coconut shell charcoal (5 g), activated lotus stalk (5 g), and a combination effect of activated lotus stalk and activated coconut shell charcoal at a 4:1 ratio for appropriate time taken treatment indicated that the highest color removal efficiency (94%, 95%, 100%) respectively. Therefore, a combination of sorbent materials (4:1) might be the best choice for the dyed wastewater treatment. The resultant data of before and after treatment of wastewater were compared with WEPA standard for public health. Some tested heavy metals and physicochemical properties of treated water were within the WEPA standard. However, long term disposing of wastewater without proper treatment causes a serious problem. Therefore, treatment of wastewater before discharging into its environment is necessary for the conservation and sustainability of Inle Lake.

Keywords coconut shell charcoal, cotton, dyeing wastewater, Inle Lake, lotus stalk, silk

INTRODUCTION

Water pollution has become one of the most dangerous threats to the environment in today's world. The negative effects of water pollution are not just limited to human beings, but it is fatal for the entire ecosystem. Water comes from many sources like ground water, surface water such as lake water, pond water, river water, etc., which is why the causes of its pollution are different depending on the source. Chemical, textiles, tannery industries etc. cause high rate of pollution (Vijaya, 2014). The effluent containing heavy metals, chemicals, such dyes, oils and many other harmful materials are discharged by the industries into the water bodies without proper treatment, thus leading to contamination of said water bodies. All the wastes of the colorant category produced from various types of industries might have injurious impacts on microbial flora and fauna and may be unhealthy and sometimes even fatal to mammals. At low concentrations, dyes have an adverse effect on the life of marine animals and therefore, the food cycle. As per their design, dyes are relatively very steady molecules, created to fight against the deterioration by light, biological, chemical and other natural modes of degradation (Qada, 2008).

The most widely methods for removing dyes from wastewater systems include physicochemical, and biological methods, such as flocculation, coagulation, precipitation, adsorption, membrane filtration, electrochemical techniques, ozonation and fungal decolorization (Sotelo et al., 2002). Amongst the numerous techniques of removal of dye, adsorption is an effective and useful process. Adsorption is considered to be superior in comparison with the other techniques of dyeing wastewater treatment due to low cost, easy availability, simplicity of design, high efficiency, ease of operation, biodegradability and the ability to treat dyes in more concentrated form which can mix the wastewater and the porous material powder or granules, such as activated carbon and clay, or let the wastewater through its filter bed composed of granular materials (Zongping, 2011).

But the use of one individual process may often not be sufficient to achieve complete decolorization. The present study is to explore the feasibility of natural waste materials, lotus stalk and coconut shell charcoal as a low cost and local available sorbent materials in Inle Lake, Nyaungshwe Township, Taunggyi District of Southern Shan State in Myanmar. The lake has 22 km long and 10 km across. It is famous for its scenic beauty and the unique leg-rowing of the Inthas, the native lake dwellers. It is one of the main tourist attractions in Myanmar. Moreover, the hand weaving with lotus fiber is also a well-established part of the tourist trail. But, the dyeing wastewater and fiber extracted lotus stalks which discharged from these hand weaving workshops were adverse effect from ecosystem of Inle Lake. Therefore, through this research the potential of treatment of indigo color dyeing wastewater by the use of new waste matter (lotus stalk) which is handily available in abundance of Inle area has been explored. The used indigo color dye powder is the Bayer trademark. The chemical formula of indigo is $C_{16}H_{10}N_2O_2$ (Wouten, 1991) and its molecular structure is as shown in fig. 1.

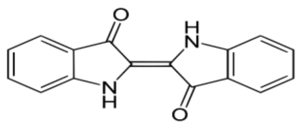


Fig. 1 Molecular structure of indigo dye

OBJECTIVES

The aim of this research is to reduce the adverse effect of wastewater from dyeing process on Inle Lake area by using the treatment with local available waste sorbent materials such as lotus stalks and coconut shell charcoal, and to protect the environmental deterioration of the lake caused by dye pollution.

METHODOLOGY

An experimental process of this research was done to evaluate the removal capacity of lotus stalk and coconut shell charcoal with respect to various parameters such as color adsorbent capacity of material with initial concentration at different doses, time and pH on indigo color dyeing-wastewater. In all the investigations, the methods and techniques involved both conventional and modern methods. All observations and measurements except scanning electron microscope (SEM) analysis were performed in laboratory of Chemistry Department, Taunggyi University, Southern Shan State, Myanmar. SEM analysis was performed in laboratory of Chemistry Department, Western University of Yangon.

Collection of samples: The fiber extracted residual lotus stalks, coconut shells and indigo color dyeing wastewater were collected from one of the silk, lotus and cotton hand weaving workshop in Inle area in December, 2018. The chemicals used in the experimental work were purchased from local chemical store. All chemicals were of reagent grade.

Preparation of sorbent materials (non-activated and activated lotus stalk): The fiber extracted residual lotus stalks were cleaned with tap water and distilled water to remove dust particles and water-soluble impurities. After that, these were cut into small pieces, dried in sunlight for 2 days until the stalks became crisp. Then using a mortar the stalks were crushed until uniform size particle was obtained and sieved to desired particle size in order to produce the non-activated lotus stalks.

In the preparation of activated sorbent material, non-activated lotus stalk powder was washed thoroughly with distilled water to remove the dust particles, then soaked overnight in 0.1 M NaOH solutions and again washed with double distilled water. Then they were soaked in 0.1 M CH_3COOH for a period of 2-3 hours to remove the traces of NaOH. It was thoroughly washed again with double distilled water till the wash water became colorless and then filtered, air dried, powdered and sieved before use.

Preparation of non-activated and activated coconut shell charcoal: The coconut shells were separated and cleaned from other materials, such as coconut fiber or soil and then dried in sunlight. The dried coconut shells were burned at burning sink or drum at 200 to 550°C for 3-5 hours to get charcoal. Some charcoal was soaked in chemical solution (25% H_3PO_4) for 24 hours to become activated charcoal. The obtained activated charcoal was washed with distilled or clean water and spread on tray at room temperature to be drained. Then, it was dried in oven at temperature 110°C for 3 hours. These non-activated and activated charcoal were ground and sieved to get the size range of 50-100 mesh. The prepared sorbent materials are shown in Fig. 2 (a) and (b).

Characterization of the surface function of prepared sorbent materials: The prepared sorbent materials were examined by Fourier-transform infrared spectroscopy (FTIR) analysis and scanning electron microscope (SEM) for a visual inspection of surface morphology.

Determination of maximum wavelength absorbed by indigo dyeing wastewater: The maximum wavelength, λ_{max} is the wavelength at which the highest absorbance of the solution has. At this wavelength, the solution is most sensitive to concentration changes. To determine the λ_{max} of collected dyeing wastewater sample, the absorbance versus wavelength graph was constructed by examining the absorbance of a certain concentration of collected dye sample using Ultraviolet-Visible (UV-VIS) spectrophotometer. The resulted graph was showed in Fig. 6 (a).

Determination of molar absorptivity of indigo dyeing wastewater: The four indigo dyeing wastewater with the various concentrations of 0.25%, 0.5%, 1%, and 1.25% were prepared and their absorbance were examined by UV-VIS spectrophotometer at 530 nm (λ_{max} of collected dye sample). Then the calibration curve of absorbance versus concentration was constructed and the molar absorptivity (ε) of indigo dyeing wastewater was determined from the slope of the trend line. The resulting data are described in Fig. 6 (b).

Treatment of indigo dyeing wastewater: In each twenty separate flasks, 100 mL of 1% original dyeing wastewater was mixed with the varying masses of 1-5 g of non-activated lotus stalk, activated lotus stalk, non-activated coconut shell charcoal, and activated coconut shell charcoal respectively and allowed to stand for 1 day at room temperature. Moreover, the varying amount of 1-5 g of non-activated coconut shell charcoal, and activated coconut shell charcoal were added in five separate flasks and allowed to stand for 2 hours. Then the mixtures were separately filtered through filter paper Whatmann No.1 and the absorbance of each filtrate was determined by UV-VIS spectrophotometer at 530 nm.

Furthermore, the 100 mL of 1% original dyeing wastewater was mixed with prepared sorbent materials (non-activated and activated lotus stalk) of various masses ranging from 1 g to 5 g were added to this solution in each separate flasks and the mixtures were allowed to stand for 1 day. After that, the mixtures were separately filtered through filter paper Whatmann No.1. To the filtrates, the desired amount of various masses (1-4 g) of non-activated coconut shell charcoal and activated coconut shell charcoal were separately added and allowed to stand for 2 hours. After sufficient time, the mixtures were filtered again and the pH of each filtrate was adjusted to 7 using 0.1 M citric acid. Finally, the absorbance of dye solutions before and after treatment were determined by Ultraviolet-Visible (UV-VIS) spectrophotometer at 530 nm. From the observed absorbance of each dye solution, the concentrations and removal percent were calculated using Beer- Lambert's law and the equation (1) respectively. The resulting data are presented in Tables 2, 3 and 4.

Assessments of quality of dye treated water: The parameters analysed to assess the treated water qualities were pH, chemical oxygen demand (COD), biochemical oxygen demand (BOD), dissolved oxygen (DO), total hardness, total alkalinity and some heavy metals. BOD, COD and total hardness were determined by titration methods. pH, DO and total alkalinity were examined by pH meter, DO probe (AMT-07) and alkalinity test kit, respectively. Arsenic and heavy metal contents were analysed by Palintest arsenator and atomic absorption spectrophotometer (SHIMADZU AA-7000). The resulting data are presented in Table 5.

RESULTS AND DISCUSSION

Fig. 2 (a) and (b) show the prepared lotus stalks and coconut shell charcoal.

(a)  (b)

Fig. 2 (a) Lotus stalk (b) Coconut shell charcoal

FTIR Analysis

Fourier transform infrared (FTIR) was used to provide structural and compositional information on the functional groups presented in the solid sorbent materials. Figure 3 shows the infrared spectrum of prepared lotus stalk. The band assignments are tabulated in Table 1.

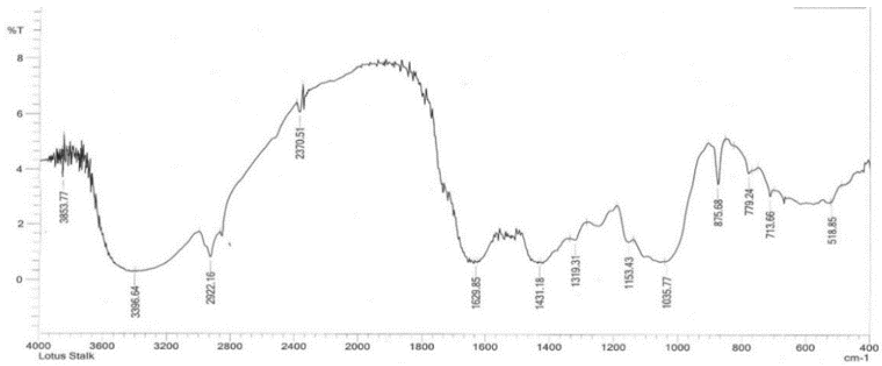


Fig. 3 FTIR spectrum of lotus stalk

The characteristic peaks of O-H stretching and C-H stretching bands were observed at 3396.64 cm^{-1} and 2922.16 cm^{-1}. The band at about 875.68 cm^{-1} shows the characteristic of the deformation of the glycosidic linkage in cellulose. Furthermore, some peaks in the 600 to 900 cm^{-1} region associated with the aromatic ring C–H out of plane bending vibration were found in the spectrum, corresponding to the aromatic skeletal vibration in lignin. A dominant absorption bands at 1629.85 and 1431.18 cm^{-1}, representing the stretching of symmetric and asymmetric C=O groups of hemicelluloses which present in the lotus stalk. The band at 1035.77 cm^{-1} corresponded to C-OH represents the stretching of alcoholic group

Table 1 FTIR spectrum assignments for lotus stalk

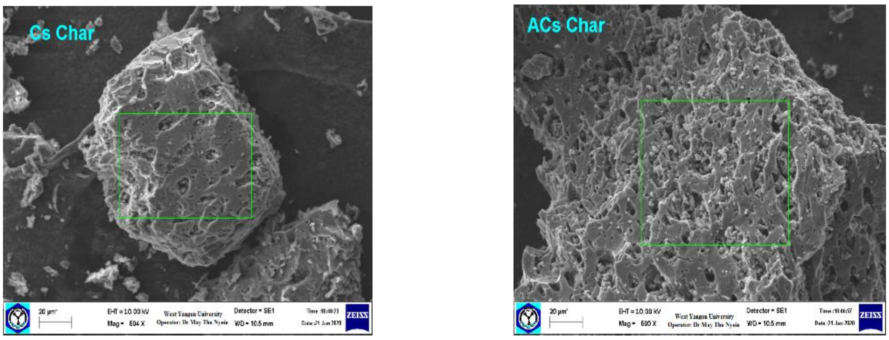
Experimental Frequency (cm^{-1})	*Literature Frequency (cm^{-1})	*Band assignments
3396.64	3200-3600	$\nu_{(OH)}$ stretching
2922.16	2800-3000	$\nu_{(C\text{-}H)}$ aliphatic, ν_{CH_2}, ν_{CH_3}
1629.85	1600-1950	$\nu_{asy\,(C=O)}$ (carbonyl)
1431.18	1400-1470	$\nu_{sym\,(C=O)}$ (carbonyl)
1035.77	1000-1200	$\nu_{(C\text{-}O)}$ (alcohol)
875.640	450-1000	$\delta_{(C\text{-}H)}$ aromatic

**Silverstein (1981)*

From the information which found in FTIR analysis, it may be confirmed that lotus stalk principally consists of cellulose, pectin, hemicellulose, lignin and chlorophyll pigments.

SEM Analysis

(a)



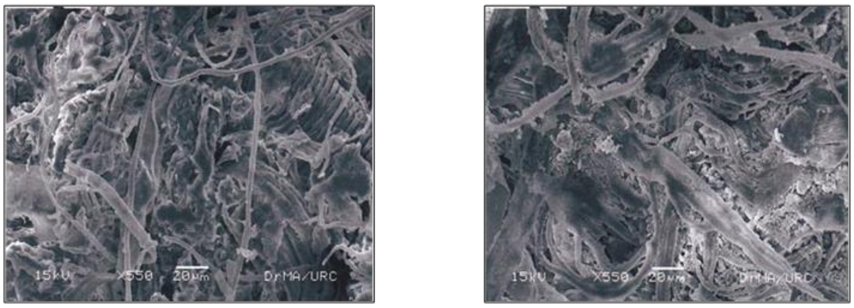
(b)

Fig. 4 SEM photograph of non-activated coconut shell charcoal and activated coconut shell charcoal

Fig. 4 (a) and (b) show the surface morphology of non-activated coconut shell charcoal and activated coconut shell charcoal. Since micro and meso pores are observed on the surface of the sorbent materials, significant adsorption is likely to occur. SEM image of the activated coconut shell charcoal revealed that a more cluster form of aggregate with cavitated pores than the non-activated one. Therefore, the activated charcoal may be responsible for the more enhanced specific sorption properties than non-activated one.

Lotus stalk has spongy like and porous structure. Fig. 5 (a) and (b) show surface morphology of lotus stalk before and after treatment of indigo dyeing-wastewater. After treatment of indigo dye is very different from surface morphology of before treatment. The significant changes of foam like and porous structure of the lotus stalk before treatment of indigo dye waste were observed in surface morphology of the lotus stalk after treatment of dye waste materials. It is one way to explain the nature of images that sorption of dye waste materials on the surface of lotus stalk may take place.

(a)



(b)

Fig. 5 SEM photographs of lotus stalk before treatment and after treatment of indigo dyeing-wastewater

Determination of λ max and Molar Absorptivity of Indigo Dyeing Wastewater

Fig. 6 (a) shows absorbance versus wavelength plot of indigo dyeing wastewater to determine λ_{max}. It is found that the λ_{max} is at 530 nm. Fig. 6 (b) shows the calibration curve of absorbance versus concentration of indigo dyeing wastewater. The molar absorptivity, ε, was determined from the slope of the line. The observed value of molar absorptivity, ε, of indigo dyeing wastewater was found to be 0.5054 $cm^{-1}mol^{-1}L$ by Beer-Lambert's Law, *$A = \varepsilon\ c\ l$, A = absorbance of the sample, c = concentration of the sample, l = optical path length*.

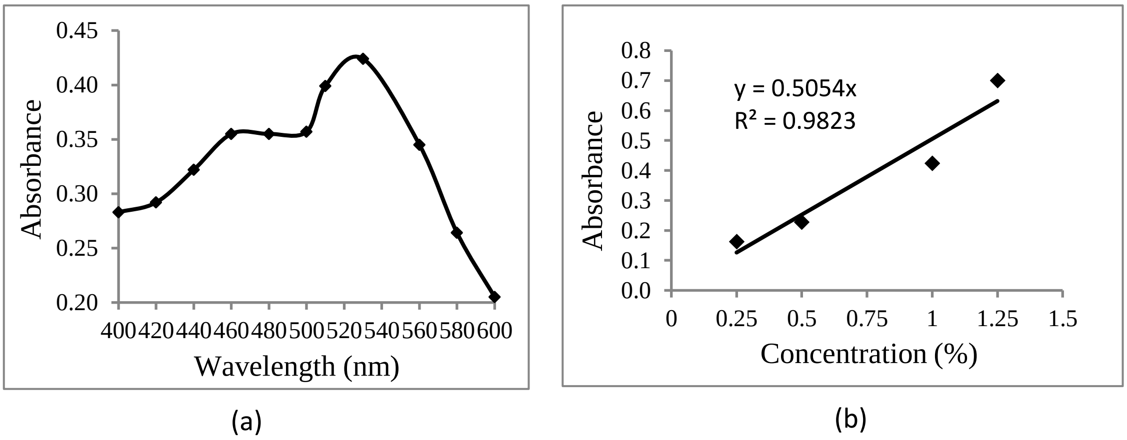


Fig. 6 (a) Absorbance versus wavelength plot of indigo dyeing wastewater and (b) Absorbance versus concentration plot of indigo dyeing wastewater

Effect of Prepared Sorbent Materials on Treatment of Dyeing Waste Water

In this research, dye color in collected sample was not completely removed by using only one prepared sorbent material at fairly time and dosage. Only if the combination effects of prepared two sorbent materials, discharge of dye color was found to be high activity.

Table 2 shows the removal efficiency of indigo dye color by each of the prepared four types of materials. It is found that the removal efficiency of the use of non-activated lotus stalk and non-activated coconut shell charcoal were not so good on indigo dye color by the use of increase dose of non-activated lotus stalk and decrease dose of non-activated coconut shell charcoal. Although the original indigo dye color is discharged, the pale yellow color which produced from lotus stalk was remained. But, the removal efficiency of activated lotus stalk and activated coconut shell charcoal were found to be fairly high.

Table 2 Removal activity of indigo dye's color by four types of sorbent materials

Materials	Time taken (hour)	Concentration of 1% original dyeing wastewater ($mol\ L^{-1}$) Before treatment (c_o)	After treatment (c_e) 1g	2g	3g	4g	5g	Removal percent (%) 1g	2g	3g	4g	5g	r	P-value
NALS	24	0.084	0.048	0.040	0.056	0.078	0.081	43	52	33	7	4	0.906*	0.034
ALS	24	0.084	0.034	0.032	0.017	0.005	0.004	59	62	80	94	95	0.963**	0.008
NACSC	2	0.084	0.049	0.044	0.041	0.038	0.039	42	48	51	55	54	0.935*	0.020
ACSC	2	0.084	0.037	0.024	0.020	0.013	0.005	56	71	76	85	94	0.988**	0.002

NALS = Non-activated lotus stalk, ALS = Activated lotus stalk, NACSC = Non-activated coconut shell charcoal, ACSC = Activated coconut shell charcoal, Volume of 1% original dyeing wastewater = 100 mL, Wavelength = 530 nm
*r = Pearson correlation coefficient, P-value = probability of obtaining result, * = significant correlation*

$$\text{Percent removal of dye} = \frac{c_o - c_e}{c_o} \times 100 \quad (1)$$

Where, c_o = initial concentration ($mol\ L^{-1}$),
c_e = equilibrium concentration ($mol\ L^{-1}$)

Table 3 shows the removal efficiency on indigo dyeing wastewater by the combination effect of non-activated lotus stalks with non-activated and activated coconut shell charcoal. From these results, it is found that the dye removal efficiencies of activated coconut shell charcoal is superior to the non-activated coconut shell charcoal. Activation of prepared sorbent materials has more effect over non activation. Therefore, the treatment of dyeing wastewater was continually performed by activated sorbent materials to achieve high efficacy.

Table 3 Comparison of removal efficiency on the indigo dyeing wastewater by the combination effect of non-activated lotus stalk with non-activated and activated coconut shell charcoal

Materials	Absorbance of 1% original dyeing wastewater		Concentration of dyeing wastewater (mol L^{-1})		Removal Percent (%)	r	P-value
	Before Treatment	After Treatment	Before Treatment	After Treatment			
NALS (1g) and NACSC (1g)	0.424	0.242	0.084	0.048	42.9		
NALS (2g) and NACSC (1g)	0.424	0.323	0.084	0.064	23.8	-0.998*	0.04
NALS (3g) and NACSC (1g)	0.424	0.436	0.084	0.086	0		
NALS (1g) and ACSC (1g)	0.424	0.235	0.084	0.050	44.6		
NALS (2g) and ACSC (1g)	0.424	0.261	0.084	0.052	33.4	-1.000**	0.005
NALS (3g) and ACSC (1g)	0.424	0.331	0.084	0.065	21.9		

NALS = Non-activated lotus stalk, NACSC = Non-activated coconut shell charcoal,
ACSC = Activated coconut shell charcoal, Volume of 1% original dyeing solution = 100 mL, Wavelength = 530 nm
*r = Pearson correlation coefficient, P-value = probability of obtaining result, * = significant correlation*

Table 4 shows the removal activity of the combination effect of activated coconut shell charcoal and activated lotus stalk. It was found to be more effective on the discharge of indigo dye color. The combination effects of various masses (1 g, 2 g, 3 g, 4 g) of activated lotus stalk and activated coconut shell charcoal were found to be (68.9, 80.7, 91.3 %, 94.1%) removal efficiency respectively. The dye removal efficiency increases with increasing usage of the amount of activated sorbent materials. But the combination effect of 4 g of activated lotus stalk and 4 g of activated coconut shell charcoal was found just a little high efficacy than 3 g combination of each type of sorbent material. This is due to the 4 g of each type of activated sorbent material only has high efficiency. The combination effect was seemed to be need to fix amount of one sorbent material and another with variable dose. Thus, the investigation was continually performed by the use of reduced mass of one of the activated sorbent materials. In this study, the main attention is to explore the effect of lotus stalk materials on the discharge of color of dyeing wastewater. Therefore, the observation was performed by the use of lotus stalk as major sorbent material. The optimum condition was found to be the combination effect of 4 g of activated lotus stalk with 1 g of activated coconut shell charcoal (100%).

Table 4 Removal efficiency on the indigo dyeing wastewater by the combination effect of activated lotus stalk and activated coconut shell charcoal

Materials	Absorbance of 1% original dyeing wastewater		Concentration of dyeing wastewater (mol L^{-1})		Removal Percent (%)	r	P-value
	Before Treatment	After Treatment	Before Treatment	After Treatment			
ALS (1g) and ACSC (1g)	0.424	0.132	0.084	0.026	68.9		
ALS (2 g) and ACSC (2g)	0.424	0.082	0.084	0.016	80.7		
ALS (3g) and ACSC (3g)	0.424	0.037	0.084	0.007	91.3	0.976**	0.004
ALS (4g) and ACSC (4g)	0.424	0.025	0.084	0.004	94.1		
ALS (4g) and ACSC (1g)	0.424	0.000	0.084	0	100		

ALS = Activated lotus stalk, ACSC = Activated coconut shell charcoal
Volume of 1% original dyeing solution = 100 mL, Wavelength = 530 nm
*r = Pearson correlation coefficient, P-value = probability of obtaining result, * = significant correlation*

Statistical analysis of observed results were performed with Pearson correlation analysis. The results were significant correlated for non-activated sorbent materials and highly significant correlated for activated sorbent materials.

Table 5 shows the assessments of quality of dyed wastewater before and after treatment process. By comparing the resulted data with the WEPA wastewater discharge standards for public area, the tested parameters of dye treated water were within the desirable range for ecosystem of Inle Lake.

Table 5 Assessments of Quality of Dye Treated Water

Parameters (ppm, except pH)	1 % original dyed wastewater	Treated water	Wastewater discharge standards for public area (WEPA, 2013)
pH	8.2	7	6-9.5
BOD	13.8	10.0	30
COD	54	22	120
DO	3.97	3.04	-
Total alkalinity (as $CaCO_3$)	300	70	600
As	ND	ND	0.25
Cd	0.0618	0.0180	0.03
Cu	0.1450	0.0457	0.5
Fe	2.8185	0.4299	2.0
Pb	0.0307	0.0154	0.2

CONCLUSION

From this study, it may be concluded that the removal of dyeing wastewater from Silk and Lotus Hand Weaving Workshop in Inle Lake area by activated lotus stalk and activated coconut shell charcoal has been found to be useful for controlling water pollution caused by dyes. From this experiment, it is clear that the removal of color of dyes is influenced by the amount of adsorbents and contact time. The completely destruction of dye color, the highest removal (100%) was favorable for the combination effect of activated lotus stalk (4g) and activated coconut shell charcoal (1g) in 100 mL of 1% original indigo dyeing wastewater. Thus, with the experimental data obtained in this study, it is possible to design and optimize an economical treatment process by recycling local waste materials for the dye removal from Silk, Lotus and Cotton Hand Weaving Workshop effluents in Inle area.

ACKNOWLEDGEMENTS

The authors would like to express special gratitude to Rector Dr Mu Mu Myint, Taunggyi University and our Ministry of Education for giving us the opportunity to present this research paper. I also thanks to Professor and Head, Dr Ah Mar Yi, Department of Chemistry, Taunggyi University, our co-workers and friends for their guidance, helpful and encouragements during this field. We wish to express our grateful thanks to Shan State Young Entrepreneurs Association (SSYEA) in Taunggyi City for their kind help and financial support throughout this research paper. Moreover, we also thank the reviewers of IJERD for their help in improving the quality of our research paper and their critical reviews.

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Research article

Diversity of Arthropod Natural Enemy Species in Intensive Monsoon Rice Growing Area, Nay Pyi Taw, Myanmar

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Received 20 January 2020 Accepted 27 November 2020 (*Corresponding Author)

Abstract This study was conducted to investigate the species diversity of arthropod natural enemy species structure in intensive monsoon rice cultivation areas during 2018. The study site is Kyee Inn village, Pyinmana Township, Myanmar, and over 550 ha. Data collected from (300 m x 300 m) grid pattern and 56 grid points (G) using a D-Vac vacuum suction-machine. This study identified eight orders, 30 families, 57 genera, and 28 arthropod natural enemy species. The highest species richness occurred in Order Hymenoptera, followed by Order Coleoptera and Order Hemiptera. The diversity of natural enemy was varied widely with different grid points. The recorded equitability (evenness) was equally abundant in most grid points, but some have high single-species dominance. The highest number of *Cyrtorhinus lividipennis* (Order Hemiptera) found in G18, even though G18 displayed a medium diversity index and low equitability. The population of *Cyrtorhinus lividipennis* was higher than other species in all grid points. It may due to food sources are abundant during the growing season. Fortunately, we observed many natural enemy species, and it should conserve for natural balance to maintain the pest population.

Keywords natural enemy community, species diversity, equitability, intensive monsoon rice

INTRODUCTION

Rice (*Oryza* spp.) is the most important and widely cultivated crop globally. It is the staple crop for more than 60 percent of the world population. Rice is a dietary staple throughout all Myanmar. In Myanmar, paddy sown total area is 7.28 million hectares (monsoon and summer rice), and rice production is 28.32 million metric tons (MOAI, 2014). Arthropods are the most diverse and dominant constituent of biodiversity in terrestrial ecosystems. It is the largest animal phylum constituting about 85% of all known animals in the world (Odegaard, 2000).

In agricultural fields where pesticide use is minimized, crop production commonly depends on natural controls provided by a pest's natural enemies. These have an important role in regulating pest populations (Barbosa, 1998). The importance of natural enemies is particularly highlighted when a pest resurgence takes place (Dent, 2000). Indiscriminate use of agrochemicals, such as insecticides, harms these natural enemies and causes a loss in such beneficial organisms' biodiversity. Agro-biodiversity performs several ecosystem services (Dudely et al., 2005).

The biodiversity of beneficial natural enemies may be a pivotal resource to improve productivity and sustainability in agriculture (Schmitz, 2007). The arthropods, natural enemies of rice insect pests, include a wide range of predators and parasitoids such as carabid beetles, aquatic and terrestrial predatory bugs, and dragonflies. Parasitoids include many hymenopteran wasp species and some dipteran flies (Bambaradeniya and Amerasinghe, 2003). Beneficial insects provide regulating ecosystem services to agriculture such as pollination and the natural regulation of plant pests

(Getanjaly, 2015). Although most of the farmers are familiar with some rice insect pests in Myanmar, they don't know the important role of arthropod natural enemies and are not familiar absolutely. Thus, it is crucial to study the species richness of natural enemies in their habitat and conserve them to improve biological control.

OBJECTIVE

This research investigates the species richness and diversity of natural enemies on monsoon rice to support farmers' valuable information.

METHODOLOGY

Study Site

The study was conducted in 56 farmers' fields during the monsoon rice season at Kyee Inn village, Pyinmana Township, Nay Pyi Taw, which lies between 19°70'66"-19°72'62" N and 96°22'43"-96°25'73" E from July to November 2018. The sampled area is 2.4 Km wide by 3.9 Km long (550 ha). The Manawthukha rice variety is grown in the study fields using farmers' usual practices.

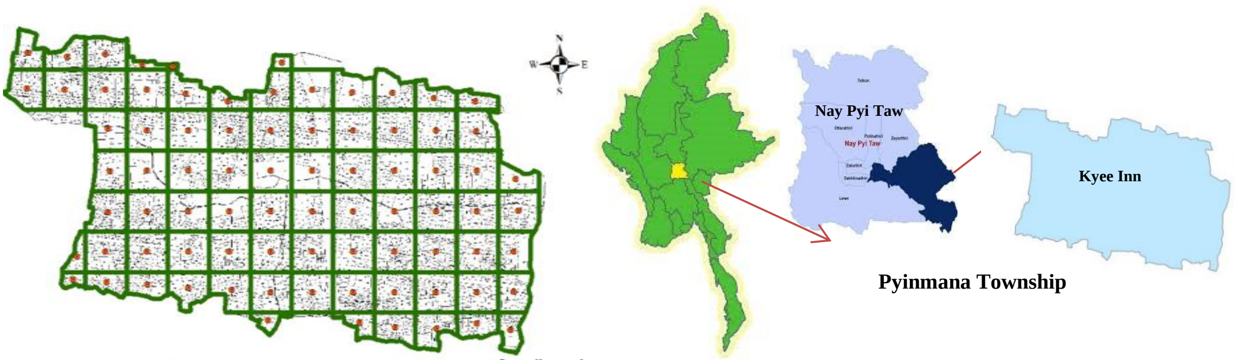


Fig. 1 Study areas at Kyee Inn Village, Pyinmana Township, Myanmar

Species Sampling

Arthropod natural enemies were collected on a 300 m by 300 m grid pattern, resulting in 56 grid points started at 20 days after sowing until harvest time. Five samples were taken at random from each rice field. All samples were collected near the center of the plot, at least 5m from the edge, to reduce edge effects using D- Vac Vacuum Insect Net - Hand Carry Model 122S (made by Rincon – Vitova Insectaries). The collection from 4-5 hills of rice plant after sowing, but only 2-3 hills after the rice plant reached maximum tillering at the fortnightly interval. Sampling duration was fixed at 1 to 2 min, depending on the rice's growth stage, and each sampling repeated three times. All samples inside the enclosure were collected and transferred to plastic bottles containing ethyl acetate with cotton wool, with species identification conducted in the laboratory for identification. All the collected samples were stored in 90% methylated spirit.

Identification of Species

Species identification was made in the JICA-ELB1 Laboratory, Department of Entomology and Zoology, Yezin Agricultural University. All the collected samples were stored in 90% methylated spirit. Morphospecies identification was made by using the textbooks of Insects of Australia (CSIRO, 1970), Manual of Nearctic Diptera, Volume 1, 2, 3 (McAlpine et al., 1981), and Pests of rice and their natural enemies in Peninsular Malaysia (Vreden and Ahmadzabidi, 1986) with OLYMPUS SZ 61 camera attached microscope (10x × 45x).

Data Analysis

The abundance and species richness of arthropod natural enemies were measured by the Shannon-Wiener function (Krebs, 1978). Shannon-Wiener function was used to measure the index of species diversity by the following formula:

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

Where;
H = index of species diversity or information content of sample (bits/individual)
S = number of species
P_i = proportion of total sample belong to i^{th} species (Krebs, 1978)
More even or equitable distribution among species will also increase species diversity measured by the Shannon-Wiener function (Krebs, 1978). Equitability (evenness) measured in;

$$E = H/H_{max}$$

Where;
E = equitability (range 0 – 1)
H = observed species diversity
H_{max} = maximum species diversity = $\log_2 S$

RESULTS AND DISCUSSION

Species Diversity and Abundance of Natural Enemy Species

There were eight orders, 30 families, 57 genera, 28 species identified in this study (Table 1). The observed arthropod orders are Araneae, Coleoptera, Dermaptera, Diptera, Hemiptera, Hymenoptera, Odonata, and Orthoptera. In 2014, 44 species from seven orders of natural enemy species were observed in Nyaungbingyisu, Nay Pyi Taw (Khin Ngu War Thant, 2016). May Thet Hlaing (2017) surveyed 118 species in Nyaungbingyisu (Pobbathiri Township), 62 species in Kyarku, Dekkhinathiri Township, and 105 species Zalaung, Oattarathiri Township, and 103 species in Yezin Agricultural University Campus. Hurlbert et al., (1989) found that the numbers of species and individuals and the diversities and evenness values were distinctly different according to habitat, type of field, and rice growth stage. The criterion used by (Rahayu et al., 2006) holds that species biodiversity is high when the value is greater than 3, a medium between 1 and 3, and low when less than 1. In our study, high diversity index occurs at 11 grid points and a medium at 44 grid points. The remaining grid points displayed a low level of diversity. Therefore, the overall species diversity index was considered in the medium criterion (Fig. 2.a, b).

Alatalo (1981) devised an index of species abundance (evenness or equitability) typically on a scale ranging from near 0, indicating low evenness or high single-species dominance, to 1, which means an equal abundance of all species, or maximum evenness. According to the results, the recorded equitability (evenness) of 19 grid points show a low index of evenness, while 37 grid points are approaching equal abundance ($\geq$ 0.5) (Fig. 3.a, b). According to the results, the recorded equitability (evenness) of most grid points in the study area was nearly equally abundant, and some are high single-species dominant. The highest diversity index (3.44) is in G31 and the most evenness (0.82) in G32 (Fig. 2.b and Fig. 3.b).

On the other hand, the lowest diversity index (0.99) and least equitability (0.22) occurs in G46 (Fig 2.b and Fig 3.b). Therefore, the diversity of natural enemy species varied widely according to different grid points due to adjacent habitats, cropping patterns of the area, farmers' practices such as irrigation, pesticides, fertilizers, and pests.

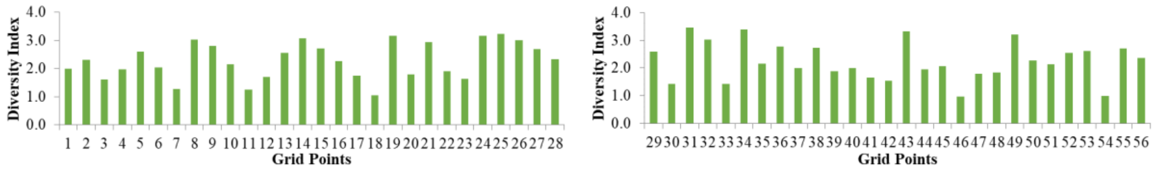
Table 1 Recorded natural enemy species from the study area, Kyee Inn Village, Pyinmana Township, 2018

No.	Order	Family	Genus	Species	Mean	SE (±)
1.	Araneae	Tetragnathidae	*Tetragnatha*	*maxillosa*	18.29	4.83
2.	Araneae	Araneidae	*Araneus*	sp.	8.60	3.46
3.	Araneae	Oxyopidae	*Oxyopes*	sp.	3.40	3.16
4.	Araneae	Linyphiidae	*Atypena*	*formosana*	3.20	3.20
5.	Araneae	Lycosidae	*Hippasa*	sp.	2.40	1.29
6.	Araneae	Lycosidae	*Trochosa*	sp.	0.67	0.49
7.	Araneae	Lycosidae	*Lycosa*	sp.	0.43	0.43
8.	Coleoptera	Staphylinidae	*Bledius*	*filipes*	12.40	12.40
9.	Coleoptera	Coccinellidae	*Micraspis*	*crocea*	1.57	1.41
10.	Coleoptera	Anthicidae	*Anthicus*	sp.	1.33	0.72
11.	Coleoptera	Staphylinidae	*Paederus*	*riparius*	1.33	0.88
12.	Coleoptera	Carabidae	*Bembidion*	sp.	1.00	1.00
13.	Coleoptera	Carabidae	*Casnoidea*	*indica*	0.71	0.47
14.	Coleoptera	Coccinellidae	*Harmonia*	*octomaculata*	0.50	0.50
15.	Coleoptera	Coccinellidae	*Menochilus*	*sexmaculatus*	0.40	0.24
16.	Coleoptera	Carabidae	*Clivina*	*fossor*	0.33	0.33
17.	Coleoptera	Carabidae	*Ophionea*	*nigrofasciata*	0.33	0.21
18.	Coleoptera	Carabidae	*Eucolliuris*	*fuscipennis*	0.20	0.20
19.	Coleoptera	Staphylinidae	*Lathrobium*	sp.	0.20	0.20
20.	Coleoptera	Carabidae	*Anillus*	sp.	0.17	0.17
21.	Coleoptera	Carabidae	*Anoplogenius*	sp.	0.17	0.17
22.	Coleoptera	Hydrophilidae	*Berosus*	sp.	0.14	0.14
23.	Coleoptera	Staphylinidae	*Stenus*	sp.	0.14	0.14
24.	Dermaptera	Anisolabididae	*Euborellia*	*annulipes*	1.00	1.00
25.	Dermaptera	Forficulidae	*Doru*	sp.	0.29	0.18
26.	Diptera	Pipunculidae	*Tornosvaryella*	*oryzaetora*	2.57	1.93
27.	Hemiptera	Miridae	*Cyrtorhinus*	*lividipennis*	199.20	133.46
28.	Hemiptera	Veliidae	*Microvelia*	*douglasi*	3.00	1.90
29.	Hemiptera	Pentatomidae	*Zicrona*	sp.	0.71	0.71
30.	Hemiptera	Reduviidae	*Polytoxus*	*fuscoviftatus*	0.50	0.50
31.	Hemiptera	Mesoveliidae	*Mesovelia*	*vittigera*	0.43	0.43
32.	Hemiptera	Reduviidae	*Peregrinator*	*biannulipes*	0.33	0.33
33.	Hemiptera	Reduviidae	*Rhynocoris*	sp.	0.20	0.20
34.	Hemiptera	Reduviidae	*Zelus*	sp.	0.14	0.14
35.	Hymenoptera	Dryinidae	*Aphelopus*	sp.	15.60	15.35
36.	Hymenoptera	Eulophidae	*Elasmus*	sp.	15.00	11.66
37.	Hymenoptera	Dryinidae	*Gonatopus*	*zealandicus*	7.14	4.72
38.	Hymenoptera	Braconidae	*Bracon*	sp.	7.00	5.05
39.	Hymenoptera	Pteromalidae	*Trichomalopsis*	sp.	4.43	2.36
40.	Hymenoptera	Formicidae	*Dorymyrmex*	sp.	4.40	4.15
41.	Hymenoptera	Eulophidae	*Tetrastichus*	sp.	3.67	2.08
42.	Hymenoptera	Formicidae	*Myrmecocystus*	*mexicanus*	3.00	3.00
43.	Hymenoptera	Eurytomidae	*Eurytoma*	sp.	1.17	1.17
44.	Hymenoptera	Diapriidae	*Trichopria*	*basalis*	1.00	0.82
45.	Hymenoptera	Platygastridae	*Macroteleia*	sp.	0.57	0.20
46.	Hymenoptera	Diapriidae	*Trichopria*	*drosophilae*	0.50	0.34
47.	Hymenoptera	Braconidae	*Phanerotoma*	sp.	0.40	0.40
48.	Hymenoptera	Formicidae	*Leptothorax*	sp.	0.33	0.33
49.	Hymenoptera	Formicidae	*Pheidole*	sp.	0.29	0.29
50.	Hymenoptera	Formicidae	*Lasius*	sp.	0.20	0.20
51.	Hymenoptera	Formicidae	*Manica*	sp.	0.20	0.20
52.	Hymenoptera	Halictidae			0.20	0.20
53.	Hymenoptera	Ichneumonidae	*Charops*	*brachypterum*	0.20	0.20
54.	Hymenoptera	Braconidae	*Spathius*	sp.	0.17	0.17
55.	Hymenoptera	Formicidae	*Solenopsis*	sp.	0.17	0.17
56.	Hymenoptera	Ichneumonidae	*Xanthopimpla*	*flavolineata*	0.17	0.17

Table 1 (contd.)

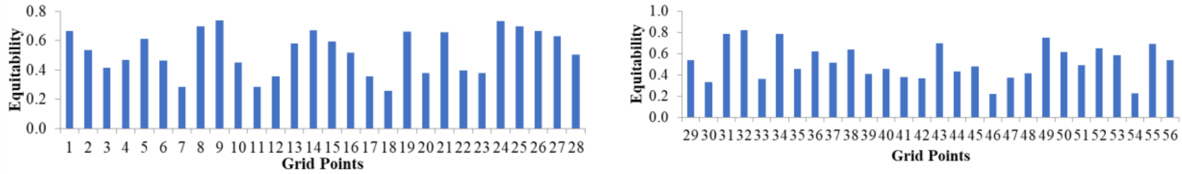
No.	Order	Family	Genus	Species	Mean	SE (±)
57.	Odonata	Coenagrionidae	*Agriocnemis*	*pygmaea*	5.50	5.50
58.	Odonata	Coenagrionidae	*Agriocnemis*	*femina*	3.29	2.65
59.	Orthoptera	Gryllidae	*Anaxipha*	*longipennis*	3.17	1.40
60.	Orthoptera	Gryllidae	*Metioche*	*vittaticollis*	0.17	0.17

These results were consistent with the finding of several authors have concluded that the abundance and diversity of predators and parasitoids within a field are closely related to the nature of the vegetation surrounding the field (Hopper, 1989). There is wide acceptance of the importance of vegetation surrounding the field margins as the reservoirs of crop pests' natural enemies.



(a) (b)

Fig. 2 Diversity index of natural enemies on rice during monsoon season in study area (a) grid points 1 to 28 (b) grid points 29 to 56



(a) (b)

Fig. 3 Equitability in distribution of natural enemies on rice during monsoon season in study area (a) grid points 1 to 28 (b) grid points 29 to 56

The highest species richness of natural enemies occurs in the Order Hymenoptera, which includes ten families, 20 genera and six species identified. The second highest species richness from Order Coleoptera consists of five families, 16 genera and nine identified species. Order Hemiptera has the third-highest species richness includes five families, eight genera and five identified species.

In Order Araneae, family Tetragnathidae, the highest mean number of *Tetragnatha maxillosa* (18.29 ± 4.83 individual) occurs at G10. *Tetragnatha maxillosa* is a spider species that is very active during the night and preys upon brown planthopper (*Nilaparvata lugens*), leafhopper (*Nephotetteix* sp.), and some other insect pest species (Betz and Tscharntke, 2017). Spiders are used as a biological control agent of rice pests instead of chemicals (Khan, 2013). In Coleoptera, the highest mean number of *Bledius filipes* (12.40 ± 12.40 individual) from the family Staphylinidae occurs in G16. It might feed on algae and detritus (Mark, 2006). The mean number of *Anthicus* sp. (1.33 ± 0.72 individual) from family Anthicidae occurs in G43. Ant-like flower beetles are mainly saprophagous, some species being predaceous or anthophilous (feeding on flowers) (Telnov, 2008). Insects are directly beneficial to humans by producing honey, silk, wax, and other products. Indirectly, they are important as pollinators of crops, natural enemies of pests, scavengers, and food for other creatures (Hoffmann and Frodsham, 1993). Under Order Dermaptera, the highest mean number of *Euborellia annulipes* (1.00 ± 1.00 individual) from the family Anisolabididae is observed in G56. In Order Diptera, the highest mean number of *Tornosvaryella oryzaetora* (2.57 ± 1.93 individual) from the family Pipunculidae is in G22. In Order Hemiptera, the highest mean number of *Cyrtorhinus lividipennis* (199.20 ± 133.46 individual) belongs to the family Miridae in G18. Predators are mainly from Order Heteroptera include *Cyrtorhinus lividipennis* (Miridae) and *Microvelia douglasi* (Veliidae), being the most abundant species (Heong et al., 1991).

Under Order Hymenoptera, the highest mean number of *Aphelopus* sp. (15.60 ± 15.35 individual) belongs to the family Dryinidae and occurs in G7. Noyes (2008) reported that several species of Eulophidae are important in biocontrol programs throughout the world. Hymenoptera is the most important insect order due to many insect species that are potential pollinators and parasitoids. Its ecological specialist species are also being used widely for habitat quality assessment (Trevis, 1996). In Order Odonata, the highest mean number of *Agriocnemis pygmaea* (5.50 ± 5.50 individual) belong to the family Coenagrionidae and occur at G43. In Order Orthoptera, the highest mean number of *Anaxipha longipennis* (3.17 ± 1.40 individual) belongs to the family Gryllidae from G29. Among them, the observed dominant rice natural enemy species is *Cyrtorhinus lividipennis* belonging to Order Hemiptera. This result was consistent with the finding of Heong et al., (1990), who stated that the mirid bug *Cyrtorhinus lividipennis* was found to predate on the eggs and nymphs of both leafhoppers and planthoppers, preferring mainly BPH eggs. The population density of *Cyrtorhinus lividipennis* increase in the abundance of the BPH and WBPH. Brown planthopper and Whiteback planthopper provide a broader range of food sources for an extended period during the growing season.

CONCLUSION

This study indicates that, arthropod natural enemy species diversity is medium in most of the grid points for the study period. Sample results yielded eight orders, 30 families, 57 genera, and 28 species of arthropod natural enemies in the study. According to the results, the observed species diversity index was considered in the medium criterion. The recorded equitability (evenness) of most grid points was nearly equally abundant, and some are high single-species dominance. The population of *Cyrtorhinus lividipennis* was higher than other species in all grid points. Therefore, the diversity of natural enemy species varied widely according to different grid points due to adjacent habitats, cropping patterns of the area, farmers' practices such as irrigation, pesticides, fertilizers, and pests. Therefore, it may be assumed that the Brown planthopper and Whiteback planthopper populations are abundant in this and previous year and found vegetation near the field in this study area. Brown planthopper and Whiteback planthopper provide a wider range of food sources for an extended period during the growing season. Some insects such as *Bledius filipes*, *Anthicus* sp., *Berosus* sp. from Order Coleoptera and *Manica* sp. from Order Hymenoptera are found as beneficial insects because of vegetation near the field. Proper identification and understanding of natural enemies, as well as beneficial insects, is the first step in implementing biological control and enhancing pollination activity. Therefore, Natural enemies and beneficial insects in rice fields play an important role in agriculture. Suppose we create a better environment for natural enemies by using non-chemical control methods at different rice growth stages. In that case, many natural enemies may suppress pest populations, which may benefit the farmers. The present study's findings may help provide valuable information for farmers to improve biological control techniques. Additionally, further studies should be undertaken to establish the abundance and different natural enemies present in this area.

ACKNOWLEDGEMENTS

The authors would like to thank the generous financial and technical training support provided by the Japan International Cooperation Agency (JICA) Project for Capacity Development of Yezin Agricultural University (YAU-JICA TCP). We are also appreciative of the authorized persons from the Department of Agriculture (DoA) for facilitating the farmers' participation in this project.

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Research article

Profitable Management Styles of Small-Scale Pig Farming in Rural Areas of Cambodia

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Received 15 January 2020 Accepted 29 November 2020 (*Corresponding Author)

Abstract For years, farmers in rural Cambodia have practiced small-scale pig farming mainly with family-based production. However, in recent years, there has been an increasing inflow of imported pigs grown with a lower production cost in neighboring countries. In addition, the share of products from domestic large-scale pig farming using commercial production systems has been increasing. This situation has led to price fluctuations in Cambodia's highly competitive pig and pork meat market, which affect family-based small-scale pig farming in rural areas. This study aimed to identify various management styles of small-scale pig farming and analyze their business status to discuss the profitable management styles under low sale price conditions. To grasp the pig farming styles, key informant interviews were conducted with government officers, middlemen, and pig farmers in the Treang and Tramkak districts of Takeo Province and in urban markets of Phnom Penh. The economic statuses of pig farming were clarified by interviewing the pig farmers and observing their rearing practices in the same areas to compare the profitability of different management styles. As a result, three pig farming styles were identified: fattening, breeding, and both. On the other hand, some farmers fed their pigs mainly with rice liquor residues with compound feeds, while some did not use rice liquor residues at all but mainly compound feeds. The comparative analysis of their economic statuses clarified that combining the fattening and breeding operations and feeding the pigs with both compound feeds and rice liquor residues effectively decreased the production costs and yielded comparatively high profits.

Keywords small-scale pig farming, import, by-product, agro-processing, animal feed

INTRODUCTION

In Cambodia, which is positioned as one of the least developed countries in the world, about 80% of the population of about 15.57 million people (WB, 2015) lives in rural areas (MOP, 2013). Among the working population, 64.3% are engaged in the agriculture sector (ADB, 2015) and account for 28.2% of the gross domestic product of the country (WB, 2015). The Cambodian government has prioritized the sector for poverty alleviation through increased income from agriculture, including crop and livestock production (MOP, 2014). Due to recent economic and population growth, the demand for meat has increased and this can enhance livestock production (MAFF 2015). Since then, pork has been the most consumed meat in Cambodia, and small-scale farmers have supplied about 70% of the pigs consumed (Huynh, et al., 2006). However, the importation of pigs and pork meat from Vietnam and Thailand has been increasing (Tornimbene and Drew, 2012). Cambodian domestic pig production peaked in 2006, before starting to decrease (FAO, 2020). Since mid-2015, the price of pigs has been decreasing due to increasing pig imports, and local farmers cannot meet their daily expenses (Phnom Penh Post, 2016). Tornimben and Drew (2012) argued that the increase of lower priced imported products has discouraged Cambodian farmers from raising pigs and in extreme cases, abandon their business. Vathana and Takeya (2006) clarified the advantageous conditions of that have resulted in lower production costs in those neighboring countries compared to small-scale Cambodian pig production. In addition, in 2012 the Association of South East Asian Nations signed a free trade agreement to lift the tariff barriers of all items within the region (FAO, 2012). This loss of protection could greatly impact small-scale pig farmers under more severe business environments in the near future. Moreover, as large-scale pig companies with commercialized production systems have increased their supply share in Cambodia, the family-based small-scale pig farming faces more challenges competing with cheaper and higher quality pigs from both imported and commercialized products (Thai, 2018). Strom et al (2017) clarified that small-scale pig farmers recognized the main constraints to pig-keeping were high feed costs and pig diseases as well as low pig sales prices. Recently, the high cost of compound feed and high labor requirement make it less attractive for farmers to continue this business (Ashley et al., 2018).

Previous studies on pig farming in Cambodia discussed the advantages of utilizing agricultural by-products as pig fattening feeds (Vathana and Takeya, 2004). Yagura et al (2010) suggests that the by-products of rice milling and rice liquor production can be used as pig fattening feeds when available in appreciable quantities. However, no research has been found that gives a detailed situation on how small-scale pig farmers in Cambodia are coping with the declining price of pigs due to the increasing pig importation.

This study aimed to identify various management styles for small-scale pig farming and analyze their business statuses to discuss the profitable management styles under low sales price conditions.

METHODOLOGY

This study consisted of three field studies, including key informant interviews, semi-structured interviews, and structured interviews with small-scale pig farmers on their management styles and business statuses to determine the more profitable management styles for pig farming in the rural areas of Cambodia. The key informant interviews aimed to determine the necessary information for further field studies, including the location and recent situation and issues of pig farmers in the survey area. In order to identify existing management styles of pig farming, semi-structured interviews were conducted with all the available pig farmers in the survey area according to the result of key informant interviews. Finally, semi-structured interviews were conducted with pig farmers who had different management styles to analyze their business status, including all the necessary costs and sales to calculate their profit. Then, a profitable management style and its characteristics were discussed through a comparative analysis among the business status of different management styles.

Target Area and Data Collection

The surveys for this study were conducted in Tramkak and Treang districts of Takeo Province (Fig. 1) which are in rural regions where the numbers of small-scale pig farming were confirmed with the rice liquor production (Hamano, et al., 2013). Takeo Province is located between Phnom Penh (capital city) and the Vietnam border, which are connected by the National Roads.

The key informant interviews were conducted to understand pig farming management styles and its distribution system in the survey areas in August 2016. The key informants selected for the study were government officers at animal husbandry offices, the district office under the provincial Department of Agriculture, the merchants at the local markets, slaughterers, middlemen, and several pig farmers.

Semi-structured interviews and observations to collect data on the economic status of pig farming were conducted in August and September 2016. First, the simple survey to understand the farmers' management styles, which could be breeding or/and fattening, as well as their feeding operation and main material, was conducted with 21 farmers in the two districts. Five of these farmers with different management styles took part in the detailed survey through semi-structured interviews on their economic status and observation of their operations. The data on the production costs on revenue were collected, including the cost of piglet, feeding in several growth stages, facility and health care, growth periods and weight increases of pigs, the weight of sold a pig and its sales price, and profit from the various management styles.

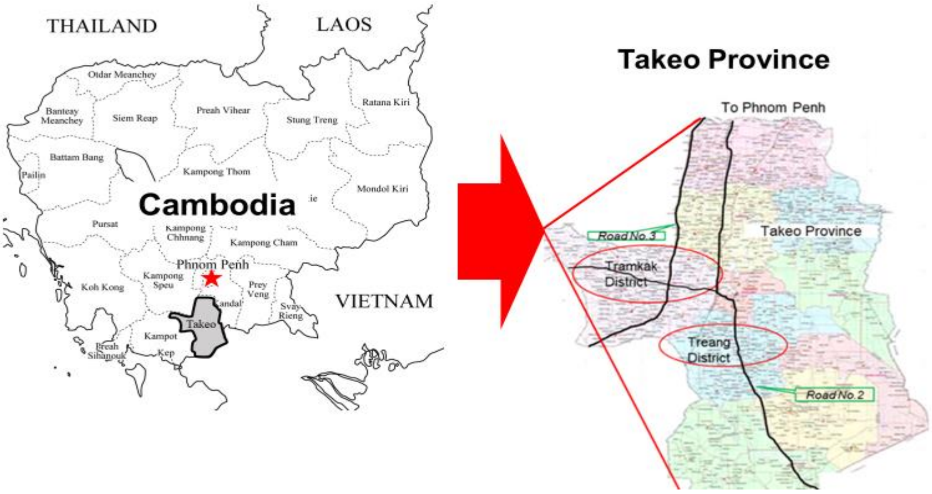

Fig. 1 Target areas for the survey

An analysis of the profitability was conducted by comparing the profit per pig (head) and the farmers' monthly income from pig farming. The monthly incomes were also simulated under the lower sales prices than those at surveyed time, -1,000 Riel (4,000 R = 1.00 USD), -2,000 Riel, and -3,000 Riel to examine which management styles can survive under a fluctuating pig market.

RESULTS AND DISCUSSION

Management Styles of Pig Farming

Pig farmers were targeted and interviewed to grasp their operation styles in the areas. As a result, 21 farmers were interviewed and three styles of operation were confirmed: only breeding (2 farmers), breeding and fattening (8 farmers), and only fattening (11 farmers). Their feeding operations were also confirmed. Fifteen farmers fed the pigs mainly with rice liquor residues and compound feeds, while 6 farmers mainly used compound feeds without rice liquor residues (Table 1).

Table 1 Identified management styles of pig farming

Management style	No. of interviewed pig farmers		
	Main feed material		
	Rice liquor residue and compound feeds	Compound feeds	Total
Breeding	1	1	2
Breeding + fattening	3	2	5
Fattening	11	3	14
Total	15	6	21

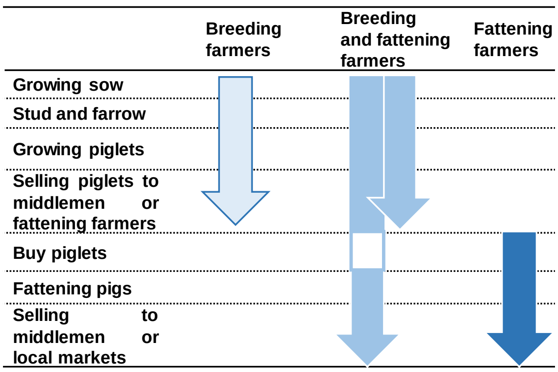

Fig. 2 Chain of pig production system

Fig. 2 shows the distribution flows of the piglets and fattened hogs according to the results of key informant interviews and semi-structured interviews with the 21 pig farmers. Three types of pig farmers, only breeding, breeding and fattening, and only fattening, were identified. The farmers who breed and fatten the pigs obtained all piglets from their own breeding. One breeding cycle is generally about 5 months. The farmers who only fattened the pigs purchased the piglets directly from breeders or from middlemen. The fattened pigs were sold through middlemen or transported by pig farmers themselves to the local markets in the surveyed areas, where they were marketed either by a slaughterer in the same district, by a middleman, or sometimes by the farmer himself.

Business Status in Different Management Styles

To conduct semi-structured interviews on production cost and sales revenue and observe the pig farming practices, five of the 21 interviewed farmers were selected for the survey. The farmers included: two farmers (A and B) who focused only on fattening using rice liquor residues and compound feed; one farmer (C) who focused only on fattening using compound feeds without rice liquor residues; and two farmers who managed both fattening and breeding, one (D) of which used liquor residues and compound feeds while the other (E) only used compound feeds. There was no chance to interview the farmers of animal breeding in detail.

The farmers were asked about their production costs and sales revenue for one fattening cycle for farmer A, B, and C, and one cycle of breeding and fattening for farmer D and E. Table 2 shows compares the profitability of different management styles based on the production costs including feeding and piglet costs, sales revenue, fattening periods, and increase in weight.

Farmer A focused on pig fattening by feeding them mainly with rice liquor residues and compound feeds. The rice bran from a neighboring miller and water convolvulus from her garden and pond were used as feeds. Farmer A bought 17 piglets, each of which weighed about 7 kg. Three piglets died from a disease in the very beginning, and the remaining 14 pigs were sold at a weight of 79 kg each after 5 months of fattening. Feeding costs were the highest proportion at 63.3% of the total costs at 5,268,000 R. The piglet cost was the second highest proportion at 32.3% of total expenses. Health and facility cost shared 4.4%. The sales of 14 pigs at a price of 8,000 R/kg earned a profit of 3,532,000 R.

Farmer B focused on pig fattening by feeding them mainly with rice liquor residues, compound feeds, and rice bran. Three pigs weighed about 35 kg each; they were fattened for 3 months after purchase, and all of them were sold at a weight of 105 kg each. Farmer B only purchased pigs that had been grown for 2–3 months since the risk of managing them is low compared to piglets with a higher risk of disease and death. The pigs can also be fed with rice liquor residues from the starting point, while piglets, after weaning, require a different compound feed for about a month. The pig cost was almost as high as the feeding cost, making up 48.0% and 49.5% of the total production cost (2,012,000 R), respectively. Farmer B sold the three pigs at a price of 8,500 R/kg and made a profit of 666,000 R.

Farmer C managed pig fattening operation by feeding the pigs with only compound feed and rice bran without rice liquor residues. The feeding cost shared the highest ratio at 68.6% of total costs at 1,921,000 R. Subsequently, piglet cost for 5 piglets which weigh around 5 kg each shared 26.0% of the total cost. All 5 piglets were fattened to 65 kg/head on average and sold at a price of 8,000 R/kg gaining the profit of 679,000 R.

Farmer D managed both the breeding and fattening operations. The farmer fed pigs with rice liquor residues, rice bran, and compound feed. Table 3 shows the production costs and sales in the breeding stage. Farmer D grew a total of 28 piglets from 3 mother pigs (sows). Nine of them were sold as piglets; 11 were fattened as hog for sales; 2 females were grown to be sows, while 6 died before weaning. For the breeding stage, the feeding cost for sows and piglets shared 77% of the total breeding cost at 744,000 R. The sales of 9 piglets gained a profit of 801,000 R in breeding stage. In the fattening stage (Table 2), the total cost of farmer D was 2,783,000 R for 11 fattened pigs. In addition, for the feeding cost and piglet cost were 85.9% and 13.4% respectively of the total cost. No medicines and vaccines were used during the fattening stage. All 11 fattened pigs were sold at 7,800 R/kg with 63 kg of each body weight and generated a profit of 2,638,000 R.

Farmer E also managed both the breeding and fattening operations. The pigs were not fed with rice liquor residues. As shown in Table 2, 20 piglets were grown by farmer E from two sows. Thirteen of them were sold as piglets, while the remaining seven were fattened. The feeding cost at the breeding stage was 83.1% of the total breeding cost of 1,423,000 R. The profit from the 13 piglets sold was 1,677,000 R. The breeding cost per head could be considered as the piglet cost per head at the fattening stage in Table 2. The total cost of Farmer E was 3,104,000 R for 7 fattened pigs for 4 months fattening period. The feeding cost and the piglet cost were 83.6% and 16.0% respectively of the total cost. The 7 pigs were sold at 8,500 R/head with 5 kg body weight and gained a profit of 393,000 R.

Profitability among Different Management Styles

Farmer A and farmer C were compared based on their differing feed management systems, as far as using rice liquor residues, on the similar conditions of the piglets, at 5 to 7 kg/head and around 1 month old, for fattening initiation. The feeding cost per pig for farmer A was 9.8% lower than that for farmer C. The feeding cost to increase 1 kg weight in famer A's pigs was 24.2% lower than that of farmer C. The fattened pigs were sold at the same price, therefore farmer A's sales revenue per pig was 21.0% higher than farmer C, based on the weight of pig sold. Therefore, the profit per pig of Farmer A was 85.3% higher than that of farmer C. The monthly income per pig of farmer A was 47.1% higher than that of farmer C. Using rice liquor residues in the feed resulted in improving the cost effectiveness per 1 kg of weight gain, contributing to lowering the feeding cost per pig and achieving a lower total cost and higher profit per head. As a result, the monthly income per pig was also higher even though farmer A's system took 1 month longer than farmer C's. Although farmer B fed the pigs with rice liquor residues and compound feeds, the initial cost for purchasing bigger pigs, feeding cost per pig, and feeding cost to gain 1 kg weight were 39.5% and 42.5% higher, respectively, than those of farmer A. As a result, production cost per pig for farmer B was 78.5% higher than for farmer A. Profit per pig for farmer B was 11.9% lower than for farmer A. However, farmer B took only 3 months to build 70 kg weight in the pigs while famer A took 5 months to build 72 kg, and contributed to farmer B's attainment of a higher monthly income per pig that was 48.0% higher than that of farmer A.

The main difference between farmer D and E was the feeding operation of either using rice liquor residues or not using them for both breeding and fattening management. The feeding cost per sow and per piglet of farmer D were 51.7% and 49.1% lower, respectively, than the feeding cost for farmer E. As a result, the production cost per piglet of farmer D was 52.1% lower than that of farmer E. Additionally, the feeding cost per pig and feeding cost to gain 1 kg of body weight for farmer D's pigs were 41.5% and 45.5% lower, respectively, than those of farmer E. As a result, the production cost per pig was 43.0% lower than that of farmer E. Profit per pig for farmer D amounted to about 4.3 times that of farmer E's pigs. Monthly income per pig for farmer D was 3.4 times of that for farmer E.

The profitability between only fattening management and both breeding and fattening management can be compared between farmer A and farmer D under the same feeding operation of using rice liquor residues, compound feeds, and rice bran (Table 2). The feeding cost per pig and the feeding cost to increase 1 kg weight on the pigs of farmer A at 238,000 R and 3,328 R, respectively, are similar to those of farmer D at 217,000 R and 3,439 R, respectively. However, the piglet cost per head for farmer D is 34,000 R, which is 66.0% lower than that for farmer A.

As a result, the production cost per pig for farmer D is 32.7% lower than that for farmer A. Since the body weight of farmer A's sold pig was 79 kg, which is 16 kg heavier than that of Farmer D's sold pig, the sales revenue per pig for farmer A is 27.6% higher than that for farmer D. Profit per pig and monthly income per pig for farmer A were 252,000 R and 50,000 R, respectively. This was similar to price per pig and monthly income per pig for farmer D at 240,000 R and 48,000 R, respectively, and were higher than those for farmer C and farmer E.

Table 2 Comparisons of profitability in different management styles

Farmers	A	B	C	D	E
Management styles	Fatten -	Fatten -	Fatten -	Fatten Breed	Fatten Breed
Compound feeds	Use	Use	Use	Use	Use
Rice liquor residue	Use	Use	Not use	Use	Not use
Pigs for starting	17	3	5	11	7
Pigs marketed	14	3	5	11	7
Death loss	3	0	0	0	0
Growing period (month)	5	3	4	5	4
Feed cost (‘000 R)	3,335	996	1,318	2,390	2,595
Piglet cost (‘000 R)	1,700	966	500	372	498
Facility cost (‘000 R)	83	50	3	21	11
Health cost (‘000 R)	150	0	100	0	0
Total cost (‘000 R)	5,268	2,012	1,921	2,783	3,104
Total weight of sold pigs (kg)	1,100	315	325	695	412
Average starting weight (kg)	7	35	5	-	-
Average sold weight (kg)	79	105	65	63	59
Unit price of sold pig (R/kg)	8,000	8,500	8,000	7,800	8,500
Revenue (‘000 R)	8,800	2,678	2,600	5,421	3,498
Profit (‘000 R)	3,532	666	679	2,638	393
Profitability (fattening) (%)	40.1	24.9	26.1	48.7	11.2
Feed cost/pig (‘000 R)	238	332	264	217	371
Feed cost to gain 1 kg weight (R)	3,328	4,743	4,393	3,439	6,306
Piglet cost/pig (‘000 R)	100	322	100	34	71
Production cost/pig (‘000 R)	376	671	384	253	444
Sales revenue/pig (‘000 R)	629	893	520	493	500
Profit/pig (‘000 R)	252	222	136	240	56
Monthly income/pig (‘000 R)	50	74	34	48	14
Monthly fattening income (‘000 R)	706	222	170	528	98
Monthly income from piglet sales (‘000R)	-	-	-	160	335

Note:

- *The feeding cost included feed material and purchased feed price and amount during the several stages of fattening period. Feeding cost using the rice liquor residues were accounted at zero cost since rice liquor earned incomes.*
- *Piglets cost consisted of the unit price per head and the numbers purchased for fattening operators. Piglet cost for both the fattening and breeding operators consisted of numbers of sows and piglets with breeding costs included the feeding cost of sow and piglets, as well as the facility and health management costs.*
- *The facility cost accounted with 10 years of pig house depreciation and health management cost.*
- *The labor cost was not included in the calculation since all the respondents operated with only family members.*

Profitable Management Style under the Low Sales Price

Fig. 3 simulates the change in the monthly income per fattened pig under declining sales prices. Farmers reported that lower pig sales price per kg of weight in the past were in the range of 5,000 R-7,000 R which were 1,000 R-3,000 R lower than the current sales prices at around 8,000 R-8,500 R. Farmers C and E who fed the pigs with compound feed without rice liquor residues faced a deficit when sale prices decreased 2,000 R and 1,000 R respectively.

On the other hand, farmer A and D, who feed the pigs with both rice liquor residues and compound feed, can remain profitable with sales price decreasing 3,000 R. The amount farmer B generated on a monthly basis as income per pig was around 1.5 times that of farmer A and D at the sales price during the survey. However, if the sales price went down by 2,000 R, farmer B would run into a deficit due to the higher production cost per pig compared to Farmer A and D. The comparison between farmer A and D also shows that farmer D can keep advantageous income during the sales price declines due to a lower production cost than farmer A.

Table 3 Comparisons of economic statuses of breeding managements

Farmers	D	E
Mother pigs	3	2
Born piglets	28	20
Sold piglets	9	13
Fattened piglets	11	7
Grown as sow	2	0
Dead piglets	6	0
Production cost ('000 R)		
Feed: sows	518	1,073
Feed: grown piglets	56	110
Facility	42	15
Health	128	226
Total cost	744	1,423
Cost/ piglet	34	71
Sales, cost, profit: Sold piglets ('000 R)		
Unit price for sales	123	200
Sales revenue	1,107	2,600
Production cost	306	923
Profit	801	1,677
Monthly income	160	335

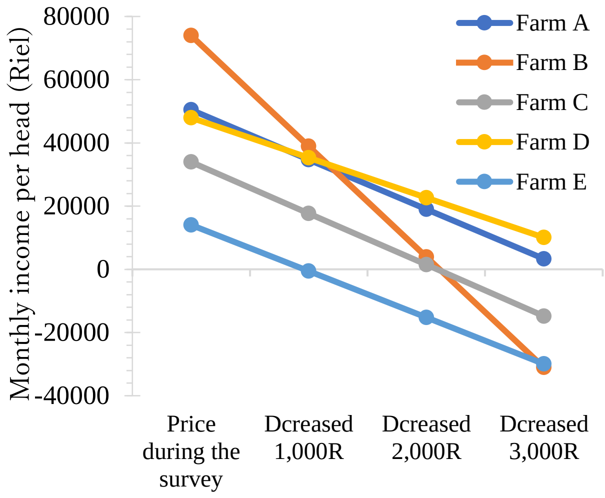

Fig. 3 Monthly incomes per fattened pig

The comparison of the feeding operations between rice liquor residues and/or compound feeds shows that rice liquor residues contributed in lowering the feeding cost. The feed management of farmers A and D with rice liquor residues, compound feeds, and rice bran showed a higher feed cost efficiency to increased body weight relationship than those of farmers C and E who used only compound feeds and rice bran. Comparing farmers who deal with breeding and/or fattening operations revealed that an integrated management of both can contribute to a decrease in piglet costs for fattening. The total cost of breeding sows by feeding them with rice liquor residues can produce piglets at a lower cost than the purchasing price in the market, which includes the margin of breeders and middlemen. As a result, the initial fattening cost can decrease, and it can contribute to the decrease in the total cost. Additionally, breeding can generate income from piglet sales.

CONCLUSION

This study aimed to identify the management styles of small-scale pig farmers in Cambodia and to discuss the profitability of each style by comparing their economic statuses. The results of the interviews and observations to farmers indicated the effectiveness of integrated pig farming operations with breeding and fattening stages and feeding management with rice liquor residues and compound feeds to decrease the production costs. The results showed possible challenges for small-scale farmers to sustain a profitable status despite the lower sales prices of pig markets in Cambodia.

The integrated management requires more skills and knowledge on both fattening and breeding management, including mating and taking care of small piglets that could easily die from diseases. Wider spaces to take care of sows and piglets are also necessary. To feed pigs with rice liquor residues, a farmer needs to manage rice liquor production and sales activities, which require equipment and stable operations and sales. Thus, further studies are necessary to understand how the farmers obtain and accumulate the information and experiences of the production techniques and business managements, how they cope and optimize their businesses within the limited resources in labor, finance, land, equipment, and materials in family-based small-scale productions, and what kind of external interventions are necessary and effective.

ACKNOWLEDGEMENTS

We thank Faculty of Animal Science, Royal University of Agriculture, Cambodia, for supporting this survey. This study was supported by Grants-in Aid for Scientific Research (No. 16714767) from the Ministry of Education, Culture, Sports, Science and Technology of Japan.

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Research article

Selection Index for Yield and Yield Contributing Traits in Improved Rice Genotypes

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Received 15 January 2020 Accepted 29 November 2020 (*Corresponding Author)

Abstract To select improved rice lines according to a selection index, a field experiment was conducted using fifty improved rice genotypes, during the dry season of 2017 at the Department of Plant Breeding, Physiology and Ecology, Yezin Agricultural University, Myanmar. The examination used a Randomized Complete Block Design with three replications. Days to 50% flowering, plant height, number of effective tillers per hill, filled grain percentage, 1000 seed weight, number of spikelets per panicle, harvest index and yield per plant exhibited highly significant differences indicating the existence of genetic variability among the improved rice lines. There was not much variability in panicle length. Seed yield per plant was positively and significantly correlated with days to reach 50% flowering, plant height, the number of effective tillers per hill, filled grain percentage, number of spikelets per panicle and the harvest index at phenotypic and genotypic levels. This shows that indirect selection on these traits would be effective in improving grain yield. At the genotypic level, path coefficient analysis shows that number of spikelets per panicle, the 1000 grain weight, filled grain percentage, number of effective tillers per hill, plant height and harvest index has a positive influence on seed yield. The selection index based on the combination of number of effective tiller per hill, filled grain percentage, number of spikelets per panicle and seed yield per plant (ETPP+FGP+SPP+SYPP) has the highest genetic advance and relative efficiency. This indicated that indirect selection via these traits would be more efficient than direct selection using yield alone. Therefore, the genotypes; YAU-1215-S-S-S-41-1-1, YAU-1211-9-3-1, YAU-1211-71-1-1, YAU-1211-118-2-1 and YAU-1201-151-1-1 could be selected based on multiple traits selection for further evaluation.

Keywords correlation, genotypic, path analysis, phenotypic, selection index

INTRODUCTION

Improving grain yield is one of the main objectives of many breeding programs. Seed yield is linked to a complex inheritance and it is an ultimate expression of different factors. It is highly affected by environmental variations. The knowledge of the interrelationship among various yield and yield component traits is necessary for an effective breeding program (Sarwar et al., 2004). Path coefficient analysis can estimate the causes and measurement of the relative importance of each of the yield components can also separate the direct effects from the indirect ones that are due to other characters (Ibrahim et al., 2012). Moreover, the effectiveness of a plant breeding programs depends on the ability of a breeder to select superior individuals or families for many traits of interest (Strefeler and Wehner, 1986a).

The economic value of a plant depends on the value of its different traits, therefore, plant breeders should consider simultaneous selections for several traits to maximize the economic value of a plant (Rabiei et al., 2004). Moreover, breeding and selection programs often incorporate several characters simultaneously (Hill et al., 1998). It is necessary to choose individuals with the best combination of desirable traits when considering several traits. The basis for this selection is a selection index, which is a combination of traits to select, according to their relative weighting. Gains from selection for any given trait is expected to decrease as additional traits are included in the index, therefore the choice for traits to be included must be done accurately (Hallauer and Miranda, 1981).

The Smith Hazel index is considered the optimum index when accurate estimates of variances and covariance are available (Hazel, 1943; Strefeler and Wehner, 1986b). However, this index requires a quantitative genetic study to estimate genetic variances and covariance and the assignment of relative economic weights to each trait (Strefeler and Wehner, 1986a). The Smith (Smith, 1936) and Hazel (Hazel, 1943) index and its various modifications (Kempthorne and Nordskog, 1959; Tallis, 1962; Elston, 1963; Pešek and Baker, 1969) have been shown to be the most efficient methods to achieve aggregate genetic progress compared with any other direct single trait selection methods.

OBJECTIVE

The objectives of this study were to determine the interrelationship between yield and yield contributing characters and to select the rice line(s) based on the selection indices and their relative efficiencies in providing improvement in yield.

MATERIALS AND METHODS

Fifty rice genotypes developed at Yezin Agricultural University (YAU), Myanmar were used in this study. These genotypes were developed by crossing parental lines such as Sin Thwe Latt, Yadanar Toe, Sin Thu Kha, Long 8, Shwe Thwe Yin and Long 6. Pedigree, bulk and single seed descent methods were used to develop these lines. The genotypes were evaluated at the Department of Plant Breeding, Physiology and Ecology at YAU during the 2017 dry season. The experiment site was located in Yezin Agricultural University, Zeyar Thiri Township, Nay Pyi Taw, Myanmar, latitude 19° 10' N and longitude 96° 07' E with an elevation of 102 m above sea level.

These genotypes were grown in a randomized complete block design, with three replications. The spacing was 20 cm × 20 cm with 100 hills per block. Standard agronomic practices and plant protection measures were applied to ensure good crop growth and complete grain development. The data collected were; days to 50% flowering (days) (DTF), plant height (cm) (PH), number of effective tillers per hill (no.) (ETPP), panicle length (cm) (PL), filled grain percentage (FGP), 1000 grain weight (g) (TGW), number of spikelets per panicle (no.) (SPP), harvest index (HI) and seed yield per plant (g) (SYPP). All the traits were measured following the guidelines provided by the Standard Evaluation System for Rice (SES) prepared by the International Rice Research Institute, Philippines (IRRI, 2002).

Analysis of variance (ANOVA) and correlations were generated using STAR v.2.0.1 (STAR, 2014). Path coefficient analysis was worked out using SPAR v 2.0 (Statistical Package for Agricultural Research, Version 2.0) software and R programs. Selection indices were constructed using the method developed by (Smith, 1936) based on the discriminate function of (Fisher, 1936). The economic weight for Smith Hazel Index was used to evaluate the direct effects from path analysis. The 10 % selection intensity was used to estimate genetic advances. The estimates of genetic advance were expressed as a percentage of the genetic progress obtained from seed yield per plant alone, which was assumed to initially be 100%, and it was used to compare the relative efficiencies of the different selection indices.

RESULTS AND DISCUSSION

Mean Performances and Analysis of Variances for Yield and Yield Component Traits

The analysis of variance revealed statistically significant differences at 0.1% probability level among the genotypes, for all traits except panicle length (Table 1). This indicates that there is much genetic variation among genotypes in all characters.

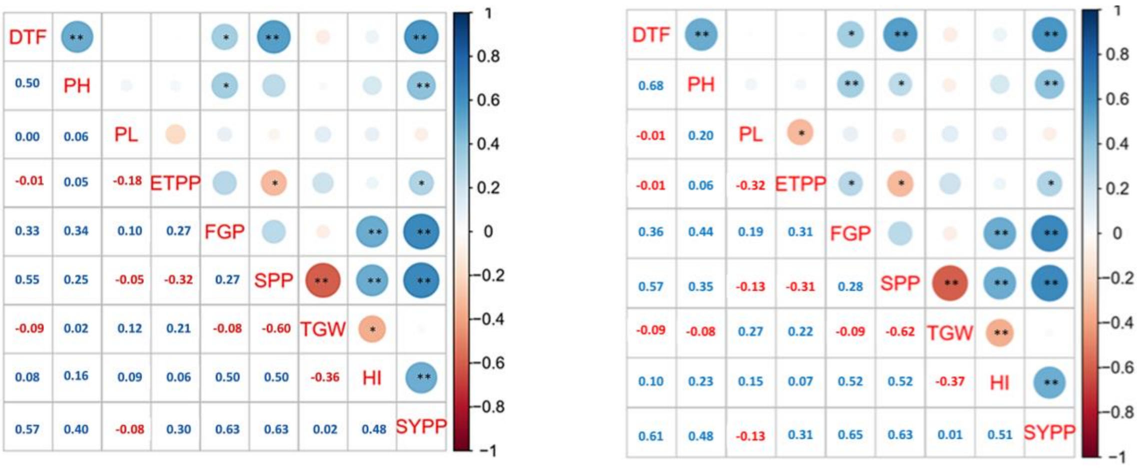
Table 1 Analysis of variance for yield and yield components in 50 rice genotypes

Trait	Replication	Genotype	Error
Days to 50% flowering	2.007	79.728**	5.367
Plant height	179.554	657.449**	294.131
Panicle length	6.125	5.679	4.012
No. of effective tillers per hill	4.903	6.509**	0.747
Filled grain percentage	14.992	94.504**	4.966
No. of spikelets per panicle	534.068	2422.678**	102.384
1000 grain weight	3.079	28.801**	1.013
Harvest index	0.0009	0.0067**	0.0004
Seed yield per plant	19.227	145.634**	7.989

** *Significant at 1% probability level*

Correlation Coefficient Analysis

There were 12 positive and 3 negatively significant correlations at phenotypic level and 14 positive and 4 negatively significant correlations at genotypic level for the nine traits measured (Fig. 1 a and b). At genotypic and phenotypic levels, seed yield per plant was positively and significantly correlated with days to 50% flowering, plant height, number of effective tillers per hill, filled grain percentage, number of spikelet per panicle and harvest index. This showed that indirect selection based on these traits will improve grain yield.



(a) **(b)**

Fig. 1 Phenotypic correlation (a) and genotypic correlation (b) among agronomic traits in 50 rice genotypes

*The tests of significance were indicated as **, * at 1% and 5 % probability level, respectively. The blue colour shows the positive association and red colour indicates the negative association and the intensity of the colour indicates the degree of association.*

Path Coefficient Analysis

At phenotypic level and genotypic level, all of the direct effects, with the exception of one, were below one, suggesting that inflation due to multicollinearity was minimal (Fig. 2). At both levels, the direct effects for number of spikelets per panicle were positive and of greater magnitude than direct effects for the other traits. At phenotypic level, number of spikelets per panicle (1.07), 1000 grain weight (0.60), number of effective tillers per hill (0.42), filled grain percentage (0.30), plant height

(0.04) and harvest index (0.01) showed a significant positive direct effect with seed yield per plant. At genotypic level, path coefficient analysis showed that number of spikelets per panicle (1.05), 1000 grain weight (0.67), filled grain percentage (0.34), number of effective tillers per hill (0.32), plant height (0.14) and harvest index (0.02) influenced seed yield directly in a positive direction. These are the primary yield components in tested genotypes. In other words, when there is an increase in the performance of these characters, seed yield per plant can also increase. However, days to 50% flowering (-0.15) and panicle length (-0.17) had direct negative effect on seed yield per plant.

At genotypic level, days to 50% flowering (0.61) followed by harvest index (0.55), plant height (0.37) and filled grain percentage (0.30) exhibited a high order of positive indirect effect on seed yield per plant via number of spikelets per panicle. The remaining estimates of indirect effects in this analysis were too low to be considered of any consequence. The estimates of residual factors (0.0581) were negligible in the present study. The residual effect determines how best the causal factors account for the variability of the dependent factor such as the standard evaluation score. Residual effect indicated that the characters which are selected in this study contributed 94% of variability of the standard evaluation score.

Therefore, the number of effective tillers per hill, filled grain percentage and number of spikelets per panicle had significant positive correlation with seed yield as well as exercising a positive direct effect on seed yield, suggesting the selection for these traits would be helpful for the improvement of seed yield. Path analysis studies revealed that the traits, such as the number of effective tillers per hill, filled grain percentage and number of spikelets per panicle can be considered as selection criteria in improving the seed yield of rice as these have a prominent direct effect. Hence, selection for these traits will improve the yield.

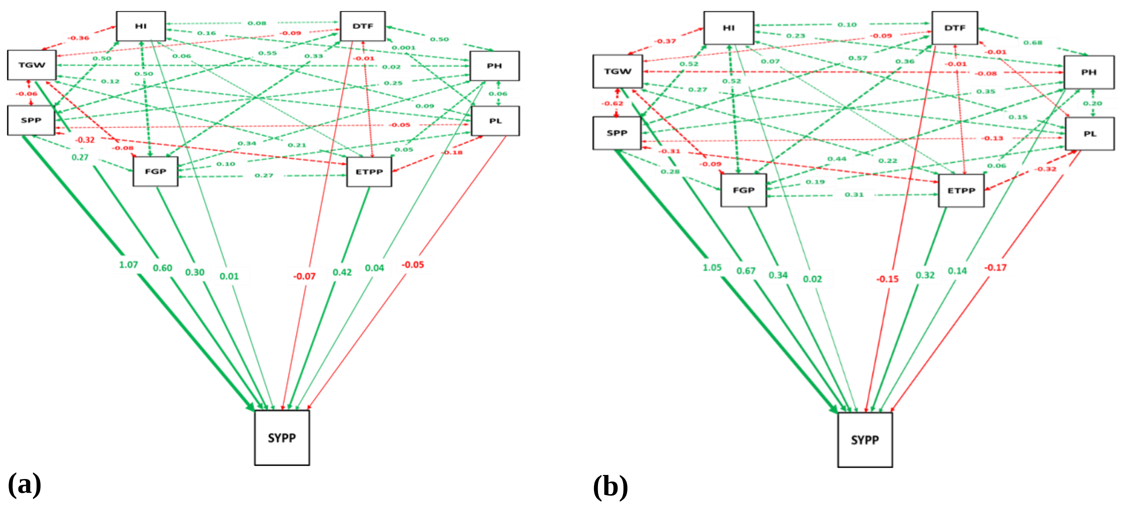


Fig. 2 Direct and indirect effects of seed yield and other related traits in path analysis at (a) phenotypic level and (b) genotypic level

Selection Indices

Fifteen selection indices containing two or more traits simultaneously were constructed. Out of fifteen, four selection indices were more efficient than direct selection for seed yield per plant. Using different combinations of yield and yield contributing traits, different selection indices were formulated and their expected genetic gain and relative efficiencies were estimated (Table 2). It was observed that among all selection indices, the index based on number of effective tiller per hill + filled grain percentage + number of spikelets per panicle + seed yield per plant (ETPP+ FGP+ SPP+ SYPP) had the maximum genetic advance (57.79) with relative efficiency (498.65). Among the others, the indices based on filled grain percentage + number of spikelets per panicle + seed yield per plant (FGP+SPP+SYPP), number of effective tillers per hill + number of spikelet per panicle + seed yield per plant (ETPP+SPP+SYPP), number of spikelets per panicle + seed yield per plant

(SPP+SYPP) showed high genetic gain with relative efficiency over straight selection for grain yield alone. Therefore, an improvement of grain yield is suggested through these selection indices.

Table 2 Selection indices for seed yield and their relative efficiency in YAU promising rice genotypes

Index	Genetic advance (g)/plant	Relative efficiency (%)
ETPP + FGP + SPP + TGW + SYPP	55.94	482.63
FGP + SPP + TGW + SYPP	55.93	482.54
ETPP + SPP + TGW + SYPP	54.51	470.36
ETPP+ FGP + TGW + SYPP	13.82	119.20
ETPP + FGP + SPP + SYPP	57.79	498.65
SPP + TGW + SYPP	54.60	471.10
FGP +TGW + SYPP	13.51	116.57
FGP + SPP + SYPP	57.67	497.61
ETPP + TGW + SYPP	11.68	100.80
ETPP+ SPP + SYPP	56.36	486.32
ETPP+ FGP + SYPP	13.54	116.84
ETPP + SYPP	11.25	97.03
FGP +SYPP	13.28	114.55
SPP + SYPP	56.31	485.83
TGW + SYPP	11.40	98.33
SYPP	11.59	100.00

Table 3 Comparison between relative genetic score of 50 rice genotypes based on the best selection index (ETPP + FGP + SPP+ SYPP)

Rank	Genotypes	Selection Index (Selection Score)	Rank	Genotypes	Selection Index (Selection Score)
1	YAU-1215-S-S-S-41-1-1	187.776	26	YAU-1201-187-1-1	127.507
2	YAU-1211-9-3-1	185.773	27	YAU-1215-B-B-B-168-1-1	126.567
3	YAU-1211-71-1-1	173.982	28	YAU-1215-B-B-B-10-1-1	125.120
4	YAU-1211-118-2-1	172.725	29	YAU-1201-206-2-1	122.602
5	YAU-1201-151-1-1	171.689	30	YAU-1211-121-2-1	122.587
6	YAU-1201-151-1-3	169.348	31	YAU-1201-202-2-1	122.458
7	YAU-1215-S-S-S-78-3-1	168.001	32	YAU-1214-B-B-B-33-1-1	122.174
8	YAU-1211-116-3-4	165.081	33	YAU-1201-90-2-2	120.390
9	YAU-1211-26-1-2	164.421	34	YAU-1201-90-1-1	117.818
10	YAU-1201-1-2-1	162.572	35	YAU-1214-183-3-3-1-1-1	117.552
11	YAU-1215-S-S-S-40-2-1	160.616	36	YAU-1201-202-2-2	116.408
12	YAU-1211-22-2-1	158.096	37	YAU-1201-61-3-3	115.993
13	YAU-1201-39-2-1	155.626	38	YAU-1215-188-3-1-2-1-1	115.741
14	YAU-1215-S-S-S-55-2-1	138.238	39	YAU-1215-B-B-B-139-3-1	112.413
15	YAU-1211-223-3-1	137.691	40	YAU-1215-B-B-B-134-1-1	112.031
16	YAU-1215-B-B-B-153-3-1	137.037	41	YAU-1214-183-3-4-1-1-1	109.247
17	YAU-1215-S-S-S-77-2-1	134.943	42	YAU-1201-61-3-1	107.198
18	YAU-1215-73-2-3-1-1-1	134.882	43	YAU-1215-S-S-S-115-1-1	103.131
19	YAU-1201-74-1-2	134.623	44	YAU-1215-B-B-B-141-3-1	102.619
20	YAU-1201-187-1-2	132.461	45	YAU-1201-16-2-1	101.812
21	YAU-1214-S-S-S-77-1-1	131.854	46	YAU-1201-121-3-1	99.830
22	YAU-1215-188-3-1-1-1-1	129.958	47	YAU-1215-80-1-2-1-1-1	95.564
23	YAU-1201-202-1-2	129.379	48	YAU-1215-B-B-B-52-3-1	95.304
24	YAU-1201-9-1-1	129.155	49	YAU-1215-S-S-S-113-1-1	79.839
25	YAU-1214-183-35-1-1-1-1	127.852	50	YAU-1214-187-1-1-1-1-1	77.424

Selection based on yield alone may be often misleading due to high environmental influence and multiple traits selection can improve selection efficiency and can attain largest economic gain. Therefore, utilizing the best selection index (number of effective tiller per hill + filled grain percentage + number of spikelets per panicle + seed yield per plant) (ETPP+FGP+SPP+SYPP), the relative genetic score of each genotype was determined (Table 3). It was found that the genotypes YAU-1215-S-S-S-41-1-1, YAU-1211-9-3-1, YAU-1211-71-1-1, YAU-1211-118-2-1 and YAU-

1201-151-1-1 were superior among all genotypes tested, having the optimal combination of attributes. These genotypes should be used for further evaluation.

CONCLUSION

Except panicle length, all the tested genotypes have a high variation in all studied traits. Number of effective tillers per hill, filled grain percentage and number of spikelets per panicle had significant positive genetic correlation with seed yield as well as employed positive direct effect on seed yield at genotypic and phenotypic levels. The selection index based on the combination of number of effective tiller per hill, filled grain percentage, number of spikelets per panicle and seed yield per plant (ETPP+FGP+SPP+SYPP) resulted the highest genetic advancement and relative efficiency. This indicates that indirect selection via these traits would be more efficient than direct selection considering yield alone. Therefore, the genotypes; YAU-1215-S-S-S-41-1-1, YAU-1211-9-3-1, YAU-1211-71-1-1, YAU-1211-118-2-1 and YAU-1201-151-1-1 are superior among all genotypes and could be selected for further evaluation.

ACKNOWLEDGEMENTS

The authors would like to express their sincere thanks to Japan International Cooperation Agency (JICA), Project for Capacity Development of Yezin Agricultural University for financial and technical support to conduct this study.

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Research article

Production and Quality of Biogas from Pilot Biodigesters using Cow Manure

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Abstract Biogas systems are being applied at commercial pig farms and at starch processing plants to manage their wastes and produce biogas for generating electricity or heat for on-site use. The installation numbers are increasing in Cambodia. The data on potential biogas production quantity from different feedstocks as well as on biogas quality are required to design the biogas systems. The purposes of this study was to determine biogas production and biogas quality from dairy cow manure produced in pilot digesters, and to analyze the variation in biogas production and quality during the year of 2019 and 2020. Pilot bio-digesters were installed at the Biogas Technology and Information Center, a research unit located in the Royal University of Agriculture, to obtain these data, since it is easier to do the experiments with the pilot digesters than that with commercial ones. The experiments were conducted during the year of 2019. In the experiments, 3 identical floating drum bio-digesters were used. Each bio-digester has 1 m^3 of volume and has been supplied mixture of 5-10 kg of fresh manure from dairy cattle with 5-10 liters of water every day. The daily biogas production quantity was recorded using a gas flow meter attached to the outlet of each bio-digester; also the gas quality, such as methane, carbon dioxide, oxygen, and hydrogen sulfide was measured using a portable biogas analyzer. The average rate of biogas production was around 37 liters of biogas per kg of wet manure. Average percentage of methane was around 52%, and average concentration of hydrogen sulfide varied from around 390 ppm to 604 ppm. These two parameters are the main indicators of biogas quality.

Keywords biogas, floating drum digester, cow manure, methane, hydrogen sulfide

INTRODUCTION

Global warming is the worldwide concern which is caused by greenhouse gas emissions. In Cambodia, methane is a major greenhouse gas from animal production. Ministry of Environment

(2002) projected that methane emission from domestic livestock would be 545 Gg in 2020 compared to 303 Gg from rice production, 2 Gg from grassland burning, and 5 Gg from agricultural residue burning.

Recently in Cambodia, animal production has increased in all kinds of animals, especially commercial farms. In 2017, there were 83 commercial cattle farms, 653 pig farms with total number of cattle and pig 20,363 heads, and 742,771 heads, respectively (MAFF, 2018a). According to Prakas no. 549 of the Ministry of Agriculture, Forestry and Fisheries issued on December 12, 2018, all commercial animal farms are required to manage their waste properly, especially using biogas systems (MAFF, 2018)

Currently, some commercial farms and agro-processing plants have already installed biogas plants to treat their waste and convert biogas to electricity for use on farms. To design biogas systems, data on potential biogas production and quality from various feedstocks are required. These data are available in other countries but not in Cambodia. To obtain these data in local condition, the use of pilot digester is more appropriate since it is difficult to do on commercial biogas systems.

OBJECTIVE

The objectives of this study were (1) to determine biogas production and quality from dairy cow manure by pilot digesters and (2) to analyze the variation in biogas production and quality during the year of 2019 and 2020.

METHODOLOGY

Experimental Procedure

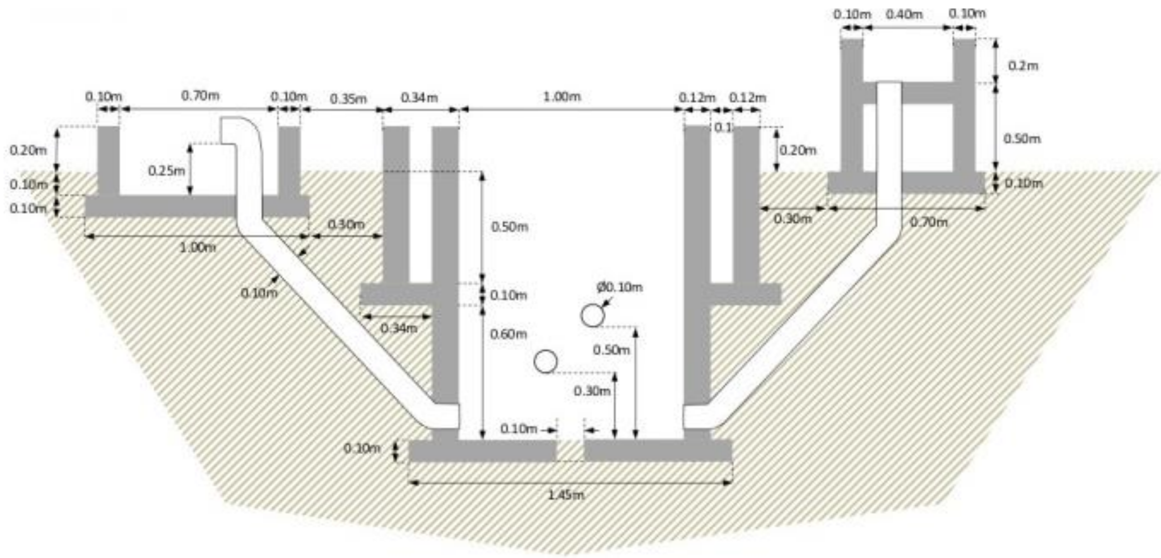
The experiment was conducted in 2019 and early 2020. Fresh cow manure was collected from dairy cattle farm located on the campus of the Royal University of Agriculture. The ratio of manure to water was 1:1 to bring down the percentage of DM to around 10% in the mixture (Farouk et al., 2017). The mixture was thoroughly mixed and solid pieces of grass were removed before feeding into the digesters to avoid sludge build up in the digesters. Daily manure used was 5kg/day or 10kg/day (fresh manure). At the beginning feeding rate of 5kg/day was used to start up the digester and then was increased to 10kg/day. Ground water was used to mix with the manure.

Table 1 Amount of feedstock and water used

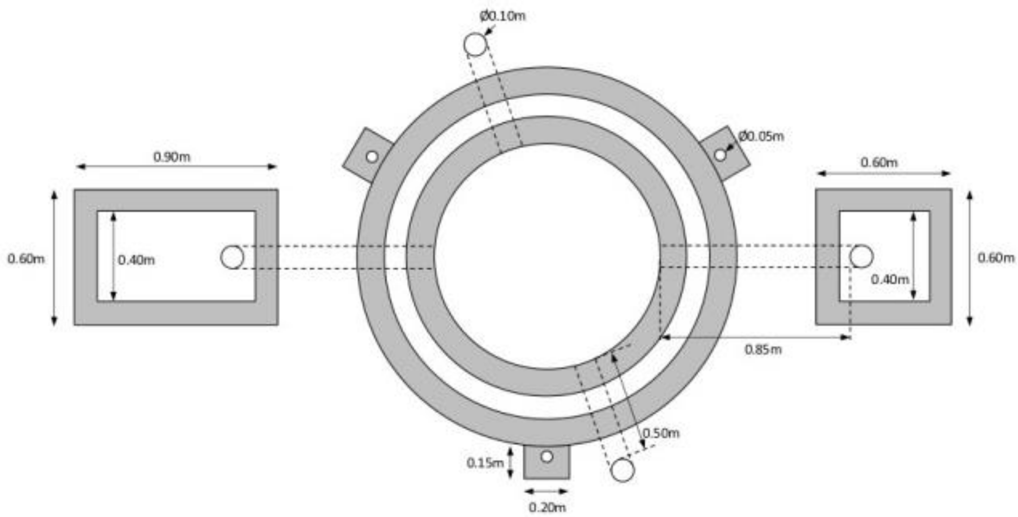
Digester	Mass of Feedstock (kg)	Mass of Water (liter)	Mix Ratio	Remark
Digester 1	5 to 10	5 to 10	1:1	- 25 February to 11 March 2019, 8kg/day of cow manure used - 12 March to 29 July 2019, 10kg/day of cow manure used - 30 July 2019 to 31 January 2020, 5kg/day of cow manure used
Digester 2	10	10	1:1	
Digester 3	10	10	1:1	

Three floating drum biodigesters of identical design were used, see Fig. 1. This design was selected because it would ease the modification of the digester for various experiments. It is equipped with two sampling pipes on the sides of the digester from which substrate can be extracted for analysis. Each biodigester has a total volume of $1m^3$. The hydraulic retention time was around 47 days, which depends on daily feeding rate of 5 kg or 10 kg, to ensure complete anaerobic digestion of the feedstock.

The duration of data collection was shown in Table 2. Digester 1 was started up in December 2018 and started to produce stable biogas in February 2019 and the daily biogas production was recorded. It took longer than 1 month before the digester started to produce biogas. After the low biogas production was observed for Digester 1, it was opened in September 2019 to make sure that there was no sludge building up in the digester. The digester 1 was restarted up again and began producing biogas in October 2019. Digester 2 and Digester 3 was completed the construction and started up in July 2019. During long holidays such as Cambodian New Year in April and Pchum Ben in September and Water Festival in November, data was not collected daily.



(a)



(b)

Fig. 1 Drawing of the pilot digester (a) side view (b) top view

From July to early August 2019, the biogas composition was measured once every two weeks. It was done daily since late August 2019 when the air injection experiment was conducted on Digester 2 to remove H_2S.

Daily biogas production was measured by using gas counter which was attached to the outlet end of the pipe. To avoid direct emission of methane into the atmosphere, it was burned by using a biogas stove after passing through the gas counter.

For the quality of the biogas produced, contents of methane, carbon dioxide, oxygen, and hydrogen sulfide were measured using a portable gas analyzer. The gas analyzer, Geotech Biogas 5000, was regularly calibrated to ensure its accuracy in measuring. At the beginning, the biogas quality was measured weekly. Later on, it was measured daily since there was a need to test hydrogen sulfide removal using air injection into gas holder of the digesters. The content of hydrogen sulfide before and after the air injection need to be measured daily.

Table 2 Duration of Data Collection

Digester	Duration of data collection	Remark
Digester 1	February 2019 to January 2020	-In September 2019, the digester was opened since the low biogas production was observed. After new startup, the digester started produce biogas in October 2019. -24 February to 11 March 2019, 8kg of manure per day
Digester 2	July 2019 to January 2020	
Digester 3	July 2019 to January 2020	

RESULTS AND DISCUSSION

Production of Biogas

During the monitoring, the average daily biogas production of digester 1, digester 2, and digester 3 were 238 L/day, 426 L/day, and 371 L/day, respectively. The average daily biogas production of the digester 1 was the lowest since it was fed mostly only 5 kg of cow manure per day. The average daily biogas production of digester 1 was only 71 L/day in February 2019. At that time, it was the beginning of biogas production after it was started up in December 2018. The daily biogas production of digester 1 and digester 2 were similar. The two digesters were constructed at the same time and fed 10 kg of cow manure daily. The fluctuation of average biogas production in each month may have been caused by quality of animal feed and weather conditions. Matos et al. (2017) reported that biogas production potential from dairy cattle manure raised under organic production system is lower than that of the conventional one which supplement commercial feed in the animal diet. Daily biogas production is higher in summer than in winter as reported by Choudhury et al. (2019) during evaluation of hydrogen sulfide scrubbing systems on two US dairy farms.

Table 3 Average daily biogas production of each digester (L/day)

	Digester 1				Digester 2				Digester 3			
Month	Avg (L/day)	Min (L/day)	Max (L/day)	Std (L/day)	Avg (L/day)	Min (L/day)	Max (L/day)	Std (L/day)	Avg (L/day)	Min (L/day)	Max (Lday)	Std (L/day)
Jan-19												
Feb-19	71	55	90	15								
Mar-19	159	67	223	42								
Apr-19	290	251	512	77								
May-19	253	184	300	25								
Jun-19	250	152	302	34								
Jul-19	251	178	316	33	467	417	523	38	428	200	517	125
Aug-19	192	133	596	92	466	158	544	68	354	123	501	101
Sep-19					375	104	500	99	375	104	500	99
Oct-19	411	175	652	133	453	276	599	70	416	259	579	80
Nov-19	199	66	549	123	409	146	494	73	302	227	419	52
Dec-19	179	24	367	80	390	126	497	107	306	176	429	76
Jan-20	204	98	350	71	423	227	719	108	415	299	664	79
Average	223				426				371			

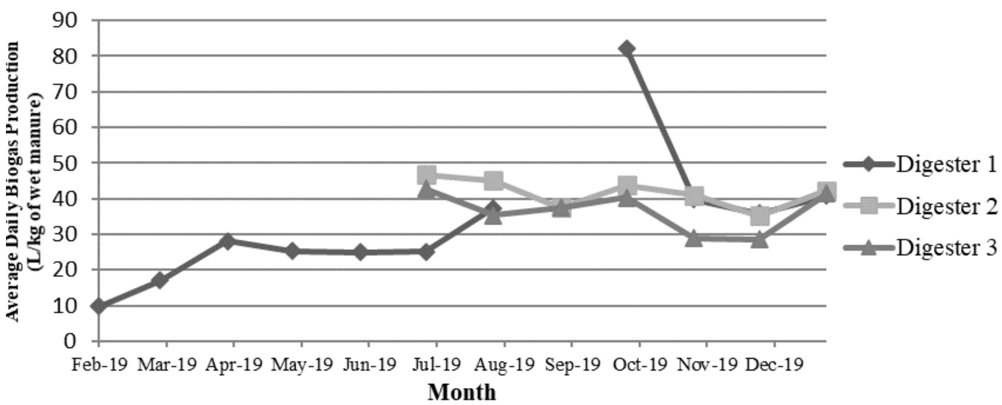


Fig. 2 Average daily biogas production per kg of wet manure (L/kg)

Average daily biogas productions per kg of wet manure were 33 L/kg, 42 L/kg, and 36 L/kg in digester 1, digester 2, and digester 3, respectively; see Fig. 2. The mean biogas production of the three digesters was 37 L/kg of fresh manure. After opening for checking in August 2019, the digester was restarted and began to produce biogas in early October 2019. In October 2019, the rate of biogas production was highest, around 80 L/kg of wet manure, due to the change of feedstock from cow to pig manure which yield higher biogas production rate from the same mass. Aremu and Agarry (2012) reported a little higher biogas production from pig manure than cow manure in Lithuania. Matulaitis (2015) found higher methane content in biogas produced from pig manure than from cattle one.

Quality of Biogas

Table 4 Biogas composition

	Digester 1					Digester 2					Digester 3				
Month	CH_4 (%)	CO_2 (%)	O_2 (%)	H_2S (ppm)	Bal (%)	CH_4 (%)	CO_2 (%)	O_2 (%)	H_2S (ppm)	Bal (%)	CH_4 (%)	CO_2 (%)	O_2 (%)	H_2S (ppm)	Bal (%)
Jul-19	48.8	35.0	1.1	410.5	14.6	50.7	35.3	0.3	446.5	13.8	50.9	35.6	0.2	503.0	13.4
Aug-19	48.2	36.2	0.6	410.0	14.6	51.2	38.3	0.3	273.1	10.1	51.3	38.6	0.3	265.4	10.1
Sep-19						51.1	41.6	0.4	115.6	6.1	51.1	41.6	0.4	115.6	6.1
Oct-19	51.9	38.4	0.1	751.7	9.7	49.4	40.2	0.2	169.7	10.2	49.0	39.0	2.0	242.6	9.9
Nov-19	52.5	39.3	0.1	692.4	8.1	50.0	40.6	0.1	299.6	9.3	50.4	41.3	0.1	584.6	8.2
Dec-19	55.4	42.2	0.2	722.0	2.2	54.9	41.9	0.1	740.3	3.1	54.6	41.3	0.0	936.1	2.3
Jan-20	54.3	43.3	0.1	637.5	2.8	53.2	42.4	0.2	693.3	4.2	53.8	43.3	0.1	897.5	2.7
Average	51.8	39.1	0.4	604.0	8.7	51.5	40.0	0.2	391.2	8.1	51.6	40.1	0.4	506.4	7.5

The average percentage of methane in digester 1, digester 2, and digester 3 were 51.8%, 51.5%, and 51.6% respectively; see Table 4. Abubakar and Ismail (2012) reported that average methane in biogas from cow dung from slaughterhouse in Malaysia was 47% which is similar to these results. Choudhury et al. (2019) reported average methane content of 64.1±0.2% in biogas of US dairy farms. Methane content fluctuates according to digester conditions and quality of feedstock. Average percentages of carbon dioxide in the three digesters were around 40%, while average percentage of oxygen was less than 1%. The average hydrogen sulfide varied from around 390 ppm to 604 ppm. The average highest concentration of 936.1 ppm was in the digester 3 in December 2019. Mean hydrogen sulfide in biogas from dairy farms in the US was 450±42 ppm (Choudhury et al., 2019). It is suitable for use with gas heating boiler and combined heat and power (CHP) systems (Allegue and Hinge, 2014; Petersson and Wellinger, 2009). To use with engine, it is recommended that hydrogen sulfide should be reduced to 100 ppm to 250 ppm (Bioclean, 2020).

CONCLUSION

The average daily biogas production of the pilot digesters, each with $1m^3$ working volume, varied from 223 L/day to 426 L/day when feeding with 5 kg to 10 kg of cow manure per day and mixed with water using 1:1 ratio. The average rate of daily biogas production was around 37 L/kg of wet cow manure.

The biogas contained on average 51.6% methane, 39.7% carbon dioxide, 0.3% oxygen, 500ppm hydrogen sulfide, and other gases was around 8.1%. Average percentage of methane was lower than the one reported in US dairy farms, which was around 64%. However it was similar to the one in Malaysia which was around 47%. The average hydrogen sulfide varied from around 390 ppm to 604 ppm. It is suitable to use with gas heating boiler and combined heat and power (CHP) systems.

However, it is not suitable to use with gas engine without pre-treatment system which is used to reduce hydrogen sulfide concentration in the biogas to 100 ppm to 250 ppm.

ACKNOWLEDGEMENT

This paper is made possible by funding from UNIDO through the project entitled “Reduction of GHG emission through promotion of commercial biogas plants”, which is jointly implemented by the Ministry of Environment (MOE), the Ministry of Agriculture, Forestry and Fisheries (MAFF) and UNIDO with financial support from the Global Environment Facility (GEF).

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Research article

Efficiency Evaluation of Solar Pumping System for Wadi Agriculture in Djibouti

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Received 11 Septem 2020 Accepted 30 November 2020 (*Corresponding Author)

Abstract Crop cultivation in Djibouti is mainly done by irrigation agriculture obtaining groundwater from wadi aquifer. The decreasing in the efficiency of solar power generation system due to panel-on-dust is reported to be the issue in terms of energy loss in pumping up water. In this paper, the effect of dust deposition for solar pumping system was evaluated at wadi agriculture farm in Dikhil, Djibouti. The amount of panel-on-dust was measured to be 1.88 and 2.1 g/m^2 in cooler season (dry deposition) and in hot season (wet deposition), respectively. Clearance of the panel-on-dust resulted a decline in the output power of photovoltaic panel due to the rise in panel surface temperature in January (cooler season), whilst the output power increased in September (hot season) when the panel surface temperature was relatively higher. The conversion efficiency of the photovoltaic power generation was calculated to be about 5 - 6% lower in September than in January. The whole conversion efficiency of solar pumping system was estimated to be about 2%. Since the ideal conversion efficiency was calculated as 6.76%, the gap from observed value of about 4.5% can be implied by suppressing water leakages from the system in pumping process.

Keywords Djibouti, panel-on-dust, photovoltaic panel, wadi agriculture

INTRODUCTION

The Republic of Djibouti, Northeastern Africa, locates under high temperature and low-rainfall climate environment. Most of the land surface is dominated by barren land (67-89%; Shimada et al., 2006) and the rainwater easily run off from the ground surface through wadi, ephemeral riverbed. Due to this harsh natural environment, agricultural activity is very difficult. In Djibouti, groundwater is pumped up to be used since enough amount of water cannot be collected from rainwater for agriculture. In the arid land under low-latitude regions such as Djibouti, abundant solar radiation is available, hence solar power generation has a potential for the pumping system. However, initial expense for installation of solar power system costs relatively higher than that of engine system. For this reason, engine systems are the most adopted cases for wadi agriculture, although the running cost exceeds in the long run for the engine pumps and causes pressure on management. The Government of Djibouti pronounces the use of renewable energy as a great important issue for the management of sustainable water resources to enhance the agricultural productivity. Therefore, it is important to establish an optimal method for operating solar power generation system in terms of cost and efficiency. Previous studies analyzed the cost of a pumping system using photovoltaic panel in wadi agricultural farm in Djibouti, a method for estimating an appropriate scale of pumping system (Tajima et al., 2012; 2014). However, in arid areas such as Djibouti, dust tends to accumulate on photovoltaic panels, and the dust accumulation normally reduces its output power (Sulaiman et al., 2011; Ghazi et al., 2014; Maghami et al., 2016; Daher et al., 2018). When introducing a PV system for agriculture, in arid environment like Djibouti, it is necessary to consider the effects of dust accumulation on photovoltaic panel. However, only a few studies analyzed on this effect and evaluated quantitively on photovoltaic pump in arid area like Djibouti (e.g., Tajima et al., 2012; 2014; Aden et al., 2009). In the current paper, we investigated one whole pumping system of wadi agricultural farm, where photovoltaic power generation is introduced as groundwater pumping system, in Dhikhil, Djibouti, in order to evaluate the efficiency of the system including the effect of dust deposition on photovoltaic panel.

METHODOLOGY

The target farmland located in Dikhil city (11.08863°N, 42.40089°E) (Fig. 2). The configuration of the solar pumping system used in the farm was as follows. LORENTZ: PS1800, SOLARWORLD: SW80 poly RNA: 80 W x 18 sheets. The solar array installation inclination angle was 11°, the azimuth angle was 130° (i.e., southeast), and the area of the array was about 12 m^2.

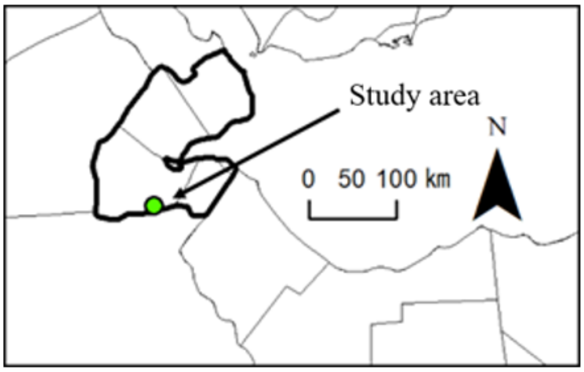


Fig. 1 Location of the study site in Djibouti

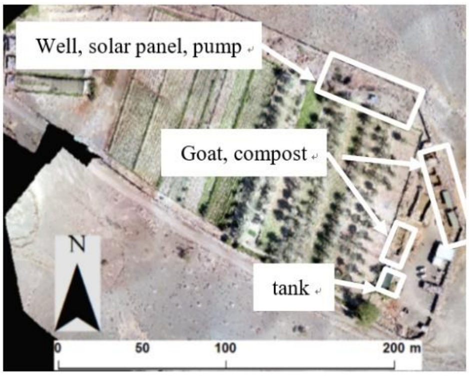


Fig. 2 Overview of the target farmland in Dikhil

Overview of solar pumping system is shown in Fig. 3, and agricultural system is shown in Fig. 4. During daytime, the farmers use solar pumping system to store groundwater into reservoir tank (about 100 m^3 storage). After around sunset, they switch to engine pumping system to pump up the groundwater from the well. The farmers use all the water needed for the farm management, such as irrigation, livestock, and others.

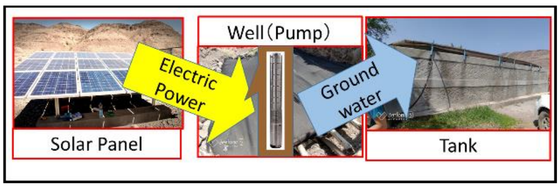


Fig. 3 Overview of solar pumping system in the target farmland

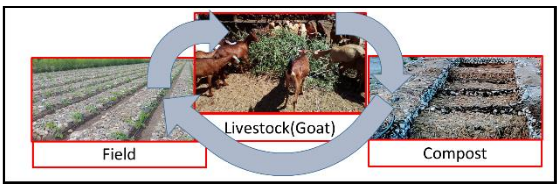


Fig. 4 Agriculture-livestock material cycling scheme in the target farmland

Survey was conducted in 2 seasons, i.e., cooler season (December 29, 2018 - January 14, 2019), and hot season (September 1, 2019 - September 30, 2019). Table 1 shows the items and periods of the data measurements, and Fig. 5 shows the overview of the measuring equipment in the farmland.

Solar pumping system consists of photovoltaic system and pump, which converts the electric power into the potential energy of water. However, the system has some loss of efficiency in the process of energy conversion (Fig. 6). The output electric power of the solar pumping system was measured by the multiplication of current and voltage. The values were compared before and after cleaning the panel-on-dust. The output efficiency was evaluated by comparing the changes in the output of the photovoltaic system with the output of the pumping system. The output efficiencies regarding panel-on-dust and panel surface temperature were also evaluated.

Table 1 Items and periods of data measurements

	Current ①	Voltage ②	Global solar irradiance ③	Panel surface Temperature ④	Temperature & Humidity ⑤	Wind Speed & Direction ⑥	Water level (Tank) ⑦	Water level (Well) ⑧	Flow rate ⑨
January	○	○	○	○	○	○	○	○	×
September	○	○	○	○	○	○	×	×	○

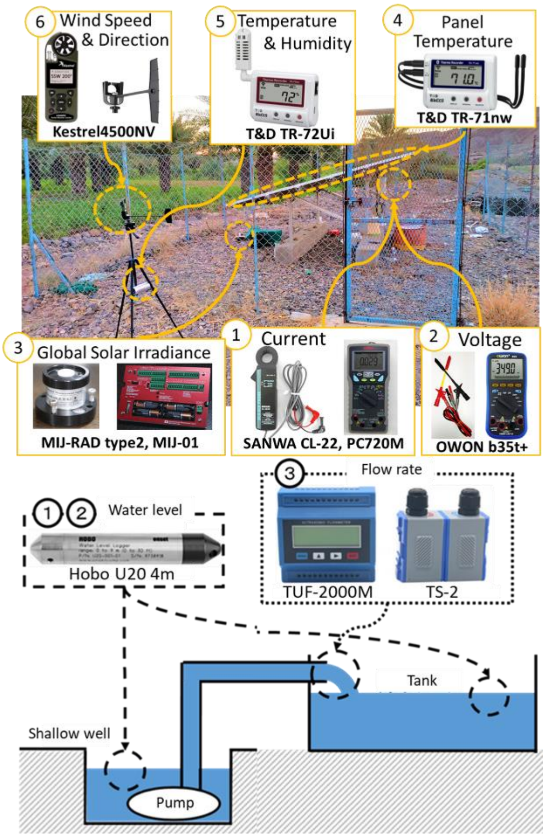


Fig. 5 Overview of the measuring equipment in the target farmland

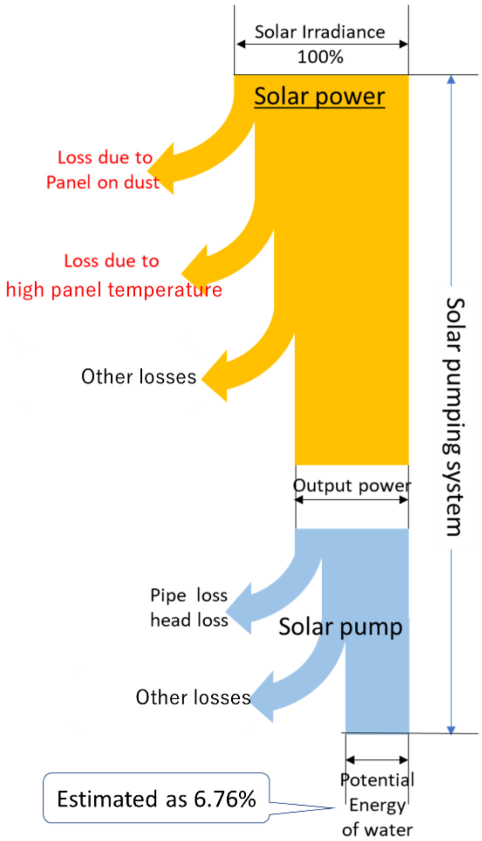


Fig. 6 The flow and loss of energy in the farm solar pumping system

RESULTS AND DISCUSSION

Cleaning of panel-on-dust was conducted on January 6, September 13 and 24, for the cooler and the hot season experiments, respectively. Fig. 7 shows the schedule and measured dry weights on cleaning of panel-on-dust. The panel-on-dust seems to occur more in September than in January. Dust accumulation for cooler season was observed to be dry deposition and weighed 1.88 g/m^2 in dry mass, while weighed more than 2.1 g/m^2 in dry mass and seemed as wet deposition due to rainfall events for hot season.

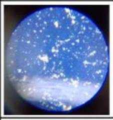
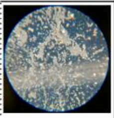
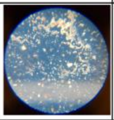
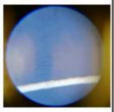
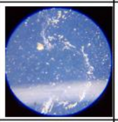
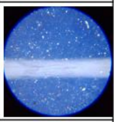
	1/6	1/7	~	9/12	9/13	9/14	9/15	9/24	9/25
Dust cleaning	○		~		○			○	
Dust weight	1.88g/m²	—	~	—	2.41g/m²	—		2.11g/m²	—
Panel surface image			~						
weather	Sunny	Sunny		Sunny 9/11 was rainy	Sunny	Sunny	Rainy	Sunny Sometimes cloudy	Sunny Sometimes cloudy

Fig. 7 Results of panel-on-dust measurement

Fig. 8 shows comparison of the output electric power of the photovoltaic system before and after clearance of panel-on-dust in January and September. As a result, the effectiveness of panel cleaning on output power was negative in January (75%), while positive in September (140%). This result indicates that clearing of the dust on the solar panel can cause decrement of photovoltaic efficiency in cooler season (January). This efficiency loss can be explained by the reason that effect of risen temperature of the photovoltaic panel surpassed the increase in input solar irradiance from the clearance of panel-on-dust.

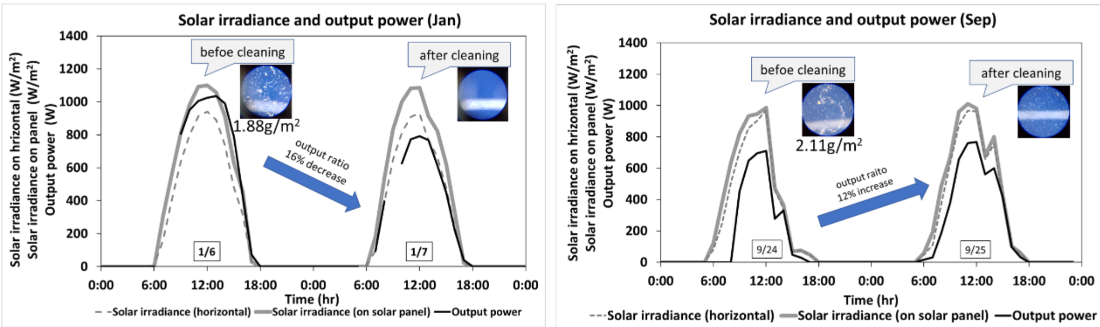


Fig. 8 Output power with solar irradiance (horizontal and on panel) before and after cleaning panel-on-dust (Left: cooler season, Right: hot season)

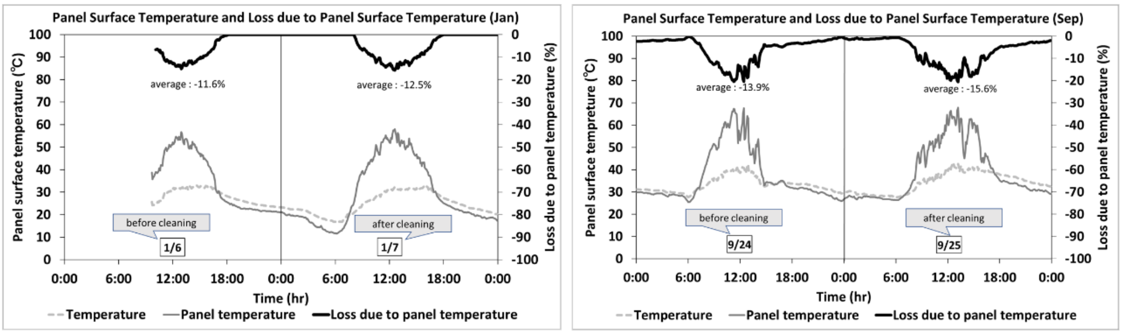


Fig. 9 Surface temperature of photovoltaic panel, air temperature and power loss before and after cleaning panel-on-dust (Left: cooler season, Right: hot season)

Fig. 9 shows panel surface temperature in January and September, and the output power loss due to the panel surface temperature. The maximum panel surface temperatures in January and September were 60.8℃ and 71.9℃, respectively. The theoretical daily power loss due to high panel temperature calculated from the photovoltaic panel specification (-0.48% $℃^{-1}$) was 11-13%, and 13-16%, in January and September, respectively. From the above results, the power loss from the high panel temperature is more remarkable in the hot season (September) than in cooler season (January). Clearance of panel-on-dust in the hot season can gain the efficiency of the output power, although theoretical energy loss from high panel temperature is relatively higher.

Table 2 shows calculated pumped water amount in January and September. Fig. 10 shows input and output energy of whole solar pumping system. Input energy is the solar radiation intensity received by the panel. The input energy was observed to be greater in January than in September. Ideal efficiency was estimated as 6.76% (Fig. 6), however, the efficiency of whole pumping system was calculated to be between 2.1 - 2.4% (Fig. 10). The reason for this gap in efficiency might cause mainly in the water loss, such as leakage from the water pipe.

Table 2 Output capacity of water pumping system before and after cleaning panel-on-dust

	1/6	1/7	9/24	9/25
Pumped water by solar	36.7 m³	35.3 m³	29.1 m³	33.6 m³
Pumped water by engine	36.0 m³	43.3 m³	38.0 m³	36.1 m³
Total pumped water	72.7 m³	78.6 m³	67.1 m³	69.7 m³

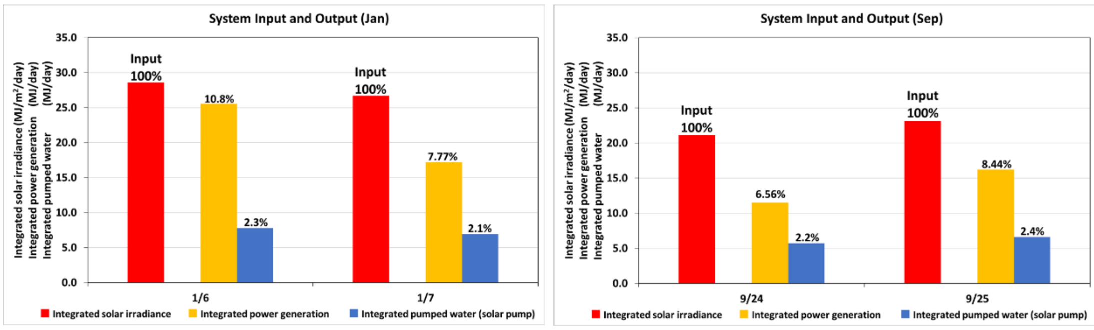


Fig.10 Input and Output energy of daily integrated energy before and after cleaning panel-on-dust (Left: cooler season, Right: hot season)

CONCLUSION

The panel-on-dust effects on photovoltaic efficiency for wadi agriculture solar pumping system in Djibouti was examined. The efficiency decline by the clearance of panel-on-dust in cooler season was discovered in this paper for the first time. This energy output loss was implied by the effect of risen temperature of the photovoltaic panel from the clearance of panel-on-dust. However, the clearance of panel-on-dust in the hot season can gain the efficiency of the output power.

The whole conversion efficiency of solar pumping system of wadi agriculture in Djibouti was also evaluated in this study. It was estimated to be slightly above 2%, although the ideal conversion efficiency was calculated as 6.76%, which gap can be caused by the water loss in the pumping process.

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Research article

Growth and Yield Performance of Different Potato Varieties under Upland Condition in Cambodia

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Received 12 March 2020 Accepted 1 December 2020 (*Corresponding Author)

Abstract In Cambodia, potato is imported. Currently, potato has the fourth largest production in the world cultivated in many countries even in semi-arid and tropical countries. Numerous new and improved varieties were developed to sustain and maintain production systems. Thus, performance evaluation of these varieties in Cambodia condition is important to improve potato production in the country. The experiment was conducted from December 2016 to March 2017 by testing 8 different imported varieties (Tornado, Corodana, Georgina, Madeira, Jelly, Julkinka, Red fantasy and Sorentina) under upland climate of Cambodia. The result showed that all varieties showed similar performance in terms of growth, but different in yield components and yield. Tornado variety was most adapted and productive varieties with an average yield of 23ton ha^{-1} followed by Madeira (19 ton ha^{-1}) while Red fantasy had the lowest production among the tested varieties under upland environment in Cambodia.

Keywords: Tornado, Madeira, Mondulkiri, upland, Cambodia.

INTRODUCTION

Potato, *Solanum tuberusom* L., is considered as an important source of carbohydrate and plays a key role for food security in many develop and developing countries (Scott *et al, 2000*). Thus, potato is currently the fourth largest production crop next after rice, corn and wheat (FAOSTAT, 2006). At the present, potato is fast adapted and grown throughout the continents, though the crop prefers cool climate (18 ºC without chilled) follow by warm environment (Havetkort and Struik, 2015). Optimum yield, at least 20 ton per hectare, has been attained in most temperate regions with average temperature of around 18-20ºC. High temperature, in the face of climate change, is one of limiting factors affecting potato production which is commonly found in most tropic and subtropics countries. In Cambodia, where the average daily temperature exceeds higher than 28 ^{o}C, fresh potato is imported mostly from Vietnam, Thailand and China. A number of production problems that account for such low yield have been identified. The major concerning of low and poor production were lack of well adapted cultivars, unavailability and high cost of seed tubers, inappropriate agronomic practices, diseases, insect pests, inadequate storage, transportation and marketing facilities (MAFF, 2016). As potato production continuously expand throughout the world, lots of new improved varieties have been bred and improved for different regions and countries. In connection with climate change, several technology package and new cultivar are highly considered as keys to maintain the production and prevent potato farming from exposed to the threat. Thus, new cultivars that are more resilient to high temperatures have been developed (Monneveux *et al.*, 2014). Some of those varieties were mainly breed in tropical countries (Muthoni and Kabira, 2015).

OBJECTIVE

The study was conducted to understand performance of different potato varieties planted in Mondulkiri province, Cambodia.

METHODOLOGY

Experiment was carried out under field condition from December 2017 to March 2018 at Mondulkiri province (12^{o}28'27" N, 107^{o}12'33" E). The site was 710 meters above the sea level with average of 26 to 30 ^{o}C and relative humidity of 70-90% upon the research conducted. Chemical and physical of the field was described in Table 1. The trial was layout in randomize complete block design with 4 replications. The treatment consisted of eight different imported potato varieties namely Tornado (IMP Potato group limited, Ireland) Coronada, Madeira, Goergina, Jelly, Red Fantasy, Jelly, Julinka, Sorentina (Europlant International, Germany).

Table 1 Soil physical and chemical properties analysis of experiment site

EC	pH	P ppm	K cmol$_c$ kg^{-1}	N %	SOM %	CEC cmol$_c$ kg^{-1}	Soil Texture			
							Clay	Silt	Sand	Class
38.0	4.20	0.1	0.42	0.29	5.07	72.4	22.3	35.3	42.4	Clay Loam

Source; Soil Laboratory, Faculty of Agronomy, Royal University of Agriculture, Cambodia

Trail was planted at density of 4.8 plants m^{-2} in plot of 6 meters long. Spacing of 70 cm between row and 40 cm between plant. Each plot was fertilized with 80 kg N ha^{-1}, 80 kg P_2O_5 ha^{-1} and 150 kg K_2O ha^{-1} at planting date. Addition of 40 kg N ha^{-1} and 100 kg K_2O were applied at ridging (45 days after planting). Weeds and pathogens were controlled chemically at the manufacturer's recommended rate to prevent biotics damage. The plots were surface irrigated every 3 days interval. Plant plants were harvested at 115 days from sowing. Growth and yield parameters were recorded. Plant height was recorded at flowering stage while number of tuber per plant, weight per tuber, weight per plant and marketable yield were measure at harvest.

RESULTS AND DISCUSSION

The result showed that all of the eight varieties reached its normal height and statistically similar to one another (P_{value}<0.05) (Fig. 1). Lizana *et al.*, (2017) explained that physical changing would not observed when the potato was cultivated under similar or little higher temperature (28 ^{o}C) which was about 30-47cm tall. The author also emphasizes that external factors such as high temperature (greater than 28 ^{o}C) would cause the change of the plant height.

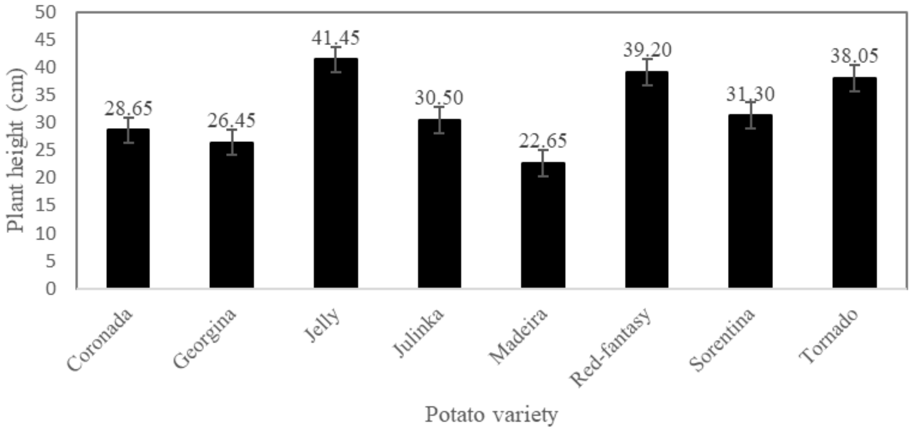

Fig. 1 Plant height at flowering stage of eight varieties

All of yield parameters were observed statistically different (P_{value}>0.05). In terms of yied component, Madeira, Julinka and Jelly had the highest number of tuber compared to Coronada and Red fantasy, but statistically similar to other three varieties (Fig. 2). Notably, the trial showed that Red fantasy produced the lowest number of tubers (Fig.2). In addition, Red fantasy also produced less weight per plant (less than 300 grams per plant) (Fig.3). However, similar result was recorded for Sorentina variety. The highest tuber weight per plant was observed for Tornado variety which could obtain about 700 grams followed by the second highest Madeira (about 600 grams per plant). Other varieties like Coronada, Jelly, Julinka and Georgina was third and not significantly different to one another (Fig.3).

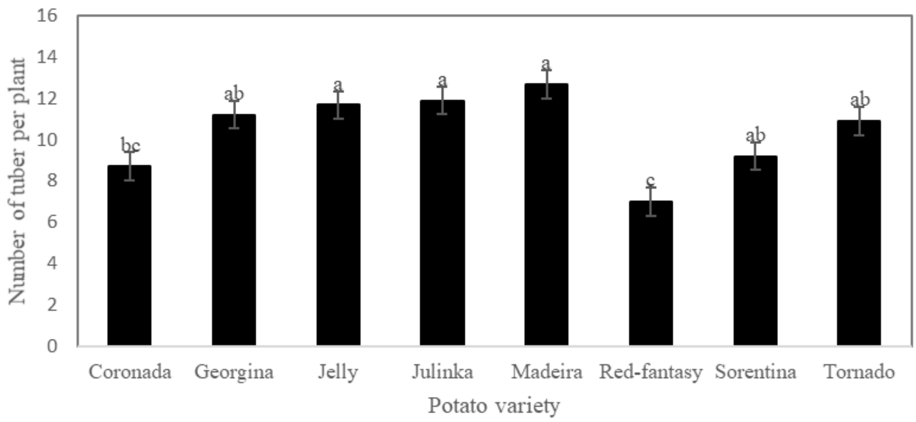

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Fig. 2 Tuber produced per plant

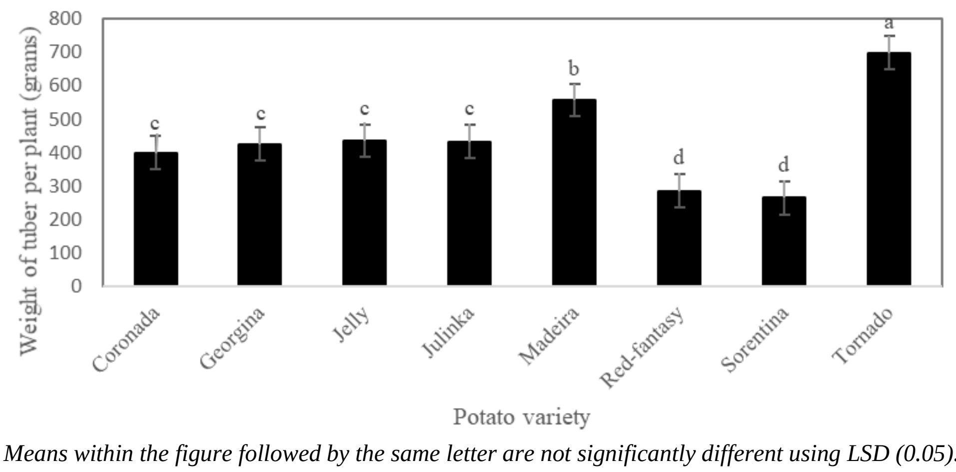

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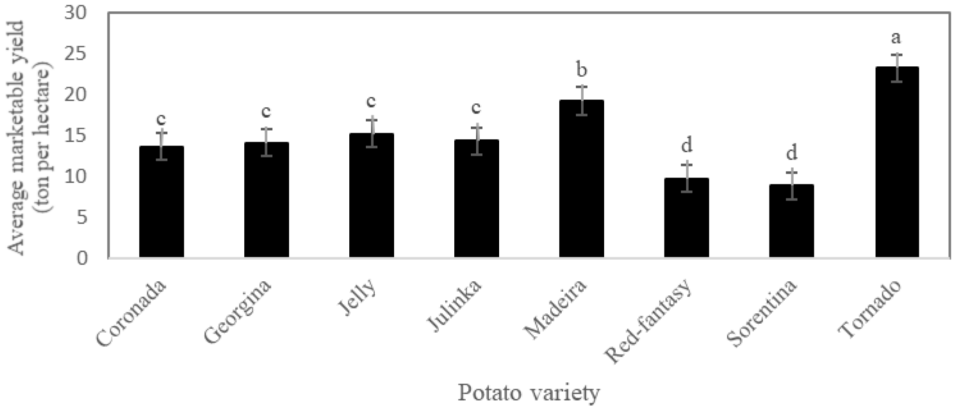
Fig. 3 Tuber produced per plant

In particular, Tornado, white flesh and red skin color, attained the highest yield (23ton ha^{-1}). It was commendably that different potato varieties result vary response to different growing condition and production system (Masengesho *et al.,* 2012; Gairhe *et al.,* 2017). Gairhe *et al.,* (2017) suggested that improved potato varieties had different response to different field condition such as altitude, soil type and ambient temperature. Author had also claimed that in warm and hot climate countries, most potato could grow well in upland rather than lowland areas, but not all improved varieties showed similar response or obtained higher yield.



Means within the figure followed by the same letter are not significantly different using LSD (0.05).

Fig. 4 Marketable yield obtain in the experiment

CONCLUSION

Our result suggested that all of the eight varieties had similar performance in terms of growth. Majority of the tested varieties were less productive (less than 13 ton ha^{-1}) which 20 percent lower than the average of global yield. However, Tornado and Madeira showed outstanding performance. Thus, Tornado, white flesh color and red skin, and Madeira, yellow flesh and skin color, were more adapted and productive in Mondulkiri province, Cambodia. Despite the yield, most of potatoes severely damage by diseases which literately susceptive for long-term production and suggested that farmers need to purchase and used only certified seeds for the production. However, the price of certified seed would cost 3.00 USD/kg with that farmers need to invest 2,000 to 3,000 USD to hectare cultivation. Thus, yield obtained should at least between 12 to 13 ton per hectare for economic benefit.

ACKNOWLEDGEMENTS

The authors would like to express his sincere thankfulness and appreciation to KOPIA Cambodia Center (2016-KHM-03), assistance funds, the Europlant International for the seed, GIZ for technical advice, my assistant; selected farmers for supporting and encouragement, key informants and information; your mighty support being my greatest source of motivation and inspiration.

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Research article

Reaction of Different Rice Varieties to Bacterial Blight

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Abstract Rice is the major food crop in Myanmar and bacterial blight is one of the devastating diseases affecting production. In this study, 37 local rice varieties and 41 rice lines were tested at Yezin Agricultural University, Myanmar, to three different isolates of *Xanthomonas oryzae* pv. *oryzae* to evaluate the resistance levels of these different rice varieties. The three bacterial isolates used in this experiment were collected from Zeyathiri, Zabuthiri and Pyinmana townships in Nay Pyi Taw Union Territory. At maximum tillering stage, the uppermost fully expanded leaves were inoculated by the clipping method. Three weeks after the inoculation, the percent leaf area of the inoculated leaves was visually estimated and the disease reaction of the rice varieties determined. The thirty-seven local rice varieties were classified into seven groups, with this grouping based on the reaction patterns to the three isolates. Group VII, which contained two varieties, Nga Sar Kay and Sinthukha, was moderately resistant to Pyinmana isolate and moderately susceptible to the Zeyathiri and Zabuthiri isolates. The rice varieties included in Group I to Group VI showed susceptible reactions to testing with all three isolates. Among YAU rice lines tested, YAU-1211-71-1-1 exhibited moderate resistance to the Pyinmana isolate only. Apart from the line mentioned above, all the other YAU rice lines, did not exhibit resistance reactions to the test isolates. Nga Sar Kay, a local rice variety, has the potential to be used in the future rice breeding programs and YAU-1211-71-1-1 is the promising one to be used in areas where rice bacterial blight disease is prevalent.

Keywords bacterial blight, resistant varieties, rice, *Xanthomonas oryzae* pv. *oryzae*

INTRODUCTION

Rice (*Oryza sativa* L.) is the most widely eaten staple food crop, especially in Asia, and is consumed by more than half the world's population. Unfortunately, rice crops are threatened by a considerable number of diseases (more than 40 diseases) of fungal, bacterial and viral origin, and these diminish rice yields throughout the world (Singh et al., 2013). Among rice diseases, bacterial leaf blight (BLB) caused by *Xanthomonas oryzae* pv. *oryzae* (Ishiyama) (Swings et al., 1990) is one of the most destructive and widespread diseases of rice. In Myanmar, bacterial blight is also one of the most serious diseases present, and every year, its occurrence has been reported from the different rice growing regions throughout the country (Lwin, 2006). Higher losses are common in tropical Asian countries, such as Myanmar, because of the prevalence of virulent pathogen populations and the susceptibility of the high yielding cultivars in tropical area (Aye et al., 2007). Yield losses due to the disease are estimated to range from 0.5% to 50% (Myint et al., 1983; Win, 2013).

Many control strategies, including various cultural practices, application of various chemicals and systematic use of chemical fertilizers have been attempted in an effort to control bacterial blight disease, but these management tactics have not been very effective. Although chemical control plays an important part in an integrated disease management program, it has a detrimental effect on human health and non-target, beneficial microorganisms. Non-systematic use of agricultural chemicals can also contribute to the emergence of new races of the pathogen and ultimately prove a waste of money for resource limited farmers. The most feasible, effective and economical way of controlling bacterial blight in Myanmar, is the exploitation of the host plant resistance. Moreover, use of resistant varieties is also compatible with other disease control methods. Although research on varietal resistance is conducted irregularly in Myanmar, varietal resistance is probably the most important area to focus on for effective disease management.

OBJECTIVE

This study was conducted to evaluate the resistance levels of different rice varieties and lines to *Xanthomonas oryzae* pv. *oryzae.*

METHODOLOGY

Test Varieties and Preparation of Plants

Thirty-five local rice varieties, and 41 YAU rice lines were used in this study. Manawthukha was used as a 'susceptible' control and Sinthukha was used as a 'resistance' control variety. Seeds of these rice varieties were obtained from the Department of Plant Breeding, Physiology and Ecology, Yezin Agricultural University. Firstly, rice seeds were sterilized in hot water at 56 ˚C for 15 minutes and germination accomplished using the paper towel method. Germinated seeds were sown in 20 cm × 20 cm plastic pots containing sterilized soil, and twenty- one day old seedlings of each of the test varieties were transplanted individually in plastic pots, containing 3 kg of lowland soil, and these were watered as necessary. Fertilizer application was carried out according to the standard methods of managing rice plants.

Bacterial Isolates

Three very virulent isolates (Isolate I, Isolate II and Isolate III which were collected from Zeyathiri, Zabuthiri and Pyinmana townships in Nay Pyi Taw Union Territory) of *Xanthomonas oryzae* pv. *oryzae* were used for inoculation in this experiment.

Inoculum Preparation and Inoculation

Isolates from preserved tubes were sub-cultured on peptone sucrose agar (PSA) (Tsuchiya et al., 1982) medium plates and incubated for two days. The bacterial suspension was prepared by suspending the bacterial mass from PSA plates in sterilized distilled water and adjusted to 10^8 cfu/ml using a Thermo Scientific Evolution 201 Uv-Visible Spectrophotometer. In order to distinguish the inoculated isolates, plants in a pot were bundled into three groups by labelling with different colored ties (Aye et al., 2007). Inoculation was done at maximum tillering stage, by clipping the uppermost fully expanded leaves of five tillers 2-3 cm from the leaf tips with a pre-sterilized pair of scissors, which were then dipped in the bacterial suspension (Kauffman et al., 1973).

Disease Assessment and Data Analysis

Percent leaf area infected on inoculated leaves were visually estimated 21 days after inoculation. Disease reaction of the rice varieties to the bacterial isolates were determined based on the disease scores (IRRI 1988) (Table 1).

Table 1 Standard Evaluation System for Rice (for bacterial blight) (IRRI, 1988)

% Leaf area infected	Score scales	Description
1-5	1	R
6-12	3	MR
13-25	5	MS
26-50	7	S
>50	9	HS

R: Resistant, MR: Moderately resistant, MS: Moderately susceptible, S: Susceptible, HS: Highly susceptible

RESULTS AND DISCUSSION

Reaction of Myanmar Local Rice Varieties

Thirty-seven Myanmar local rice varieties were evaluated for their reaction to three isolates of *Xanthomonas oryzae* pv. *oryzae*. Based on the reaction patterns to these three isolates, 37 rice varieties were characterized into seven varietal groups, Group I-VII is shown in Table 2. Thirteen Myanmar local rice varieties belonging to Group I were highly susceptible to Isolate I and Isolate II, and susceptible to Isolate III. Group II consists of seven rice varieties, which showed moderate susceptibility to Isolate III and were high susceptibility to Isolates I and Isolate II. In Group III, Khao Phee Phan and Thiri Done Pathein were highly susceptible to Isolate I, susceptible to Isolate II and moderately susceptible to Isolate III. Only one variety, Kauk Kyi Shan Ma, showed the same reaction (susceptible) to all three test isolates. Three varieties in Group V were susceptible to Isolate I, highly susceptible to Isolate II and moderately susceptible to Isolate III. Bacterial isolates I, II and III were virulent to all plants in Group VI, including the nine rice varieties which presented susceptible reactions to Isolate I and II and moderately susceptible reactions to Isolate III. Two varieties, namely Nga Sar Kay and Sinthukha, belonging to Group VII, exhibited a moderate resistance reaction to Isolate III and a moderate susceptible reaction to Isolates I and II.

Reaction of Yezin Agricultural University (YAU) Rice Lines

Forty-one varieties of YAU's promising rice lines were also tested for their response to these three isolates of *Xanthomonas oryzae* pv. *oryzae*. According to disease severity, these YAU rice lines were classified into eight groups, Group I-VIII is shown in Table 3. Group I include only the Manawthukha variety, which was highly susceptible to all test isolates. In Group II, three YAU lines showed highly susceptible reactions to bacterial Isolates I and II and a susceptible reaction to Isolate III. The three rice lines included in Group III expressed highly susceptible reactions to Isolate II and susceptible reactions to Isolates I and III. In Group IV, YAU-1201-90-2-2 showed the same reactions to Isolate I and II as in Group III but it displayed a moderately susceptible reaction to Isolate III. The twelve rice lines that belonged to Group V were susceptible to all test isolates. Group VI included nineteen tested lines and they were susceptible to Isolates I and II and moderately susceptible to Isolate III. Two rice lines in Group VII, YAU-1211-116-3-3 and YAU-1211-223-3-2, presented moderately susceptible reactions to the three test isolates. The lowest disease severity values were found in the varieties YAU-1211-71-1-1 and Sinthukha, which belong to Group VIII. Compared to other test varieties, these rated as moderately resistant to Isolate III and moderately susceptible to Isolate I and II.

In the evaluation of the reaction of rice varieties, almost all of the local rice varieties showed susceptible reactions to the three test isolates. Of the 37 Myanmar rice varieties, Nga Sar Kay and Sinthukha, expressed a moderate resistance reaction to Isolate III (Pyinmana) only. This result indicates that these varieties may harbor a gene resistant to Isolate III and so might be useful for further rice breeding program. In the present study, Sinthukha was moderately susceptible to two isolates (Isolate I and II). Although *Xa21* was used as a broad-spectrum resistance gene (Khush et al., 1990) in its breeding program, the Sinthukha variety which contains the *Xa21* gene, showed a moderately susceptible reaction to two isolates. A similar result was observed by Swamy et al., (2006) who reported that Pusa Basmati 1 and its transgenic derivative PB-*Xa21* were much more susceptible to virulent Mxo isolates than IRBB 21. The present finding is in conformity with the results of (Myint, 2008) and (Maung, 2014) who reported that Sinthukha was susceptible to a test isolate which showed a resistant reaction to IRBB 21.

Table 2 Reaction of thirty-seven rice varieties to three most virulent isolates of *Xanthomonas oryzae* pv. *oryzae*

Sr. No.	Name of local varieties	Disease reaction and Disease severity (%) to bacterial isolate		
		Isolate I (Zeyathiri)	Isolate II (Zabuthiri)	Isolate III (Pyinmana)
Group I				
1	Boke Thwin Phyu	HS (72)	HS (84)	S (43)
2	Khao Lin	HS (59)	HS (56)	S (26)
3	Muyinn Saba	HS (63)	HS (72)	S (30)
4	Yoe Wa	HS (53)	HS (63)	S (29)
5	V_{15}	HS (60)	HS (71)	S (30)
6	Bu Toyl	HS (56)	HS (72)	S (30)
7	Khun Na Yar Po	HS (63)	HS (67)	S (27)
8	Sa Wana	HS (66)	HS (90)	S (28)
9	Japan Ni	HS (73)	HS (66)	S (41)
10	Khao Mae Pan	HS (59)	HS (70)	S (29)
11	Lone Phyu	HS (55)	HS (84)	S (30)
12	Sa Bong Thaw	HS (72)	HS (86)	S (31)
13	Manawthukha	HS (73)	HS (71)	S (49)
Group II				
14	Ant Paw	HS (59)	HS (64)	MS (24)
15	Khao Pi Paung	HS (55)	HS (54)	MS (24)
16	Thu Kha-2	HS (55)	HS (67)	MS (24)
17	Tayote Hmwe	HS (59)	HS (67)	MS (25)
18	Shal Thu Kha	HS (54)	HS (66)	MS (24)
19	Aye Yar Padae Thar	HS (54)	HS (67)	MS (24)
20	Shwe Thwe Yin	HS (51)	HS (60)	MS (24)
Group III				
21	Khao Phee Phan	HS (51)	S (49)	MS (19)
22	Thiri Done Pathein	HS (52)	S (50)	MS (24)
Group IV				
23	Kauk Kyi Shan Ma	S (47)	S (44)	S (26)
Group V				
24	Kauk Kyi	S (48)	HS (60)	MS (17)
25	Khao Kham To	S (39)	HS (64)	MS (22)
26	Shwe War Yin	S (34)	HS (55)	MS (14)
Group VI				
27	Paw (1)	S (50)	S (50)	MS (25)
28	Paw San Hmwe	S (36)	S (39)	MS (21)
29	Khao Lamil	S (42)	S (45)	MS (17)
30	Naung Ta Moe Se	S (46)	S (48)	MS (21)
31	Kun Lone	S (48)	S (47)	MS (25)
32	Hmaw Bi Kyauk Nyin Hmwe	S (42)	S (27)	MS (21)
33	IR 36	S (43)	S (34)	MS (18)
34	Ma Naw Tun	S (50)	S (39)	MS (20)
35	Bu Aung Ban	S (48)	S (45)	MS (23)
Group VII				
36	Nga Sar Kay	MS (19)	MS (24)	MR (10)
37	Sinthukha	MS (16)	MS (14)	MR (8)

Sr. No.: Serial number, MR: Moderately resistant, MS: Moderately susceptible, S: Susceptible, HS: Highly susceptible

Table 3 Reaction of forty-one YAU rice lines and two check varieties to three most virulent isolates of *Xanthomonas oryzae* pv. *oryzae*

Sr. No.	Name of YAU rice lines	Disease reaction and Disease severity (%) to bacterial isolate		
		Isolate I (Zeyathiri)	Isolate II (Zabuthiri)	Isolate III (Pyinmana)
Group I				
1	Manawthukha	HS (84)	HS (90)	HS (81)
Group II				
2	YAU-1214-B-B-B-153-3-1	HS (52)	HS (66)	S (33)
3	YAU-1214-183-3-4-1-1-1	HS (54)	HS (68)	S (36)
4	YAU-1215-S- S- S-77- 2-1	HS (52)	HS (66)	S (30)
Group III				
5	YAU-1201-187-1-2	S (44)	HS (56)	S (26)
6	YAU-1201-1-2-1	S (39)	HS (53)	S (26)
7	YAU-1211-223-3-1	S (39)	HS (72)	S (28)
Group IV				
8	YAU-1201-90-2-2	S (40)	HS (54)	MS (23)
Group V				
9	YAU-1201-179-2-1	S (39)	S (43)	S (32)
10	YAU-1211-22-2-1	S (34)	S (48)	S (27)
11	YAU-1211-118-1-1	S (40)	S (48)	S (28)
12	YAU-1211-211-2-1	S (31)	S (45)	S (29)
13	YAU-1214-S-S-S-77-1-1	S (36)	S (44)	S (26)
14	YAU-1215-B-B-B-139-3-1	S (41)	S (42)	S (31)
15	YAU-1215-B-B-B-153-3-1	S (41)	S (43)	S (27)
16	YAU-1214-183-3-1-2-1-1	S (35)	S (42)	S (31)
17	YAU-1214-183-3-3-1-1-1	S (38)	S (42)	S (28)
18	YAU-1214-183-35-1-1-1-1	S (30)	S (38)	S (26)
19	YAU-1215-73-2-3-1-1-1	S (39)	S (41)	S (29)
20	YAU-1215-B-B-B-168-1-1	S (39)	S (43)	S (27)
Group VI				
21	YAU-1215-S-S-S-40-2-1	S (36)	S (49)	MS (20)
22	YAU-1215-S-S-S-41-1-1	S (29)	S (37)	MS (23)
23	YAU-1215-S-S-S-55-2-1	S (30)	S (34)	MS (21)
24	YAU-1215-B-B-B-10-1-1	S (31)	S (41)	MS (17)
25	YAU-1201-61-3-3	S (27)	S (32)	MS (19)
26	YAU-1201-90-2-4	S (32)	S (37)	MS (25)
27	YAU-1201-121-3-1	S (36)	S (42)	MS (24)
28	YAU-1201-202-1-2	S (30)	S (28)	MS (21)
29	YAU-1201-202-2-2	S (34)	S (41)	MS (24)
30	YAU-1201-202-2-1	S (38)	S (34)	MS (22)
31	YAU-1211-20-1-1	S (33)	S (40)	MS (20)
32	YAU-1211-54-2-1	S (26)	S (32)	MS (22)
33	YAU-1211-95-2-1	S (28)	S (31)	MS (19)
34	YAU-1211-116-3-4	S (33)	S (44)	MS (23)
35	YAU-1211-118-2-1	S (35)	S (44)	MS (18)
36	YAU-1211-154-3-1	S (35)	S (41)	MS (25)
37	YAU-1211-179-3-2	S (32)	S (31)	MS (22)
38	YAU-1214-183-3-1-1-1-1	S (30)	S (39)	MS (22)
39	YAU-1215-80-1-2-1-1-1	S (27)	S (29)	MS (22)
Group VII				
40	YAU-1211-116-3-3	MS (19)	MS (25)	MS (13)
41	YAU-1211-223-3-2	MS (25)	MS (21)	MS (14)
Group VIII				
42	YAU-1211-71-1-1	MS (19)	MS (24)	MR (11)
43	Sinthukha	MS (17)	MS (18)	MR (12)

Sr. No.: Serial Number, MR: Moderately Resistant, MS: Moderately Susceptible, S: Susceptible, HS: Highly Susceptible

As mentioned, in this study, all YAU rice lines except YAU-1211-71-1-1 displayed moderately susceptible to highly susceptible reactions and rice lines differed in reaction with different isolates of the pathogen. The present study reached similar conclusions to Noor et al., (2006), who stated that the *Xanthomonas oryzae* pv. *oryzae* strains which induced a susceptible reaction in one variety of rice, are not necessarily able to induce similar reaction in other varieties. YAU-1211-71-1-1 and Sinthukha varieties showed moderate resistance to isolate III (Pyinmana) in the present study. The YAU-1211-71-1-1 may also contain a resistance gene (*Xa21*) because it was developed from a cross of Sinthukha, a popular variety which is resistant to bacterial blight disease (and as mentioned, carries the resistance gene *Xa21)*, and Long 8, a hybrid rice variety which is high yielding.

CONCLUSION

The Nga Sar Kay and Sinthukha rice varieties and YAU-1211-71-1-1 rice line are moderately resistant to Isolate III (Pyinmana). Nga Sar Kay, considered as a Myanmar local variety, has potential to be used in future rice breeding program. Also Sinthukha and YAU-1211-71-1-1 show good potential for use in disease prone areas, especially in combination with other management practices. The YAU-1211-71-1-1 can be considered as a promising rice line that could be grown in bacterial blight prone areas, again in combination with other management practices. The emergence of a new race is responsible for the removal of many resistant varieties according to the gene-for-gene concept. Therefore, further research such as the investigation of new strains that have arisen in nature and the screening of rice varieties for their resistance or/ susceptibility to that race, need to be constantly and frequently undertaken in the future.

ACKNOWLEDGEMENTS

We acknowledge the financial support provided by YAU-JICA Technical Cooperation Project, Yezin, Nay Pyi Taw, Myanmar.

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Research article

Study on the Factors of Awareness for the Production and Development of Vegetables by Farmers in Cambodia

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Received 10 September 2019 Accepted 5 December 2020 (*Corresponding Author)

Abstract Recently, vegetable has also been cultivated by many farmers in Cambodia due to the increase of its demand in the local market. The main objective of this study was to clarify the awareness levels of the local farmers with an emphasis on agriculture production information for the sustainable development of vegetable production. Based on the multiple correspondence analysis results, the information required by local farmers was shown to be different depending on farm management scale. It can be concluded that it is important to provide information and technology that is adapted to the development stage of agricultural management of each local farmer. Moreover, a categorical principal component analysis is used to categorize and clarify the effectiveness of kind of agricultural production information was needed to develop vegetable production.

Keywords categorical principal component analysis, Cambodia

INTRODUCTION

In Southeast Asia, the rapid increase of population and lifestyle transition results the increase of demand in various agricultural crops particularly on vegetables. Although the main agricultural product in Cambodia is rice, vegetable has also been cultivated recently by many farmers.

According to the Census of Agriculture of the Kingdom of Cambodia (National Institute of Statistics, 2013), a wide variety of vegetables were cultivated across the country including leafy, stem and fruit bearing, root, bulb and tuberous, leguminous green, and others. Leafy vegetables such as Water Convolvulus (*Ipomoea aquatica*), Cabbage (*Brassica oleracea*), Lettuce (*Lactuca sativa*), Green Garlic (*Allium sativum*), Spring Onion (*Allium fistulosum*), Celery (*Apium graveolens*), Spinach (*Spinacia oleracea*), Watercress (*Nasturtium officinale*), Chinese Kale (*Brassica oleracea*), Clover (*Trifolium L.*), Amaranth (*Amaranthus L.*) and Pigweed (Amaranthus) are amongst of the common vegetables produced in the country. Tomato (*Solanum lycopersicum*), Bitter Melon (*Momordica charantia*), Watermelon (*Citrullus lanatus)*, Wing Bean (*Psophocarpus tetragonolobus*), Bhendi (*Abelmoschus esculentus*), Snake Gourd (*Trichosanthes cucumerina*), Ivy Gourd (*Coccinia grandis*), Winter Squash *(Cucurbita moschata*), Chili (*Capsicum*), Cucumber (*Cucumis sativus)*, Muskmelon (*Cucumis melo*), Eggplant (*Solanum melongena*), Gourd (*Lagenaria siceraria*), Green Gourd (*Cucurbitaceae*) are also some of the commonly cultivated fruit bearing vegetables. Fruit bearing vegetables were cultivated over 35,000 ha of which cucumber covers the largest area accounting 7,000 ha followed by watermelon at more than 6,000 ha while chili and pumpkins are at 5,000 ha each. However, many of these areas are cultivated in small scale and for the purpose of farmer's household consumption. In addition, many local farmers cultivate vegetables during the dry season that results lesser production than cultivated in the wet season. Those conditions contributed a limited supply of vegetable in the market. To boost up and sustain the production of vegetables in Cambodia, it was determined that there is a need to support small scale vegetable growers in technical, farm inputs and a win-win price control of vegetable in the market (Chen et al., 2018). However, there is also a need to find out the instincts of farmers on how they will deal the possible supports they need. Therefore, this study has been proposed to clarify the awareness levels of the local vegetable growers with an emphasis on agriculture production information.

METHODOLOGY

The research site was in Kampong Cham Province. It is located at the northeast of Phnom Penh, and southeast of Siem Reap. In Kampong Cham Province during the French colonial period, the hilly terrain was developed as a rubber plantation zone. The population of Kampong Cham province is approximately 1.75 million and much of the population is engaged in agriculture. Table 1 shows the acreage and domestic share of major vegetables in Kampong Cham province. According to table 1, Kampong Cham Province is a major producing center of cabbage, lettuce and muskmelon.

Table 1 Acreage of major vegetables produced in Kampong Cham Province

Kind of Vegetables		Cambodia Planted Area (ha)	Kompong Cham Planted Area (ha)	Kompong Cham Composition ratio (%)
Leafy or Stem Vegetables	Water Convolvulus	2306.5	39.9	1.7
	Cabbage	648.6	223.0	34.4
	Lettuce	824.8	153.0	18.5
	Chinese Kale	327.4	11.2	3.4
Fruit-Bearing Vegetables	Chilli	4637.8	618.4	13.3
	Cucumber	6894.5	164.0	2.4
	Muskmelon	1901.9	847.4	44.6
	Eggplant	2997.4	103.8	3.5
	Gourd	1687.4	61.8	3.7
	Pumpkin	4624.9	22.7	0.5
	Tomato	1065.2	22.7	2.1
	Watermelon	5911.8	71.8	1.2
	Bhendi	406.2	302.0	74.3
Total		34234.4	2641.5	7.7

Source: Census of Agriculture of the Kingdam of Cambodia 2013

In this study, the following two multivariate analyses are applied. Firstly, Correspondence analysis is an analysis method that visualizes the cross-tabulation and facilitates the interpretation of the survey results. In this study, correspondence analysis is an appropriate method for understanding the awareness of local farmers and the results of the response patterns of necessary agricultural information. Secondly, Categorical principal component analysis is an analysis method for classification by integrating strongly correlated variables and creating new synthetic variables. Categorical principal component analysis is an appropriate method for creating new synthetic variables from many variables such as local farmer attributes agricultural information for vegetable production, and information sources, which is one of the purposes of this study. In addition, a previous study (Yamada et al., 2018) used categorical principal component analysis to classify farm management characteristics for development assistance in rural Cambodia.

The research site was ten districts in Kampong Cham Province, Cambodia. The target area of the questionnaire survey consisted of the following ten districts: Batheay district: 45 respondents (10.3% of the total respondents), Chamkar Leu district: 50 (11.4%), Chueng Prey district: 36 (8.2%), Kaoh Sotin district: 46 (10.5%), Kampong Siem district: 38 (8.7%), Krong Kampong Cham district:

48 (11.0%), Kang Meas district: 44 (10.1%), Prey Chhor district: 36 (8.2%), Srei Santhor district: 50 (11.4%) and Stueng Trang district: 44 (10.1%).

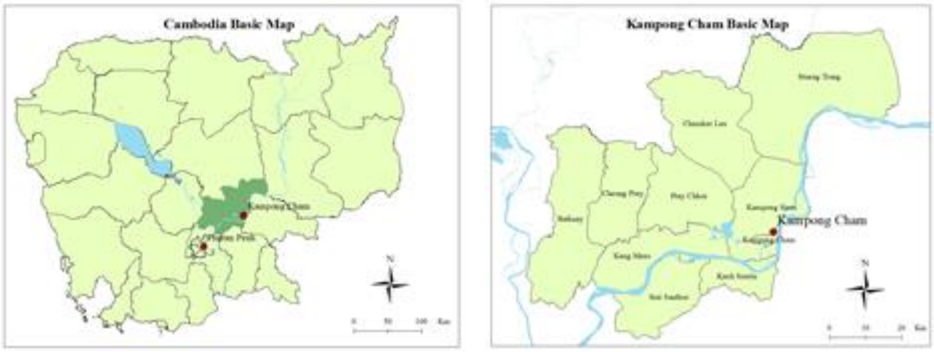

Fig. 1 Location of the study site in Kampong Cham Province

RESULTS AND DISCUSSION

Table 2 shows the index of the questionnaire carried out, which contains categories for gender, age of the respondent, educational background, farm acreage, cropping pattern, sales destination and farmers' revenues.

Table 2 Demographic information of respondents

Index		Number of response (n)	(%)	Index		Number of response (n)	(%)
Gender	1. Male	282	64.5	Cropping pattern	1.Vagetables	43	9.8
	2. Female	155	35.5		2.Rice	48	11.0
Age	1.Less than 29 years old	17	3.9		3.Rice,Vagetables	98	22.4
	2.30-39years	113	25.9		4.Rice,Vagetables,fruit	248	56.8
	3.40-49years	140	32.0	Sales destination	1.Middleman only	302	69.1
	4.50-59years	116	26.5		2.Middleman and Market in the village	53	12.1
	5.More than 60 years old	51	11.7		3.Market in the village only	57	13.0
Educational background	1. Never had been to school	42	9.6		4.Other market only	25	5.7
	2. Primary	228	52.2		5.No answer	7	1.6
	3. Secondary	133	30.4	farmers' revenues	1.Less than 1,000,000 Riel	30	6.9
	4. High school	33	7.6		2.1,000,000-2,999,999 Riel	169	38.7
	5.College/University	1	0.2		3.3,000,000-4,999,999 Riel	122	27.9
Farm acreage	1.Less than 0.5 ha	91	20.8		4.5,000,000-6,999,999Riel	57	13.0
	2.0.6-1ha	116	26.5		5.7,000,000-8,999,999 Riel	32	7.3
	3.1.1-1.5ha	117	26.8		6.More than 9,000,000 Riel	27	6.2
	4.1.6-2ha	40	9.2				
	5.More than 2.1ha	73	16.7				

Source : Survey Date

The attributes of the respondents are as follows. Concerning the "Gender" of the respondents, 64.5% were "male" and 35.5% were "female." Concerning the "Age" of the respondents, the majority of respondents were between the ages of "40-49" years (32.0%), followed by "50-59" years (26.5%) and "30-39" years (25.9%). The lowest percentage was aged "Less than 20 years" old. Concerning the "Educational background", the majority of respondents had "Primary" (52.2%), followed by "Secondary" (30.4%) and lastly "Have never been to school" (9.63%). Concerning the "Farm acreage" of the respondents, the majority of respondents were between a farm acreage of "1.1-1.5" ha (26.8%), followed by "0.6-1.0" ha (26.5%) and "Less than 0.5" ha (20.8%). Concerning the "Cropping pattern" of the respondents, the majority of respondents were "Rice, Vegetables, Fruit" (56.8%) followed by "Rice, Vegetables" (22.4%). Concerning the "Sales destination" of the respondents, about 70% of the local farmers answered "Middleman only". Concerning the "farmers' revenues" of the respondents, the majority of respondents were between the farmers' revenues of "1,000,000-2,999,999" Riel (38.7), followed by "3,000,000-4,999,999" Riel (27.9%) and "5,000,000-6,999,999" Riel (13.0%).

As a result, vegetable production is carried out by local farmers with a management area of 1.5ha or less, and most of the produced vegetables are shipped to Middlemen. In addition, women are often involved in vegetable production.

Characteristic of Respondents and Data of the Information for Sustainable development of Vegetable Production by Multiple Correspondence Analysis

This part clarifies characteristics of respondents and the information for sustainable development of vegetable production by Multiple Correspondence Analysis. The indices used for the analysis are X1: Farm acreage, X2: Farmers' revenues, X3: Information about seeds, X4: Information about machinery, X5: New technology information, X6: Information about chemical fertilizer, X7: Information about organic fertilizer, X8: Market information, X9: Information about training, X10: Price information, X11: Information about harvest and X12: Planting information. Figure 1 shows the results of the answer pattern for Characteristic of respondents and information with an emphasis on sustainable development of vegetable production by Multiple Correspondence Analysis. According to the results of Multiple Correspondence Analysis, respondents with small farm acreage and low income are X3: Information about seeds, X6: Information about chemical fertilizer and X12: Planting information. Furthermore, the local famer who answered the farm acreage as 1.1-1.5 ha was found to be related to X5: New technology information and X9: Information about training. Additionally, the local famer who answered the farm acreage as 1.6-1.2 ha and more than 2 ha were found to be related to X10: Price information and X11: Information about harvest. This clarified the characteristics of the local farmer consciousness and information of the emphasis on sustainable development of vegetable production. According to the results of Multiple Correspondence Analysis, it was clear that the preference divisions of the local farmers were difference of farm acreage as important characteristics for the classification.

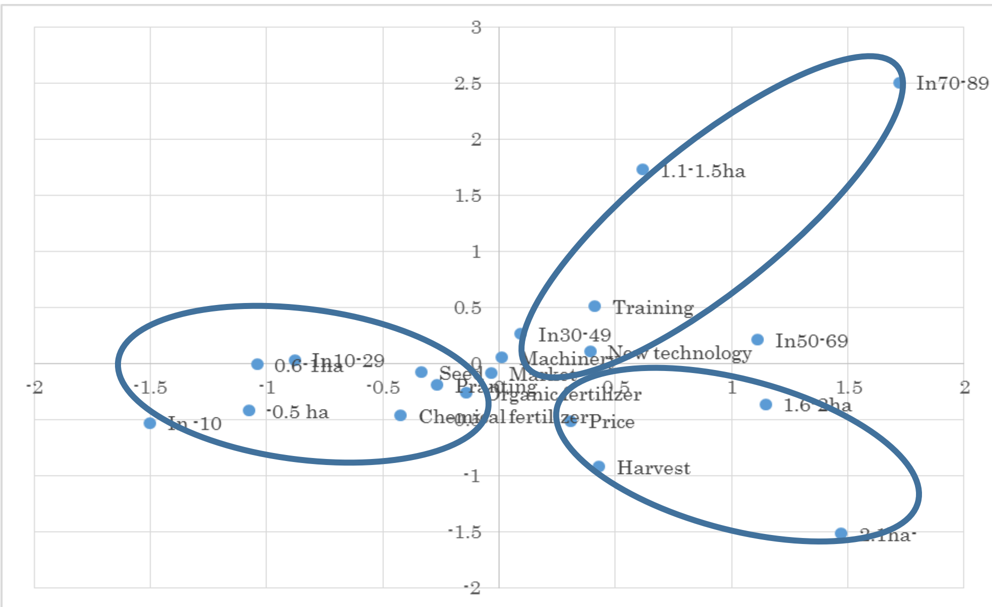

Fig. 2 The result of answer pattern for the local farmers consciousness and required agricultural information (Correspondence Analysis)

Grouping of Respondents by Category Principal Component Analysis

In this section, information on each variable, such as farmer attributes, cultivated land, the information for sustainable development of vegetable production and Information source are summarized and a "total index" is created and grouped. We employed a categorical principal component analysis for this purpose. Index and answer patterns used for categorical principal component analysis were as follows.

Table 3 Estimation results of categorical principal component analysis

	Index	FACTOR 1	FACTOR 2
X1	Gender	-0.072	0.176
X2	Age	-0.112	0.206
X3	Educational background	0.264	-0.037
X4	Cultivated land	0.294	-0.096
X5	Average annual income from agricultural activity	0.422	-0.438
X6	Cropping pattern	-0.176	0.303
X7	Sales destination	-0.402	0.361
X8	Information about seeds	0.223	0.502
X9	Information about machinery	0.348	0.538
X10	New technology information	0.208	0.078
X11	Information about chemical fertilizer	0.216	0.518
X12	Information about organic fertilizer	0.251	0.337
X13	Market information	0.342	0.149
X14	Information about training	0.570	-0.073
X15	Price information	0.486	0.511
X16	Information about harvest	0.491	0.393
X17	Pranting information	0.081	0.396
X18	Government officer (DDAFF officer)	0.494	-0.318
X19	Village leader	0.326	-0.130
X20	Other farmers in the village	-0.294	0.053
X21	Parents	-0.375	0.368
X22	Scientist	0.152	0.122
X23	NGO officer	0.538	-0.384
X24	Other (Community)	-0.090	-0.041

Sourse Sarvey date

Note Eigenvalue: Factor 1; 2.69, Factor 2; 2.44

Table 3 shows the estimation results of the categorical principal component analysis. At the same time, the eigenvalues of each factor were factor 1: 2.69 and factor 2: 2.44. In the following, it is confirmed for each principal component what index feature an element constitutes. In the following, it is confirmed for each principal component what index feature an element is constituted. Firstly, the indices positively contributing to factor 1 were X3: Educational background (0.264), X4: Cultivated land (0.294), X5: Average annual income from agricultural activity (0.422), X10: New technology information (0.208), X14: Information about training (0.570), X18: Government officer (DDAFF officer) (0.494) and X23: NGO officer (0.538). From these indices, factor 1 can be interpreted as "the factor representing the priority of information for the future of agricultural management". Secondly, the index positively contributing to factor 2 were X1: Gender (0.176), X2: Age (0.206), X6: Cropping pattern (0.303), X7: Cultivated land (0.361), X8: Information about seeds (0.502), X9: Information about machinery (0.538), X11: Information about chemical fertilizer (0.518), X17: Planting information (0.396), and X21: Parents (0.368). From these indices, factor 2 can be interpreted as "Factors expressing intention to form production areas by collaboration".

For local farmer grouping, it can be classified into the following 4 groups from each positive and negative combination of factor 1 and factor 2. Group 1 is local farmers that are positive for both" the factor representing the priority of information for the future of agricultural management" and "Factors expressing intention to form production areas by collaboration." This group is under situations that ensure stable income such as agricultural machinery is in place, has an interest in improving the quality of agricultural crops and sales outlets and also shows an understanding of cooperation with others. Therefore, it is suggested that local farmers classified as group 1 are suitable as model farmers for projects for sustainable vegetable production. The local farmers of group 2 are positive for "the factor representing the priority of information for the future of agricultural management" and negative for "Factors expressing intention to form production areas by collaboration". This group is already aiming to achieve modern agricultural production and to advance agricultural management on an individual level. This is considered to be highly adaptable to projects aimed at improving the agricultural techniques for vegetable production of local farmers, such as the start of new crops and Introduction of new customers. Group 3 are local farmers that are negative for both "the factor representing the priority of information for the future of agricultural management" and "Factors expressing intention to form production areas by collaboration." It is speculated that the local farmers in this group are in a situation where the infrastructure required for agricultural production is not well developed. Therefore, a project is needed to disseminate basic agricultural production techniques. The local farmers of group 4 are negative for "the factor representing the priority of information for the future of agricultural management" and "Factors expressing intention to form production areas by collaboration" positive. Similar to Group 3 and Group 4, the development of agricultural production infrastructure is not sufficient. However, the local farmers expect the development of regional agriculture by collaborating with others to offset its weaknesses. In addition, local farmers classified as Group 4 and Group need to propose to expand vegetable production from self-consumption by the houses to vegetable production for sale.

According to the results of categorical principal component analysis, local farmers who produce vegetables were found to have disparities in the development stage of agricultural management. In addition, it became clear that local farmers have a different awareness of the priorities of information for the future of agricultural management and their intentions for the formation of main producing areas.

CONCLUSION

In this study, focusing on the vegetable production in Cambodia, the local farmers analyzed what kind of agricultural production information was needed to develop vegetable production based on data obtained from a questionnaire survey. Therefore, the main objective of this study was to clarify the characteristics of awareness of the local farmers with an emphasis on information of agriculture production.

The results of the analysis are summarized as follows. Based on the multiple correspondence analysis results, the information required by local farmers was shown to be different depending on farm management scale. Based on the categorical principal component analysis results, the relevance of awareness for the production and development of vegetables and the information required by local farmers became clear. In addition, local farmers with multiple sales destinations are highly conscious of the factor representing the priority of information for the future of agricultural management.

According to the results of the analysis, for the development of vegetable production in Cambodia, it can be concluded that it is important to provide information and technology that is adapted to the development stage of agricultural management of each local farmer.

ACKNOWLEDGEMENTS

This work was supported by JSPS KAKENHI Grant Number JP18K05857.

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Research article

Yield and Yield Components of Potato Response to Various Planting Date in Cambodia

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Received 12 March 2020 Accepted 7 December 2020 (*Corresponding Author)

Abstract: Potato (*Solanum tuberosum* L.), a tuberous plant well known as a highly nutritional diet and an economic crop s, is the world's fourth largest production after rice, wheat and corn. Recent experiments have shown some potential places and varieties for cultivation in Cambodia. Thus, the experiment aimed to understand the response of the potential potato varieties to different planting dates in Sen Monorom town, Mondulkiri province (a mountainous area), Cambodia. The trail was laid out in randomized complete block design with 4 replications and 3 different planting dates namely October, November and December of 2018. The Coronada, certified seed from the Europlant International company in Germany, was the ideal variety used in the experiment and lasted 115 days from planting to harvest. Only the number of tuber per plant, tuber weight, weight per plant, and marketable yield were recorded. Suggested that planting date significantly affected to all measured parameters. Plot planting in December produced the highest number of tubers with an average of 9.3 tubers per plant while a similarity was noticed for October and November planting. However, the November planting surprisingly produced the highest weight per plant, heavier tuber and the highest marketable yield with 19.15 ton ha^{-1}. The two other planting dates obtained an average yield of 14.49 and 12.39 ton ha^{-1} for October and December consequently. This is understandable that November planting and harvest at end February, which is the long cold and windy season with less rainfall, was the most comprehend planting season in Mondulkiri province, Cambodia.

Keywords: Mondulkiri, Coronada, upland, Cambodia, planting date

INTRODUCTION

Potato, *Solanum tuberusom* L., is the fourth largest production crop next after rice, corn and wheat (FAOSTAT, 2006), and the key crop for food security in many developed and developing countries

(Scott et al., 2000). At the present, potato production is expanding at an incredible rate throughout the world. Despite its popularity, the crop is not an easy success production in all places. Potato prefers a cool climate followed by a warm environment for the best massive production. Optimum yield has been observed in temperate regions with an average temperature around 18-20 ^oC without chill (Havetkort and Struik, 2015). In Cambodia, fresh potato is largely imported from Vietnam, Thailand and China. Production of potato was first introduced in late 2016 under an experiment by the Faculty of Agronomy at the Royal University of Agriculture (MAFF, 2016). In most hot and tropical countries, potato farming is recommended during the rainy and short rainy season, but most upland produced areas would not be benefit due to the threat of the soil borne disease such as late blight (Gebremedhin et al., 2008; Gildemacher et al., 2009). In association with climate change, several technology packages, and cropping calendar are keys to succeed and maintain the production (Monneveux et al., 2014). Global yield losses were estimated from 18 to 32% without adaptation in production technologies packages, or 9 to 18% without consideration of cropping calendar and use ~~d~~ of heat tolerant varieties (Hijmans, 2003). Tittonell et al. (2007) suggested that yield losses in most rainfed areas is generally largely due more to management aspects than to low physical potential. The Optimum timing of the planting date is considered as one of the key factors that strongly affect potato production in a rainfed zone (Wang et al., 2008). Similar to other crops, the optimum planting date for potato is mostly specific to each production region. However, there was no scientific recommendation ~~s~~ to adaptable varieties with consideration of the environmental condition in upland production areas in Cambodia, in particular, Mondulkiri province. Therefore, manipulation of the perfect timing of the planting date is the most important key to overcome the negative impact of environmental on potato production in Mondulkiri province, Cambodia. The present study aimed to determine the optimum planting date for potato production which can produce maximum yield under the upland climate of Cambodia.

METHODOLOGY

Experiments were carried out under field conditions from October 2018 to April 2019 at Mondulkiri province (12°28'27" N, 107°12'33" E). The site was 710 meters above the sea level. The trial was laid out in randomized complete block design with 4 replications. The treatment consisted of three different planting dates namely second week of October, November and December, respectively. Plant density was 4.8 plants/m^2 in plots of 12 rows, 0.70 m apart and 25 m long. Each plot was fertilized with 80 kg N ha^{-1}, 80 kg P_2O_5 ha^{-1} and 150 kg K_2O ha^{-1} at planting date and 40 kg N ha^{-1} and 100 kg K_2O were applied at ridging (45 days after planting). Chemical and physical of the experiment field was described in Table 1. Weed and pathogens were controlled chemically at the manufacturer's recommendation rate to prevent biotics damage. The plots were surface irrigated during the growing season, according to weather station evapotranspiration data. Coronada, yellow flesh and skin color from Europlant International, Germany, were used and allowed to stand on the ground for 115 days from sowing to harvest. Marketable yield and yield components parameter were recorded. The key data was the number of tubers per plant, weight per tuber, weight per plant and marketable yield were measured at harvest.

Table 1 Soil physical and chemical properties analysis of experiment site

EC	pH	P ppm	K cmol$_c$ kg^{-1}	N %	SOM %	CEC cmol$_c$ kg^{-1}	Soil Texture			
							Clay	Silt	Sand	Class
38.0	4.20	0.1	0.42	0.29	5.07	72.4	22.3	35.3	42.4	Clay Loam

Source; Soil Laboratory, Faculty of Agronomy, Royal University of Agriculture

RESULTS AND DISCUSSION

There was significantly different yield obtained due to variation of environmental condition during the October, November and December. The highest tuber produced was recorded for December planting while statistically similar were reported for October and November. The increase temperature during the vegetative stage led to an increase in the number of stolon which led to variation in the number of tuber produced per plant. In the upland environment in Cambodia, the temperature increase was normally observed from mid-January onward while the low temperature occurred from September or when the rain fell (September-November). Wolf et al. (2017) emphasized that increased temperature for 20 days at tuber development could affect the number of tuber produced depending on genotype.

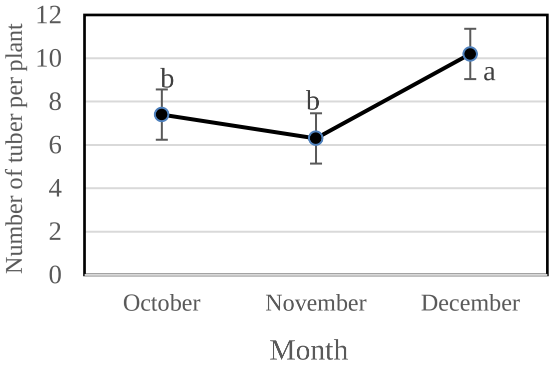

Fig. 1 Result of tuber number per plants

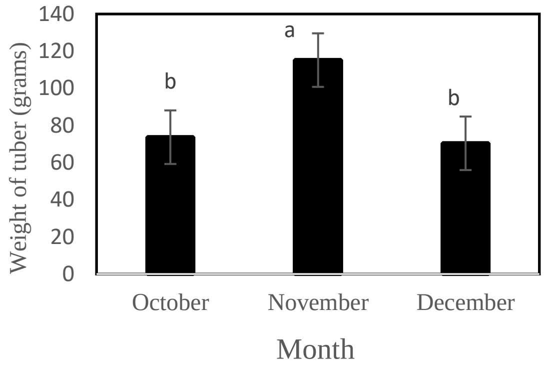

Fig. 2 Result of weight of tuber

November planting produced larger and heavier tubers than any other planting date (Fig. 2). Higher temperature aboveground over the potato favor limited tuber enlargement, which result in reduced in tuber per plant (Wolf et al., 1991; Basu and Minhas, 1991). At a higher little temperature than 28 degrees Celsius, only 50% of assimilates produced were transferred to tubers, whereas 20% more of assimilates were translocated at an optimum temperature of 18 ^{o}C (Randeni and Caesar,1986). Thus, planting potatoes in November in the upland environment of Cambodia attained the highest yield which was about 19 ton per hectare. A Decrease in marketable yield was observed for October planting which was similar to December cultivation. The result showed that November was the optimum season which was 25-35% higher than growing during October and December.

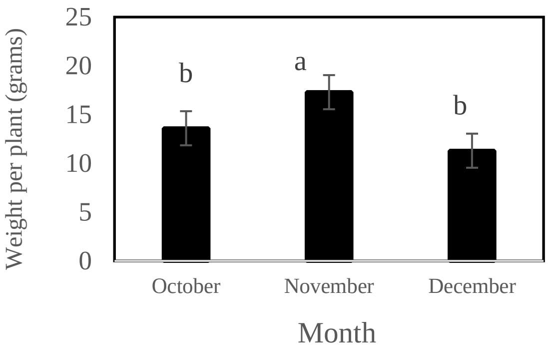

Fig. 3 Average weight of tuber per plant

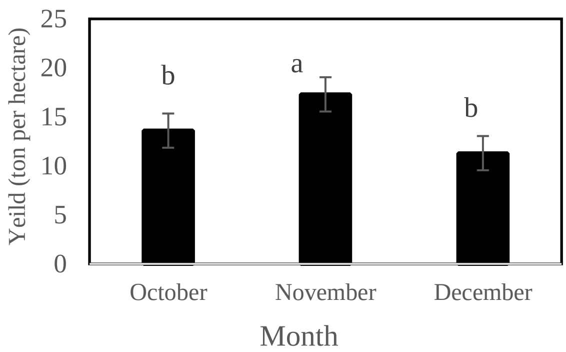

Fig. 4 Average marketable yield

Yield of the potato was relatively low due to infection by soil borne disease such as late blight. Optimum growth and yield of potato was obtained in the tropical region when there was not much rain and a cool dry climate. October was considered the main rainy season in Cambodia, with many rainy days and high precipitation (Fig. 5). The Number of rainy days started to decrease form November and little or no rainfall could be observed from middle of December and temperatures started to increase. In most hot and tropical countries, potato farming was recommended during the rainy and short rainy season, but most upland produced areas would not benefit due to the threat of the soil borne disease such as late blight (Gebremedhin et al., 2008; Gildemacher et al., 2009).

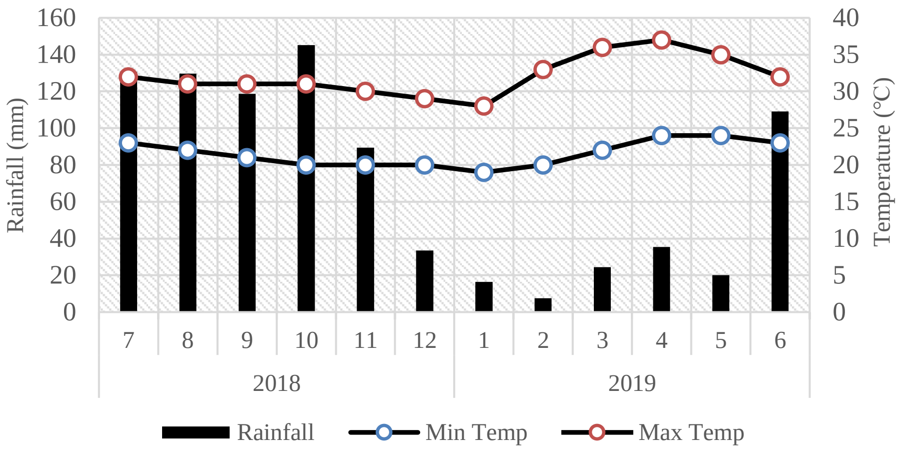

Fig. 5 Climate condition during the experiment

CONCLUSION

Our results is suggested that November was the optimum season for potato farming in upland environment at Mondulkiri province, Cambodia. Planting potatoes in this season produced large tuber and maximum yield with less damage from soil borne disease due to fewer rainy days and warm temperature without chilled or exposing the potato to high temperature. October planting was considered the second option, however well drainage system and chemical prevention need to be prepared to prevent crops from damage by excess water and spread of disease. In addition, for December planting, variety was the key to obtaining better yield due to increase in temperature during tuber bulking (45 day after sowing). Short and medium varieties are highly recommended, while long varieties are highly exposed to low productive and crops failure.

ACKNOWLEDGEMENTS

The authors would like to express their sincere thankfulness and appreciation to KOPIA Cambodia Center (2016-KHM-03), the Europlant International for delivering the seed, GIZ for technical advice, selected farmers for support and encouragement, key informants and information; your mighty support has been being my greatest source of motivation and inspiration.

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Research article

Economic Impact of Rice Tractor and Combine Harvester Custom Services in Northwest Cambodia

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Received 15 January 2020 Accepted 12 December 2020 (*Corresponding Author)

Abstract Agricultural machinery has become significantly important to carry out farm work and to address labor scarcity in Cambodia. However, rural areas face many challenges such as lack of farmers' improper machinery utilization and lack of skilled operators in order to implement agricultural mechanization. The effective use of tractor or combine harvester (CH) requires not only management knowledge and experience, but also proper the economic evaluation. This study aims to determine the potential of rice tractor and combine harvester custom service to create an economic advantage for the agricultural machinery owners. A survey of 28 tractor owners (group T), 21 CH owners (group CH), and 23 tractors and CH owners (group B) in Banan District, Battambang Province was conducted in March 2019. The result indicated that the annual custom service area by group T, CH, and B were 133.4 ha, 213.1 ha, 398.9 ha (tractor 180.8 ha, and CH 216.1 ha), respectively. The average operating cost was estimated at 30.0 USD/ha for group T, 58.9 USD/ha for group CH, and 26.2 USD/ha (tractor) and 56.3 USD/ha (CH) from group B. Among the costs incurred, depreciation cost was the highest cost, followed by diesel and labor costs. In some cases, owners tend to offer higher pay to skilled operators to work for them especially during the peak seasons. The break-even point per year were estimated at 116.4 ha for group T, 117.5 ha for group CH, and 113.0 ha (tractor) and 109.6 ha (CH) for group B. In general, custom service by group seemed to vary on the field and infrastructure conditions, operators' skill, frequently machine breakage, and owners' desire to gain profit. Therefore, this study suggests that the owners should prolong the economic life of tractors or CHs by conducting proper and regular maintenance that will eventually lead to decrease break-even area.

Keywords tractor, combine harvester, custom service, operating cost, break-even point, payback period

INTRODUCTION

In some areas of Cambodia, rice farming system has been changed in agricultural sense from single cropping to double cropping per year and transplanting method to direct seeding method. Also, the use of animal powers has been declined from 47% in 2001 to 33% in 2013 (Chhim et al., 2015). Due to urbanization, the size of rice cultivated land has been reducing, and productivity is also declining due to non-availability of inputs such as fertilizers, labor inputs, and machineries. According to Ministry of Agriculture Forestry and Fishery (MAFF) Cambodia, the total labor force was decreasing from 57.6% in 2009 to 45.3% in 2014.

Agricultural machinery has played a significant role in increasing agricultural production by completing farm operations in time, reducing production costs, and address labor scarcity (Chan et al., 2014). Currently, Cambodia has imported hundreds of modern farm machineries to enhance land preparation or harvesting proportionally. The number of tractors increased 5-fold from 2,602 units in 2001 to 13,701 units in 2015. The number of CHs increased 18-fold from 325 units in 2006 to 5,893 units in 2015. The most common model utilized by farmers is Kubota. However, the implementation of mechanization in a rural area still faces many challenges, such as improper machinery use, the high cost of machinery, and lack of skilled operators (Abu et al., 2015). Due to poverty, some farmers found it difficult to access all inputs and acknowledge in modern farm machinery. And there are available the custom services (custom service refers to a business that is managed by either group or individual person to provide farming operation with any farm machineries in the set of rate or fee) from other farmers to other farmers but the demand is still not enough (Banan district annual report, 2017). The effective use of a tractor or combine harvester requires not only management knowledge and experience but also proper economic evaluation.

OBJECTIVE

This study aims to determine the characteristics and the awareness of farmers about various aspects of mechanization; and examine costs and profitability of the business to create economic advantage for the owner.

METHODOLOGY

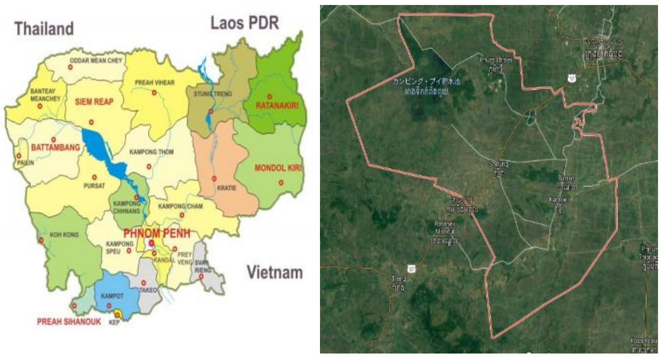

Fig. 1 Map of Cambodia and Banan District
Source: Google image

This study is conducted in Banan District, Battambang Province. Located 28 km away from Battambang city, this district is also one of the largest rice-growing areas in the province. There are also a prevalent large number of farmers using tractors and combine harvesters. The total rice field area of this district is 47,321 ha, of which 38739 ha are wet season rice and 8,582 ha are dry season rice (Banan district annual report, 2017). Kamping Pouy and Kanghot dam is the main irrigation system that brings the water to supply the whole district for farming usage.

Primary data were collected through farm questionnaire survey of randomly selected 72 machinery owner-farmers in Banan district in March and August 2019. The respondents were further divided and categorized into tractor owner-farmers, CH owners, and tractor and CH owners. Data was obtained both in wet and dry seasons for land preparation and harvesting paddy rice. The collected data included a year of purchase, initial purchase price, hectares of tractor and CH utilization, operator wage, repair and maintenance, and fuel costs, and rates of service charge.

Simple descriptive methods cost and return, break-even, and payback analysis were utilized.

RESULTS AND DISCUSSION

General Characteristics of Respondents

The 72 respondents were categorized into three groups: namely group tractor (T) has 28 tractor owner-farmers, group combine harvester (CH) has 21 CH owner-farmers, and group both (B) has 23 tractors and CH owner-farmers. Table 1 show average age of the owners was 40 years, with at least 14 years in farming experience. There is no significant difference between those groups.

Table 1 General characteristic of machinery owners

Items	Group T	Group CH	Group B
n	28	21	23
Average family size (persons)	3.8	4.0	3.5
Average member involves in rice farming (persons)	1.8	2.1	2.0
Average age (years old)	43.4	42.1	44.6
Average farm experience (years)	14.9	14.2	16.1
Education background (years)	7.8	7.5	7.3

Source: Field survey, 2019

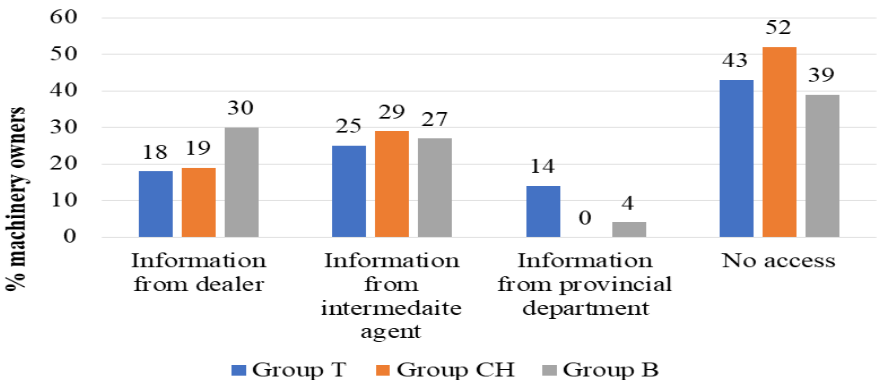

Fig. 2 Percentage of machinery owners accessed to information

In this study, approximately 20% of machinery owners have attended training programs related to tractor and CH at least one time a year. According to the interviewed owners, training programs are related to managing, maintenance and repair, and operation of machinery properly, which is usually provided by the Kubota dealer. Yet, there was no training provided by the provincial department or extension workers.

The rate of machinery owners' access to information related to tractor and CH is still limited. Those three group owners commonly received the information from intermediate agents, such as neighbor farmers, friends, and relatives, and some received information from the dealer rather than from the provincial department (Fig. 2).

Tractor and Combine Harvester Utilization

In the survey area, most tractors and CH worked seasonally with an average of 200 days/year. The variation of working days between tractor and CH is due to differences in local climatic conditions and land conditions. Tractors work mostly concentrated on land preparation (plowing, harrowing, and rotavating) and the working hours about 7 to 8 hours/day with an average capacity of about an hour/ha. CH work focused only on rice harvesting and frequently can harvest at least 4 to 5 ha/day (about 2 hours/ha).

Table 2 shows that total annual utilization of group T was from the owners' farm (40%) and remaining (60%) was custom service. Group CH, approximately 85% of CH was from custom service. Besides, annual utilization of a tractor and CH on group B owners' farm was 36% (tractor), and 28% (CH), and remaining from custom service. This result means that tractor or CH owners only offered custom service during the rice cropping season and after they completed with their farm. Aside from that, machines are stored in the shed or parked in open area when they not in use.

Table 2 Average annual use per tractor and CH by group machinery owners

Items	NHH	Average operated land (ha)	%
Group T	28	133.4	
Own farm		53.0	40
Custom service		80.4	60
Group CH	21	213.1	
Own farm		31.0	15
Custom service		182.1	85
Group B	23		
Tractor		181.2	
Own farm		65.6	36
Custom service		115.6	64
Combine harvester		216.1	
Own farm		60.6	28
Custom service		155.5	72

Source: Field survey, 2019

Total Cost of Tractor and Combine Harvester Custom Service

Table 3 shows average annual operating cost, which calculated both custom service and the owners' farm. Tractors and CH operators are the owners, owners' relatives, or hired operators. Approximately 80% of tractor and CH operators are hired operators who have reimbursed on a hectare basis. Machinery owners commonly contracted operators during land preparation and harvesting. Sometimes machinery owners tend to offer higher pay to skilled operators to work for them, especially during peak seasons.

Table 3 Average operating cost per tractor and CH operation

Items	Group T	Group CH	Group B	
	Tractor	CH	Tractor	CH
Annual operated land (ha)	133.4	213.1	180.8	216.1
a. Fixed cost (USD)	*1,832.0*	*5,574.9*	*1,895.7*	*5,205.0*
b. Variable cost (USD)	*2,169.7*	*6,981.8*	*2,841.6*	*6,963.4*
Repair	60.0	423.4	89.0	296.9
Operators	388.7	1,291.3	509.5	1,597.2
Diesel	1,648.2	5,133.6	2,164.8	4,971.7
Commission broker	72.8	133.5	78.3	97.6
c. Total annual cost (c=a+b)	*4,001.7*	*12,556.7*	*4,737.3*	*12,168.4*
Total operating cost (USD/ha)	30.0	58.9	26.2	56.3

Source: Field survey, 2019
Note: Fixed cost consists only depreciation

As a result, average operating cost was estimated at 30.0 USD/ha for group T, 58.9 USD/ha for group CH, and 26.2 USD/ha (tractor) and 56.3 USD/ha (CH) from group B. Diesel is the highest single cost of total variable cost, followed by labor and repair cost. The higher cost of diesel and repair may be due to differences in machine age, annual use, operator skill as well as field conditions. Few machine owners revealed that they commonly did not use the aging tractor or CH for providing custom service because of low power and high risk of failure.

Fig. 3 presents the relationships between total operating costs per hectare and the annual use of three group owners. In order to derive a function for each cost, the least-squares regression method was used to determine the best fit function. The total operating cost is taken as the dependent variable (y) and annual use rates as the independent variable (x). The curves describe in terms of data points related to the above cost items per hectare to annual hectares of use. The r square value could explain at 83% and 84% of the observed variations in group T and B, respectively. This result indicated that there is a significant contribution to the annual use of decreasing total costs. The total operating costs of machinery owners per hectare show a quick decline with an increase in annual use. The result suggests that there is a great potential to reduce total operating costs by increasing annual use (ha).

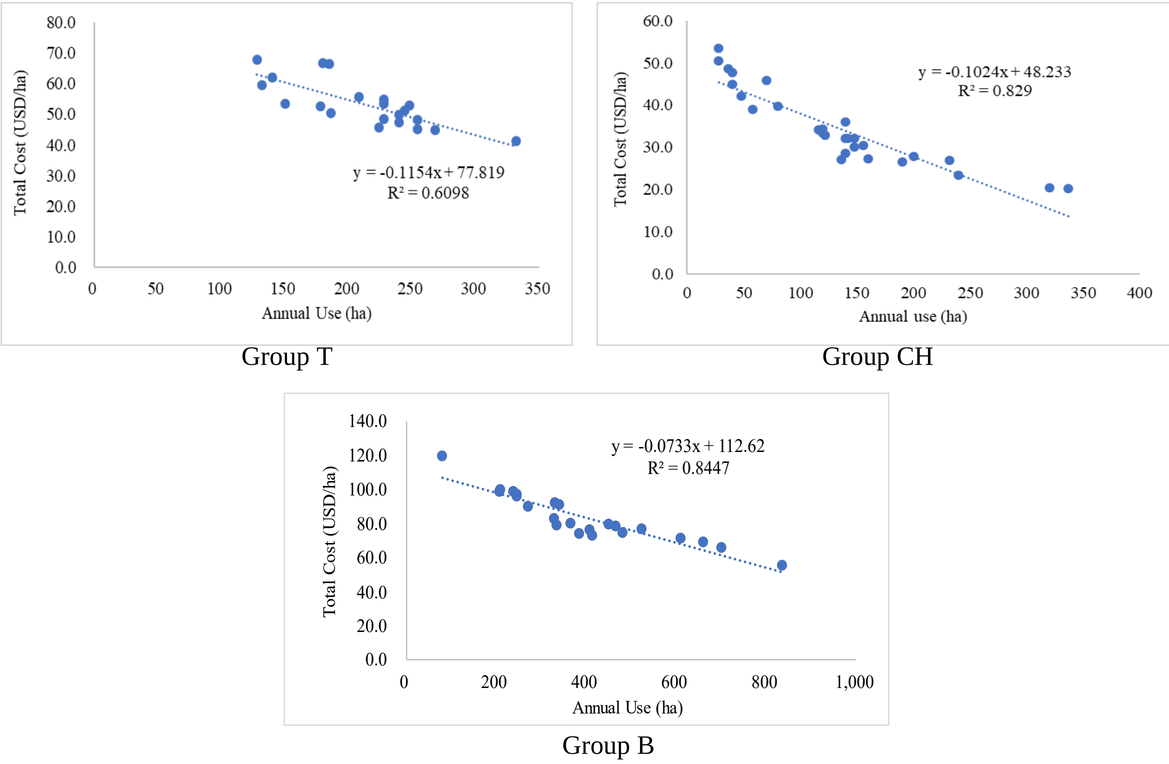

Fig. 3 Relationships between total cost per hectare and annual use

Service Charge and Profitability of Tractor and Combine Harvester Custom Service

Normally, farmers contacted machine owners before any operations to secure their place to be available on time. In addition, farmers usually asked the same custom service providers of the previous year because they have been satisfied with that service. But in some emergency cases, farmers made decision to choose a new custom service provider who can respond to their needs.

The service charge of ploughing ranged from 25 USD to 29 USD per hectare, and rotavating ranged from 27 USD to 33 USD per hectare. The harvesting operation depends on the rice varieties and season (wet and dry season). The service charge of wet season rice varieties is about 85 to 90 USD per hectare, while the price of dry season rice varieties ranged from 68 to 80 USD per hectare.

In some cases, it found that the rate of harvesting service was a bit higher than the average estimated. The reasons were that rice stalks are bent and difficult to harvest, so hiring farmers had to pay higher rates according to an agreement made by farmer and machinery owners.

Table 4 Average profitability per tractor and CH operation

Items	Group T	Group CH	Group B	
	Tractor	CH	Tractor	CH
Annual operated land (ha/year)	133.4	213.1	180.8	216.1
Service charge (USD/ha)	**32.0**	**80.2**	**32.5**	**79.7**
Annual revenue (USD/year)	4,268.8	17,090.6	5,876.0	17,223.2
Annual cost (USD/year)	4,001.7	12,556.7	4,737.3	12,168.4
Annual profit (USD/year)	267.1	4,533.9	1,138.7	5,054.8
Profit (USD/ha)	**2.0**	**21.3**	**6.3**	**23.4**
Break-even area (ha/year)	116.4	117.5	113.0	109.6
Payback period (years)	11.9	3.4	8.2	3.6

Source: Field survey, 2019

Table 4 presents the average profitability per tractor and CH operation. As a result, group T, CH, and B received a profit from the operation were roughly 2 USD/ha, 21.3 USD/ha, and 29.7 USD/ha (tractor 6.3 USD/ha, CH 23.4 USD/ha). Moreover, the annual utilization of tractor and CH required for economic feasibility was evaluated using break-even analysis. The result indicated that the break-even areas per year were estimated at 117.4 ha for group T, 117.6 ha for group CH, and 112.8 ha (tractor) and 109.8 ha (CH) for group B. This means that after an additional hectare of either tractor or CH used would make a profit for the owners. Moreover, the payback period was estimated to be at 11.9 years for group T, 3.4 years for group CH, 8.2 years (tractor) and 3.6 years (CH) for group B to earn back investment.

CONCLUSION

There were no significant differences in characteristic respondents and approximately 20% from three group owners aware of training programs about tractor and CH, which is usually conducted by the dealer. Yet, there were no training programs on proper management, repair, and operate machinery provided by extension workers or department of agriculture engineering.

Generally, farmers contacted machine owners before any operations to secure their place to be available on time, and they usually asked the same service providers of the previous year. Among the operating costs incurred, depreciation cost was the highest cost, followed by diesel and labor costs. In some cases, machinery owners tend to offer higher pay to skilled operators to work for them, especially during the peak seasons. Regarding profit, the utilization of tractor and CH under current conditions was profitable for machinery owners. Three group owners should increase annual use beyond the break-even areas by providing more custom service to other farmers in order to earn back the investment on tractors or CH. This result suggests that the break-even area and payback period analysis can also give an indication for farmers to decide whether to purchase a new tractor or combine harvester or ask more custom service.

Therefore, this study recommends that the owners should prolong the economic life of tractors or CHs by conducting proper and regular maintenance that will eventually lead to shorten the break-even areas and payback period in order to gain more profit. Additionally, the government or private company should provide special training programs for the machine operators, farmers, and mechanical extension officers on proper management, repair, and operation. Also, the local government should setup the formula for ensuring the fair prices of the custom service.

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Research article

Coping Strategies of Japanese Farmers to Recent Challenges in K City, Chiba, Japan

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Received 7 February 2020 Accepted 12 December 2020 (*Corresponding Author)

Abstract Japanese agriculture has been facing various challenges such as increasing population of elderly farmers and lack of successors. Moreover, several environmental and market issues have tested the capability of Japanese farmers to cope. Through a case study approach, this study aims to clarify the coping strategies of farmers in K City, Chiba Prefecture to recent challenges and determine the issues to support and sustain their local agriculture. A series of visits were conducted in 2018 and 2019, and in-depth key-informant interview was conducted in June 2019. In-depth key-informant interview revealed that farmers from K City organized a Farmers' Market at their own initiatives to sustain and support the local agriculture for the next 10 to 20 years. Since the establishment of the Farmers' Market in 2003, the farmers faced pesticide residue reports on turnip and various vegetables in 2008 and 2010, respectively; radiation residue report as an effect of the 2011 Great Tohoku Earthquake and Nuclear Plant Meltdown have brought negative impacts to the farmers as harmful rumors on the safeness of the agricultural products from K City spread to name a few. Farmers have initiated innovative actions and adapted strategies to overcome these challenges. SWOT analysis revealed that the farmers, at their own expense, regularly tested the produce for pesticide and radiation residue to assure its quality and safeness. However, if not continued, misconception among consumers will prevail then lead to distrust. They even provided other services such as restaurant, café, farm tour and seminars. On the other hand, the farmers recently tend to supply to other markets aside from the Farmers' Market, conveying a significant supply issue to be addressed. In general, these strategies and initiatives which reflect the farmers' passion and motivation to achieve sustainability seemed to be the factors that made them resilient to the changing environment.

Keywords resiliency, farmers' market, motivation, adaptation strategies, SWOT analysis

INTRODUCTION

Japanese agriculture has been facing various structural challenges that need to be addressed for the sector to survive. Among these, some of the most important challenges are the increasing population of elderly farmers and lack of successors (Brady, 2016) and decreasing population of newcomers (MAFF Japan, 2018). The average age of farmers in Japan is 66 years old (MAFF Japan, 2018; OECD, 2019) which implies that the sector highly depends its labor on elderly people. The dependence of labor on elderly people can affect the production of the agriculture sector in the long run, in terms of loss in human capital once they are only treated as those who receive social services (Haga, 2018). According to Su et al. (2018), lack of farm successors and insufficient agricultural laborers are some of the factors that contribute to the abandonment of farmland which can have a significant impact on the socio-economic conditions of the farmers as well as on environment in terms of rural landscape loss. On the other hand, the Organization for Economic Co-operation and Development (OECD, 2019) stated that the number of newcomer farmers is less than the numbers of farmers who are exiting the agriculture sector. One way to support and encourage these farmers is to provide accessible markets.

On a more micro-level, Japanese farmers are often faced with several environmental and market issues which test their capability to cope. Japan is an archipelago located in the Pacific Ring of Fire which makes it vulnerable to earthquakes. The Great Tohoku Earthquake, the strongest recorded earthquake to hit Japan which happened last 2011, left a total of 18,186 areas of damaged agricultural land in prefectures such as Tochigi, Ibaraki, and Chiba among others (MAFF Japan, 2013).

OBJECTIVE

This study aims to clarify the coping strategies of farmers in K City, Chiba Prefecture to recent challenges and determine the issues to support and sustain their local agriculture.

METHODOLOGY

This study gathered primary data through a series of visits conducted in 2018 and 2019 and an in-depth key-informant interview in June 2019. This study interviewed the president of farmer-based corporation (hereafter, A Corp) and K Farmers' Market manager through purposive sampling. In order to further grasp the situation on the ground, impromptu interview of farmers market staff, farmers and consumers were also conducted. The qualitative approach is used as this can reveal the passion and motivation of the farmers in coping with the different challenges that they encounter. The data were analyzed through SWOT analysis since it is descriptive and qualitative in nature. SWOT analysis plays an important role in certain situations in a theoretical, historical, and time frame perspective (Gürel, 2017). This study focused on the practices and experiences of a farmers group in K City, Chiba Prefecture as they have experienced various environmental and market issues that affected their local agriculture and welfare.

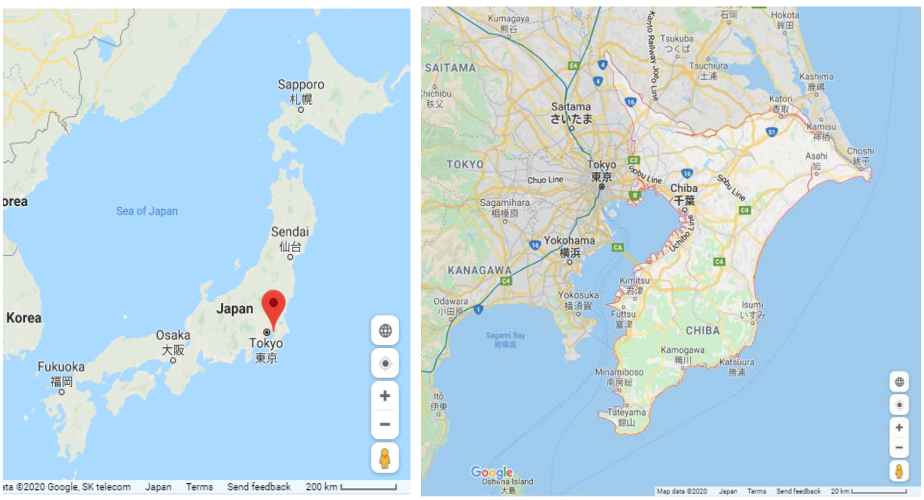

Fig. 1 Map of Chiba, Japan where the K Farmers' Market is located
Source: Google Maps

Located Northwest of Chiba Prefecture, K City is about 40 km, away from Tokyo (Fig. 1). Agriculture land accounts for 1,773 ha, of which rice fields occupy about 1,047 ha, followed by vegetables (663 ha) and fruits (63 ha). In terms of total domestic production volume, K City is considered the major producing area of turnip, leek and spinach. With proximity to Tokyo and good accessibility, it is also a popular bedroom or commuter town. Thus, this city is also experiencing agricultural land conversion to residential.

RESULTS AND DISCUSSION

K Farmers' Market Profile

The group of farmers from K City, Chiba Prefecture established a limited company in 2003, and built the K Farmers' Market at their own initiative in order to sustain and support the local agriculture for the next 10 to 20 years. In 2004, this company was converted to a corporation with 15 stakeholders. These initiatives were triggered by threats from cheap imported leek and were encouraged by the demand of local consumers for freshly harvested local produce.

In the early 2000, Japanese farmers was severely affected by imported vegetables from China (Teramachi, 2002). Harashima (2006) presented the initiatives of the Japanese government and farming communities on significant increase of imported leeks and low market price. During this time, most farmers in the study resorted to keep their harvest in cold storage since their produce could not compete with significantly low-priced imported leeks. This resulted to income losses and decrease in farmer's motivation.

As mentioned earlier, turnip is one of the famous agricultural products of K City. However, local consumers do not have the opportunity to taste freshly harvested turnips since these are commonly shipped to a wholesale market and sold via auction before some are shipped back to local supermarkets or vegetable stores.

K Farmers' Market has four (4) management principles: 1) place of sale, sharing information, and interaction; 2) consideration of consumer satisfaction; 3) promotion of local production – local consumption; and 4) development of the community. Currently, it employs six (6) full-time and 66 part-time workers. Although there were only 150 farmer-members during the early years in 2003, it grew up to 230 farmers in 2019. However, only 150 farmer-members are currently active. Among these farmers, there are only about 50 farmers who are under 40 years old, conveying that young farmers only comprise one-third of the active members. Although majority of farmers produce vegetables, there are also 15 and 10 farmers who produce rice and fruits (e.g. blueberry, strawberry, and grape among others), respectively. Agricultural products such as citrus, apples, dried persimmon, and melon are not available in K City, but these products are sourced from prefectures such as Kagoshima, Aomori, Nagano, and Ibaraki, respectively.

Fig. 2 Sticker tag produced using the label-printer

Source: Market visit, June 2019

Each farmer-member has the control on the time of harvest and the amount and kinds of produce to harvest. They can also decide on the amount per pack or set as well as on the method and place of sorting and packing. In terms of the pricing and labeling of the products, the farmer-members can decide on the price of their produce when they print sticker tags using the official label-printer. Fig. 2 shows the label of the produce which includes farmer name, product name, production area, price, and tax. It is important for them to keep a production history record, which is required to be submitted on a regular in order to be able to issue or print sticker tags for their products. Inside K Farmers' Market, the farmer-members personally display their produce and make placards for promotion. There are also no designated spot or shelf per farmer-member. A sales report is sent to each farmer-member for five times per day via SMS based on the cashier data. This enables the farmer-members to have the option of harvesting additional produce for the market. However, any unsold products should be picked up by the farmers before the market closes.

The K Farmers' Market uses Teraoka Cashier System which includes production history recording, label printer, semi-automated cashier. In order to increase transparency, the label printer requires submission of production history records and use of farm ID number. This also enables the farmer-members to set their own price. Meanwhile, semi-automated cashier requires one staff per cashier which decreases the cash handling mistakes. Although the market only accepts cash payment, accepting credit card payments is also being considered. Moreover, self-bagging is also implemented.

In terms of information sharing, the market has an official website and Facebook page where products, upcoming events, store schedules, activity reports, recommendations, and reviews are regularly showcased. As the latest initiative, the market engaged in Choku-Buy (https://choku-buy.com) for promotion and information dissemination. This encourages each farmer-member to establish individual pages on the Choku-Buy website to share updates on their farm, and each consumer to give feedbacks directly to farmers and use Choku-Buy Point Card.

Humble Beginnings and Challenges of K Farmers' Market

The K Farmers' Market was established in 2003; however, Table 1 shows the significant events and challenges that tested their capabilities to cope. Five years after the establishment, there was a report about the pesticide residue on turnip. They organized a task force in order to address the situation. They also invited experts and coordinated group studies. They had to conduct their own regular pesticide residue testing at their own expense. All these are done to regain the trust of the consumers.

Table 1 Significant events and challenges in K Farmers' Market

Year	*Challenges*	*Significant events (Farmer responses)*
2003	Sustain and support the local agriculture for the next 10 to 20 years? "All farmers should have dream, charm and pride"	Established a limited company Built the K Farmers' Market
2004		Converted to a corporation
2008	Address pesticide residue report on turnip	Organized task force; Invited experts; Visited farmer's field; Conducted pesticide residue testing
2010	Address pesticide residue report on various vegetables	Closed market; Organized task force; Invited experts; Visited farmer's field; Checked production records; Conducted seminar of safe use of pesticides; Conducted awareness survey on pesticide and its usage; Conducted pesticide residue testing; Re-opened the market
2011	Impact of Great Tohoku Earthquake and nuclear plant meltdown Identified as radiation hotspot city nearest to Tokyo[1]	Focused on farmer empowerment and collective action (e.g. invite experts; conduct training, seminars and experiments, sampling and testing by individual farmers, identify contaminated products; consumer participation; transparency on pesticide and radiation test results)
2016	Need to increase number of market visitors Promote local produce and vegetable consumption and	Established a farmers' restaurant and café

Source: Market visit, June 2019

In 2010, the farmer-members faced another report on pesticide residue concerning various vegetables. They had to close the Farmers' Market to focus on the issue. Another task force was formed and decided to check the production records, visit the farms, and examine the awareness of the farmer-members on pesticides and its usage. As this was the second time to have the incident on pesticide residue report, they resorted to conduct regular testing on all vegetables at own expense. By December 2010, the Farmers' Market re-opened after testing all 150 produce which all had negative results from pesticide residue.

Another challenge that could have destroyed their passion and motivation in sustaining local agriculture was the Great Tohoku Earthquake in March 2011. This also caused the nuclear plant meltdown and reports identified K City as a radiation hotspot nearest Tokyo (Japan Today, 29

November 2011). This started the harmful rumors about the nuclear contamination on the produce of K Farmers' Market which significantly affected their sales. Due to the harmful rumors and low trust on farmers conducting the residue testing, farmer empowerment and collective action were initiated which include inviting experts for training and seminars, conducting sampling and testing, and engaging consumers by letting them observe and understand the safety activities and procedures done to ensure quality of their produce. These gradually increased the number of market visitors.

In 2016, farmers' restaurant and café were established with a concept of traditional Japanese house. They introduced local dishes which are made and served by all female staff including the farmers' wives. This also aids in encouraging the consumers to buy local products and to consume more vegetables (e.g. vegetables in season). The restaurant and café are open every day except on Wednesdays from 11:00 AM to 03:00 PM. They offer a "No Meat, No Fish, All Local Vegetables" kind of buffet with drinks and desserts which utilizes 100 kinds of vegetables. They can serve approximately 100 customers per day. The restaurant and café have also faced challenges such as t limited kinds of local vegetables available and unstable income with only 4 hours of operation. As part of their solution, they started offering the restaurant as an activity space after 3:00 pm.

SWOT Analysis of K Farmers' Market

SWOT analysis (Table 2) revealed three main points. First, farmers conduct regular pesticide and radiation residue testing (SO1), but this incurs additional expenses to each farmer (WO1). If this is not continued, the misconception among consumers that the produce is unsafe will prevail (T1) which will lead to consumers' distrust and eventually prefer other markets (WT1). Since the K Farmers' Market value their loyal customers and those customers who once left them, they have been conducting testing until now.

Table 2 SWOT analysis of K Farmers' Market

	Strengths (S)	*Weaknesses (W)*
Opportunities (O)	1. Conduct pesticide and radiation residue testing 2. Provide alternative marketing channel to local farmers and newcomers 3. Offer different activities, products and services all year round	1. Create additional farmers' expense 2. Experience unstable and unpredictable supply of produce 3. Different thinking, priorities, and interests of farmer-members
Threats (T)	1. Possible misconception may prevail if not continued 2. New marketing channels has emerged 3. Management may not function if one role is unavailable	1. May result to customers distrust and eventually prefer other markets 2. Puts pressure to availability and variety of supply, which may result to costumer dissatisfaction 3. Lack of successors

Source: Market visit, June 2019

Second, the provision of alternative marketing channel to local farmers and newcomers is another strength of K Farmers' Market (SO2). This gave farmer-members to make their own production and marketing decisions. In other words, each farmer-member freely decides on the volume and time of harvest. They are also free to set the amount, condition and price of each package if they are transparent in the production process (e.g. production history). They even have the choice to replenish their produce or not since sales update is sent 5 times a day. However, since farmers need to collect unsold produce before the market closes, most farmer seemed not to be proactive in replenishing their produce. Market observation and key-informant interview revealed that limited choices of vegetables by 12 noon is a common. With this situation, K Farmers' Market experience unstable and unpredictable supply of produce (W2), which is getting alarming with the emergence of new marketing channels (e.g. supermarkets with designated local vegetable area). This puts more pressure to the availability and variety of supply, which may result to customer dissatisfaction (WT2).

In order to address this issue, there is a need to understand the farmers behavior towards K Farmers' Market and determine the impact of ICT to farmers.

Third, K Farmers' Market have been offering different activities (e.g. harvest festival, rice harvesting, potato harvesting), products and services (e.g. restaurant, café) all year round. This served as a "ba" or place of action (i.e. opportunities for various stakeholders to interact, share information and understand one another towards a better community) (SO3). However, with different thinking, priorities and interests of farmer-members, it seemed that all members are not active as mentioned in the previous section (W3). It is expected that management may not function if one role is unavailable (WT3). Key-informant interview clarified that there may be existing differences in values and thinking between original incorporators and current farmer-members. Therefore, aging incorporators have the responsibility to address the possible lack of successors (W3), who will be willing to continue for the next 10-20 years.

CONCLUSION

In general, the strategies and initiatives of K Farmers' Market seemed to clearly reflect the farmers' passion and motivation to achieve sustainability and resiliency under the changing environment. However, SWOT analysis revealed that despite all the strengths it possesses and opportunities it offers, K Farmers' Market needs to address the lack of successors since the original incorporators are aging, and the unstable and unpredictable supply which is further threatened by the recent emergence of new marketing channels.

For further study, there is a need to understand the farmers behavior towards K Farmers' Market and determine the impact of ICT to farmers.

ACKNOWLEDGEMENTS

We wish to extend our sincere appreciation to A Corporation President, and K Farmers' Market manager, staffs and farmers for their support and cooperation.

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Research article

The Abundance of Hemiptera and Diptera Fauna on Monsoon Rice at Nay Pyi Taw, Myanmar

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Received 20 January 2020 Accepted 12 December 2020 (*Corresponding Author)

Abstract The abundance of Hemiptera and Diptera fauna studied on monsoon rice at Kyee Inn village, Pyinmana Township, Myanmar, 2018. Insect species were collected from 56 grid points (G) using a D-Vac vacuum suction-machine. Using simple correspondence analysis, the peak number of *Sogatella furcifera* occurred in G33, the second-highest number of *Nephotettix virescens* in G35, followed by *Nilaparvata lugens* in G30, they belong to the order Hemiptera. In order Diptera, *Aedes stimulans* in G38 is the highest mean number, followed by *Chironomus* sp. and *Uranotaenia sapphirina* from G32 and *Hydrellia philippina* from G33 was observed. Correspondence analysis showed species population of order Hemiptera is more abundant than the order Diptera. The population of major insect pest species such as *Nilaparvata lugens* and *Sogatella furcifera* occurs at higher density during the study period. It is due to the usage of broad-spectrum chemical insecticides in the early crop growth stage. In order Diptera, *Hydrellia philippina* is a pest on rice, but *Aedes stimulans* and *Uranotaenia sapphirina* are not the rice pests, even though *Aedes stimulans* is a vector of dengue disease. Meanwhile, *Uranotaenia sapphirina* feeds on the invertebrate host. The results indicated that Hemipteran fauna is more abundant than Dipteran. We need to give Hemiptera's serious pests more attention to provide the proper control measure for them.

Keywords Hemiptera, Diptera, monsoon rice

INTRODUCTION

Rice (*Oryza sativa* L.) is one of the most important crops in the developing world. Insect pests are the significant biotic constraints in rice production throughout the country. Insects have the largest number of species present in the rice field. More than 100 species of insects attack the world rice crop. Almost 20 insects are considered rice pests of economic importance, including stem borers, gall midge, defoliators, and vectors like leafhoppers planthoppers that cause direct damages and transmit various diseases. The actual species complex differs in abundance and distribution from locality to locality and from year to year (Pathak and Khan, 1994). Moreover, knowledge of the species present and their role in the ecosystem can be essential for deciding whether to use insecticides (Wang et al., 2000).

Dooling (1991) stated that Hemiptera is also crucial in agriculture, which causes direct damage to plants by herbivory and indirectly by transporting diseases. Diptera is a disease vector, agricultural pests, pollinators, and biological control agents (Wikipedia, 2020). Many aquatic organisms like hemipterans, coleopterans, dipterans are known to reproduce in paddy fields (Bambaradeniya et al., 2004). Hemipteran and dipteran insects have behavioral, cellular, and chemical strategies to evade or cope with the host plant defenses making these insects incredibly destructive pests worldwide (Kaloshian and Walling, 2016). Most farmers do not realize that the role of insect species composition found in their rice field and cannot differentiate pest or natural enemies. They often apply pesticides when they see species of arthropods in the rice field. There is limited information or knowledge on the Hemiptera and Diptera fauna in the study area. Therefore, it is essential to provide necessary and critical information about the abundance of insect species as a part of a taxonomic framework to bolster rice production in Myanmar.

OBJECTIVE

The study's objective was to investigate the abundance of Hemiptera and Diptera fauna to provide a theoretical basis for pest management's sustainable control in the study area.

METHODOLOGY

Experimental Site

The experiment was conducted in 56 farmers' fields from Kyee Inn village, Pyinmana Township, Nay Pyi Taw, located between 19°70'66"-19°72'62" N and 96°22'43"-96°25'73" E. The study area 's measure 2.4 km wide by 3.9 km long (550 ha) was selected for hemipteran and dipteran fauna in the monsoon rice season of 2018. The rice cultivar was Manawthukha grown as farmers' usual practices in all experimental fields.

Insect Species Sampling

Insects were collected on a 300 m - by 300 - m grid pattern, resulting in 56 grid points (G). The species sampling was done at fortnightly intervals from 20 days after sowing (DAS) to the ripening stage. We took five subsamples at random from each rice field. We collected samples from 56 grid points collected near the center of the field, at least 5m away from the edge, to reduce edge effects by using D-Vac vacuum (Insect Net-Hand Carry Model 122S, made by Rincon-Vitova Insectaries). One sample usually came from 4-5 hills of rice plant at an early stage and 2-3 hills at maximum tillering stage. The duration sampling time is 1 to 2 min, depending on the rice's growth stage. Each sampling was performed three times in each field. All the collected specimens were immediately transferred to sample jars preserved in a labeled and filled with 90% methylated spirit (Zhang et al., 2013).

Identification of Insect Species

All the collected samples were identified to the order, family, genus, and species level using the references and keys; the textbooks of Insects of Australia (CSIRO, 1970), Manual of Nearctic Diptera, Volume 1, 2, 3 (McAlpine et al., 1981), and Pests of rice and their natural enemies in Peninsular Malaysia (Vreden and Ahmadzabidi, 1986). Species identification was done using OLYMPUS SZ 61 camera attached microscope (10 x × 45 x).

Data Analysis

Correspondence analysis of the abundance of Hemiptera and Diptera species composition was done by the software program SAS 9.1 (SAS Institute, 2008).

RESULTS AND DISCUSSION

Correspondence Analysis of Hemiptera and Diptera Fauna in Different Grid Points

Correspondence analysis was carried out to examine the most abundant insect species' mean population in different grid points (Table 1). Average values give the number of insect species. The ordination of other grid points (56 Grid Points) and the mean number per sample of insect species were different. It is necessary to provide critical data in insect species abundance as a partially taxonomic aspect in rice production. The arthropod community is also considered an essential component in rice field ecosystems, showing differences in composition, diversity, and species richness between communities of different habitats and development stages (You, 1997). The collected Hemipteran and Dipteran are used as variables.

Table 1 Contingency table of the observed Hemipteran and Dipteran in different grids points

Order	Hemipteran					Dipteran			
Grid Point	*Nephotettix nigropictus*	*Nephotettix parvus*	*Nephotettix virescens*	*Nilaparvata lugens*	*Sogatella furcifera*	*Chironomus* sp.	*Aedes stimulans*	*Uranotaenia sapphirina*	*Hydrellia philippina*
G1	1.41	0.00	1.73	7.94	16.28	3.61	6.56	7.28	3.00
G2	5.00	4.58	6.32	10.63	13.67	13.08	4.00	8.77	6.40
G3	1.73	1.00	2.65	9.95	13.08	3.87	4.00	2.24	4.24
G4	2.45	1.73	3.46	13.45	18.73	3.16	2.45	3.74	8.89
G5	3.87	0.00	3.61	7.48	10.00	3.87	2.45	1.00	2.65
G6	6.00	5.29	9.54	7.14	18.47	6.00	0.00	7.42	9.06
G7	4.24	4.58	6.78	12.21	26.17	14.90	13.30	15.68	6.56
G8	5.39	3.16	6.08	10.30	14.42	1.41	0.00	4.24	5.48
G9	6.00	4.47	8.37	8.31	11.87	0.00	6.48	7.00	5.10
G10	8.06	5.66	13.60	5.57	16.46	4.24	2.65	2.65	12.69
G11	1.41	6.08	7.48	7.35	14.53	9.00	7.14	8.49	4.12
G12	8.31	5.66	12.85	4.00	24.82	22.52	6.93	24.27	5.83
G13	8.19	4.12	10.54	5.29	11.70	4.90	7.75	2.45	6.00
G14	6.16	4.58	7.75	7.81	11.31	4.90	8.66	3.61	7.42
G15	13.19	6.71	12.69	8.06	15.75	5.20	5.00	4.47	3.74
G16	4.47	3.61	9.00	6.86	24.54	7.94	6.08	11.96	4.00
G17	6.86	3.46	9.75	7.28	16.46	16.67	4.36	11.96	6.86
G18	2.00	2.00	2.65	22.25	48.85	26.04	5.39	24.08	2.24
G19	3.32	2.45	6.63	15.23	10.20	4.36	5.10	10.10	8.37
G20	7.62	4.12	9.70	7.94	13.27	6.78	4.69	5.66	6.63
G21	10.63	4.69	12.88	7.21	10.72	5.00	7.00	4.12	6.93
G22	13.11	8.60	16.00	7.42	8.12	3.46	2.00	2.45	4.00
G23	6.78	3.74	9.06	6.78	11.05	10.91	7.62	9.59	5.66
G24	2.00	4.69	5.57	8.06	14.59	10.77	5.00	11.96	4.90
G25	5.83	3.46	5.48	9.70	13.19	6.08	6.63	2.45	4.24
G26	4.24	2.65	5.00	6.56	14.70	3.00	5.29	6.63	5.00
G27	1.73	5.66	6.48	7.68	11.87	13.75	15.56	12.25	5.29
G28	9.33	6.08	7.87	7.48	10.82	4.47	9.43	8.77	6.71
G29	9.38	14.66	24.04	6.24	11.05	16.28	4.24	9.75	3.87
G30	4.12	1.41	4.69	15.62	7.00	7.94	4.58	4.36	5.48
G31	7.75	3.61	10.54	7.62	8.00	2.83	0.00	5.92	2.83
G32	0.00	1.00	1.41	7.28	9.22	14.39	8.77	14.70	3.87
G33	1.41	0.00	0.00	6.56	10.58	0.00	1.73	3.16	5.20
G34	6.48	3.61	6.16	6.63	10.95	3.16	8.19	6.08	5.83
G35	11.40	10.05	21.31	6.86	7.14	3.87	3.74	2.00	5.10
G36	5.66	2.45	7.81	11.22	12.04	4.90	2.65	0.00	6.32
G37	4.36	1.41	4.24	6.86	17.41	7.14	3.46	5.00	4.24
G38	2.00	0.00	2.83	7.00	6.32	8.00	13.00	5.00	4.36
G39	5.57	2.45	7.21	10.86	8.94	5.66	1.73	1.41	4.69
G40	11.22	6.00	14.25	8.66	8.89	1.41	2.00	4.90	5.83
G41	5.10	2.83	5.48	11.09	14.49	6.71	7.21	10.25	3.16
G42	4.80	4.36	5.92	7.00	17.80	15.36	3.00	12.73	3.74
G43	3.00	2.45	9.43	7.07	19.62	4.90	2.65	0.00	6.93
G44	4.36	1.41	5.20	12.08	10.15	3.32	5.10	4.80	5.83
G45	3.16	5.10	7.55	16.94	20.98	9.64	4.69	7.28	5.48
G46	7.07	7.55	19.05	6.00	11.31	17.20	4.69	9.33	4.69
G47	7.87	4.24	11.83	16.16	18.33	0.00	4.00	5.10	7.21
G48	8.94	5.20	13.96	8.77	9.17	11.70	6.00	11.31	2.45
G49	6.93	5.10	7.48	9.33	15.52	2.00	13.00	8.19	5.00
G50	3.32	1.73	0.00	6.24	8.66	4.80	4.80	4.24	3.46
G51	7.81	4.58	10.77	5.20	10.63	7.48	1.73	0.00	6.32
G52	1.00	0.00	1.41	8.12	9.06	3.16	1.41	5.29	3.87
G53	5.00	3.16	7.21	8.00	14.11	3.16	1.00	9.49	3.00
G54	1.73	0.00	2.24	13.53	16.31	5.57	7.14	8.83	7.68
G55	0.00	0.00	3.16	9.43	12.12	7.81	3.16	9.33	2.24
G56	4.36	3.32	7.21	12.37	10.30	1.41	1.41	0.00	5.57

Correspondence analysis confirmed the peak number (0.37) *Sogatella furcifera* from G33, the second-highest number (0.30) *Nephotettix virescens* from G35, followed by *Nilaparvata lugens* (0.28) from G30, then *Nephotettix nigropictus* (0.20) from G22 and *Nephotettix parvus* (0.15) from G29, respectively. These species belong to the order Hemiptera. However, order Diptera, the peak mean number (0.27) *Aedes stimulans* from G38, the second-highest number (0.24) *Chironomus* sp. and *Uranotaenia sapphirina* (0.24) from G32, followed by the third highest mean number (0.18) *Hydrellia philippina* from G33. Correspondence analysis showed that the species population of order Hemiptera was more abundant than order Diptera. Therefore, Hemiptera was the dominant group in the study area. Indian Hemiptera includes several species of agricultural pests that are important from economic damage and loss to various crops. These insects act as a menace to agriculture because of some hemipteran insects' remarkable ability to transmit viral diseases of many plants in our country documented by (Ghosh, 2008).

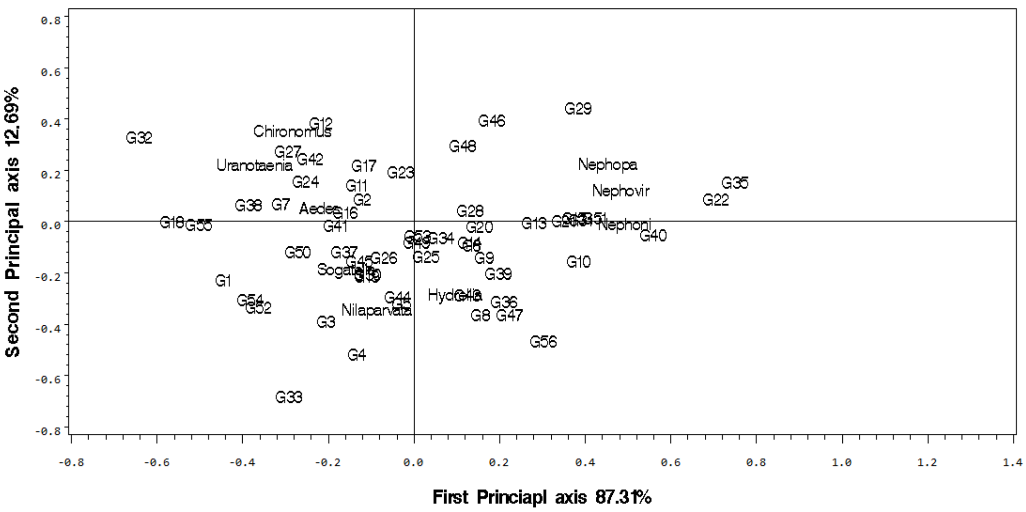

Fig. 1 Correspondence analysis of Hemiptera and Diptera species composition in different grid points

Correspondence analysis showed that the insect pest species *Sogatella furcifera* and *Nilaparvata lugens* had the most remarkable association with G1, G3, G4, G5, G26, G33, G37, G41, G44, G45, G50, G52, G54, and G55, respectively. Catindig et al., (2009) documented that Brown planthoppers transmit viral diseases while white backed plant hopper indirectly damage rice crops immensely. Similarly, *Nephotettix virescens* and *Nephotettix parvus* were closely associated with G22, G28, G29, G35, G46, and G48. *Nephotettix virescens* is a great threat to rice production because it is the most effective vector of rice tungro virus disease (Hibino and Cabunagan, 1986). Moreover, *Chironomus* sp., *Uranotaenia sapphirina* and *Aedes stimulans* were most associated with G2, G7, G11, G12, G16, G17, G23, G24, G27, G32, G38 and G42. However, *Hydrellia philippina* and *Nephotettix nigropictus* were more closely associated with G8, G9, G10, G20, G25, G34, G36, G39, G40, G47, and G56, respectively (Fig 1.). Diptera, given their diversity and abundance, drive ecosystem processes, both on land and in water. All species are of ecological importance, although the degree of their ecosystem influence varies in space and time and across taxa (Adler and Courtney, 2019). The results indicate that the mean population density of species differs widely among the different grid points. The species richness of arthropods in the rice plantation depends on the study's location, cultivation technique, and sampling methods (Zhang et al., 2013).

The first principal axis (Fig 1.) explains 87.31% of the total inertia and indicates the association between insect species and different grid points. However, the second principal axis accounts for 12.69% of the total inertia and shows that insect species also contribute to the relationship. The column categories' positions on the plot (Fig 1.) indicate that the first principal dimension is regarded as showing a contrast among insect species populations. The second principal dimension, on the other hand, is dominated mainly by different grid points. Hence, it may be concluded that about 87%

of the given data's information can be accounted for by a contrast between the insect species population belonging to the orders Hemiptera and Diptera. The different grid points may influence the remaining data (about 13%).

The distance of *Sogatella furcifera* and G45 is quite close. *Nilaparvata lugens* and grid points G5 and G44 are more intimate, and *Nephotettix nigropictus* was very close to G40, with all of these belonging to order Hemiptera. Lee and Park (as cited in May Thet Hlaing, 2018) stated that the pest species were mainly Homoptera and dominated by Delphacidae (*Nilaparvata lugens* Stal and *Sogatella furcifera* Horvath) and Cicadellidae (*Nephotettix virescens*), which involved more than 81 percent of pest abundance. These pests are responsible for substantial economic losses to rice yields. Most of the farmers use broad-spectrum insecticides such as acephate, cypermethrin, carbofuran, chloropyrifos, and imidacloprid in the study area. Multiple reports indicated that white-backed planthopper (*Sogatella furcifera*) and small brown planthopper (*Nilaparvata lugens*) had developed resistance to chlorpyrifos, buprofezin, and imidacloprid (Matsumura et al., 2014). In the agricultural field, the use of insecticides caused planthoppers damage. Similarly, under order Diptera, the distance of *Hydrellia philippina* was quite close to G8 and G36. Ferino (1968) reported that rice whorl maggot (*Hydrellia philippina*) damage led to a significant reduction in productive tillers. *Chironomus* sp. and G12 were even closer, while *Uranotaenia sapphirina* closely associated with G24, G27, and G42, respectively. Chironomids are considered potential pests, and most chironomids are root feeders (Heong et al., 1991). The resurgence of chironomids due to insecticide applications in rice has been noted elsewhere (Takamura, 1993). Flood irrigated rice fields serve as an ideal breeding site for potential vector mosquito species, resulting in a negative impact on human health, causing vector-borne diseases (Amarasinghe and Weerakkodi, 2014).

CONCLUSION

The present study reveals that the insect species population of order Hemiptera is more abundant than order Diptera. The mean population density of insect species composition varies widely for the different grid points. All experimental grid points were on farmers' fields; they sprayed insecticides in the early stages of the rice plant with a lack of knowledge of these chemical insecticides' effect on pest insects' natural enemies in the field. The consequence of this action is a major population increase in insect pests such as *Nilaparvata lugens* and *Sogatella furcifera*. The observed species *Aedes stimulans*, and *Uranotaenia sapphirina* are not pests on rice, but they live primarily in sunlit semi-permanent and water bodies with floating and emergent vegetation. *Aedes stimulans* is a vector of dengue fever disease and negative impact on human health. The obtained results indicated that order Hemiptera composed of severe pests and order Diptera composed of vector-borne mosquito species and one species feed on annelid's blood in the study area. The presences of hemipteran and dipteran species are essential things to be considered when designing pest management methods. Moreover, these findings will provide valuable information to the rice farmers in that area for a theoretical basis to improve rice insect pests' sustainable control. Therefore, further studies should be made on the relationships between these insects and their arthropod natural enemies to understand the rice ecosystem and improve pest management.

ACKNOWLEDGEMENTS

The authors would like to thank the generous financial and technical training support of the Japan International Cooperation Agency (JICA) Project for Capacity Development of Yezin Agricultural University (YAU-JICA TCP).

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Research article

Changes in Soil Physical and Chemical Properties with Depth due to Megascolicidae Movements

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Received 29 April 2020 Accepted 12 December 2020 (*Corresponding Author)

Abstract Earthworms have significant impacts on the physical and chemical properties of soils. It is known that they are remarkably improving soil fertility as well as promoting plant growth because earthworms make castings, which are rich in nitrogen, phosphorus and other nutrients. Additionally, earthworm's movements effects soil properties by their movements in the soil, notably soil aggregates, nitrogen and phosphorus concentration. Earthworms from Megascolecidae family are a major earthworms found in Japan, but there is lack of knowledge on its effect on soil properties compared to other earthworms. Subsequently, this study discusses the changes in soil aggregates, nitrogen and phosphorus concentration changes with depth due to Megascolicidae movements in the soil. An experiment was conducted using cylindrical columns of 12 cm height divided into 3 layers at 4 cm interval. Additionally, two groups were made, with litter and without litter, which were divided into subgroups with variations in earthworm numbers. The results of aggregates showed the tendency of aggregate formation in both the groups, with high formation rate in litter added group. The results of NO_3 and P_2O_5 content significantly differed among the 3 layers in the treatments. The trend of higher NO_3-N and P_2O_5 concentration was observed in middle layer and lower layer respectively. According to the results obtained, Megascolicidae movements effect the distribution of nutrients in subsurface soils.

Keywords Megascolecidae, earthworm movements, soil chemical and physical properties

INTRODUCTION

It is known that earthworms improve soil structure and enhance soil productivity (Barley, 1959b; Lee and Foster, 1991). They promote transport of nutrients and ions in subsurface soil with their bodily movements.

Earthworms are broadly divided into two families, Lumbricidae and Megascolicidae. Earthworms form Lumbricidae family are found in the area from temperate to polar regions of Europe and Asia and those from Megascolicidae family are found in the area from tropical to temperate zones of East and South East Asia. Further, ecologists divide them into three groups into anenic, epigiec and endogeic earthworms based on their habitual preferences (Bouche, 1977). Anenic earthworms are large species, which dig and inhabit upright, make deep burrows in soil and come to surface for feeding. Epigiec earthworms are small species, which lives and feeds on the surface of soil. Many literatures have been made on earthworm from Lumbricidae family on the effects of their activity to the soil properties. Langmaack et al., 1999, estimated that earthworm from Lumbricidae family (*Lumbricus terrestris*) makes 82.3 km/ha of burrows in the agricultural field. These burrows increase air and water permeability, transport oxygen and water and better penetration of roots of the soil (Kavdir and Ilay, 2011). In these literatures, many researches were concentrated on the nutrient availability in the casts on soil surface and the large part of the effects of these casts were clarified, but the knowledge of the effects of the cast in subsurface soil (12 cm depth) which will have significant roles on plant growth was limited. Therefore, this study tries to discuss the effects on soil physical and chemical properties in different layers of subsurface soil released by epigiec earthworm movements in subsurface soil.

OBJECTIVE

The objective of this study is to assess the changes in soil aggregates, nitrogen and phosphorus contents with depth due to movements by epigiec earthworm from Megascolicidae family.

METHODOLOGY

Sampling of Earthworms, Soil and Litter

Epigeic earthworms from Megascolicidae family (Fig. 1) were collected from depth up to 10 cm soil using hand-sorting method. The soil used in this experiment was Andosol, which are volcanic soils and covers 47% of land area in Japan. The soil was passed through 2 mm sieve (Fig. 2). Litter was collected from fallen leaves of oak and cereus trees (Fig. 3). The leaves were made into small pieces before using it. All the samples were collected from the same field in Kanagawa prefecture, Japan.

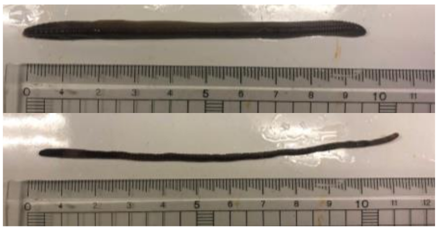


Fig. 1 Megascolicidae used in this study

Fig. 2 Soil used in the study

Fig. 3 Litter used in this study

Experimental Set-up and Conditions

Cylindrical columns of size 15 cm in diameter and 12 cm in height were used having surface area of 0.000018 m^2 for the experimental apparatus. In the experiments, the depth of soil was set 12 cm. The apparatus could be separated into three layers with intervals of 4 cm (Fig. 4). In this experiment, 0-4 cm is assumed as the subsurface soil. The experiments were conducted for 28 days in an incubator whose temperature was set at 17.1 ℃ ± 0.5 ℃ which is similar to the annual average temperature of the area where soil and litter were sampled.

In this experiment, 1.8 kg of soil was used. Patterns of soil organic matter content were set into two groups of 0% added litter and 5% added litter. Each group was further divided into three treatments with 0, 3 and 10 earthworms (Table 1). This experiment was designed with assuming the density of 1 earthworm per one column corresponding approximately 56 earthworms per one hectare. Soil and litter were mixed thoroughly for litter added group. The three column treatments were named from A1 to A3 for litter added group. Likewise, for 5% added litter group, treatments were named from B1 to B3 (Table 1).

The soil in the column was saturated before the start of the experiment by capillary action for 24 hours. After saturation, the excess water was released by gravity for 24 hours. Earthworms were put on the surface of the soil in the start of the experiment. The moisture content of soil for each treatment was maintained at 50 to 60%. To maintain the water content, weight of the treatments was measured on daily basis and equal to lost amount of water was added.

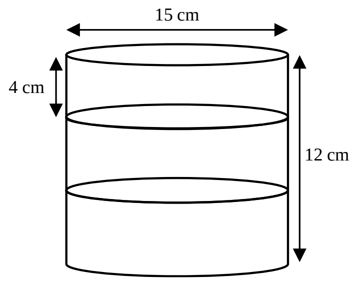


Fig. 4 Schematic diagram of cylindrical columns

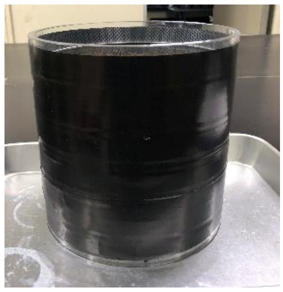


Fig. 5 Column used in this study

Table 1 Column treatment patterns

Litter added (%)	Number of earthworms / cylindrical columns	Treatments
0	0	A1
	3	A2
	10	A3
5	0	B1
	3	B2
	10	B3

Sampling and Parameters Measured

Soil was sampled on 0, 7, 14 and 28 days from the start of the experiments from each layer of 0 to 4 cm, 4 to 8 cm and 8 to 12 cm randomly at 6 different points. The samples were analyzed for water stable aggregate using Yoder's method (Yoder, 1936), total available phosphorus using Troug method (Troug, 1930) and Nitrate nitrogen using Cataldo method (Cataldo et al., 1975).

RESULTS AND DISCUSSION

Survival of Earthworms at Different Layer of Soil

Table 2 shows the change in survival of earthworms at the depth of 0 to 4, 4 to 8 and 8 to 12 cm in 0% and 5 % added litter group at 28 days of experiment. There was no earthworm found in 0 to 4 cm layer in all the groups. The number of earthworms increased with depth. In 0% added litter group, most earthworms were present at 4 to 8 cm layer. Whereas, in 5% added litter group, a greater number of earthworms were present in 8 to 12 cm layer. In B3, 12 earthworms were seen at 28 days, for which an assumption was made that new earthworms were born. With the obtained results, it was proved that the epigiec earthworm from Megascolicidae family used for this study are active in subsurface soil.

Table 2 Result of survival of earthworm at different layer of soil at 28 days

Layer (cm)	A2	A3	B2	B3
0~4	0	0	0	0
4~8	2	7	2	4
8~12	1	2	1	8
Total	3	9	3	12

Periodic Change in Water Resistant Aggregate

The ratio of 2 mm water resistant aggregates increased with time in all layers of the treatments for both the groups (Figs. 6, 7 and 8). High aggregate content was seen in 4 to 8 and 8 to 12 cm layers where the larger number of earthworms existed. Similarly, the Mean Weight Diameter (MWD) of aggregates increased in 4 to 8 and 8 to 12 cm layers with time (Figs. 9, 10, 11 and 12). Group B having added litter content increased aggregates content in all the three layers. It could be explained by the activation of earthworm metabolism by the litter, which provided nutrient to the earthworm.

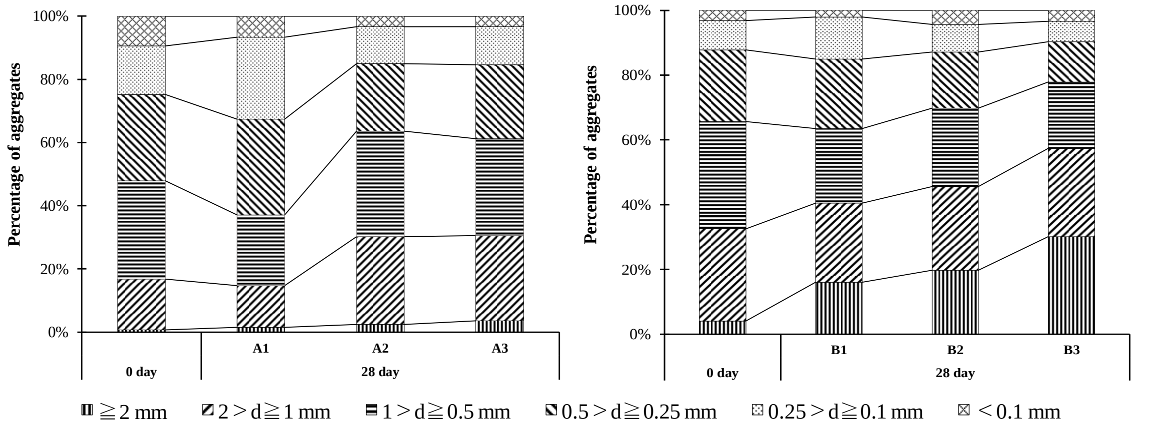


Fig. 6 Changes in aggregate percentage at 0 to 4 cm depth in A and B

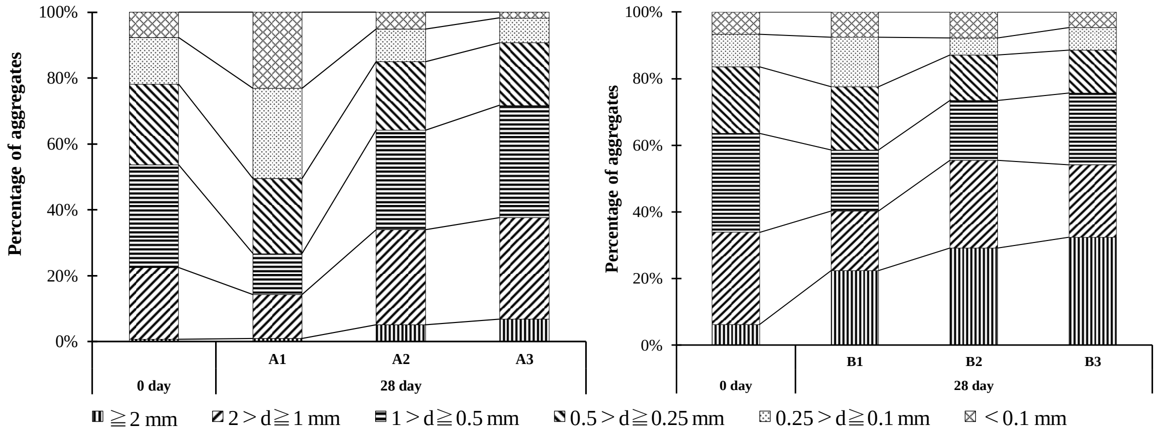


Fig. 7 Changes in aggregate percentage at 4 to 8 cm depth in A and B

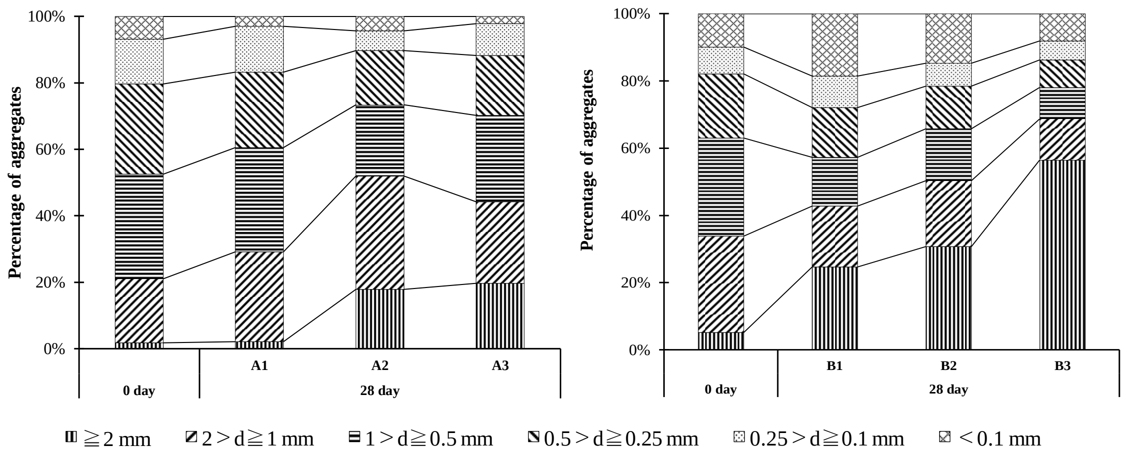


Fig. 8 Changes in aggregate percentage at 8 to 12 cm depth in A and B

The results of this study show that earthworm feeds on soil and litter and releases them in the form of casts. The released casts by the assimilation with soil to form aggregates of 2 mm or larger. This has been also showed in laboratory conditions by Kawaguchi et al., 2011, and in field conditions by Marinissen and Hillenaar, 1997; Ketterings et al., 1997 and Arai et al., 2013. In addition, Kawaguchi et al., 2011, found that 92% of casts weight had 2 mm or more water-resistant aggregates.

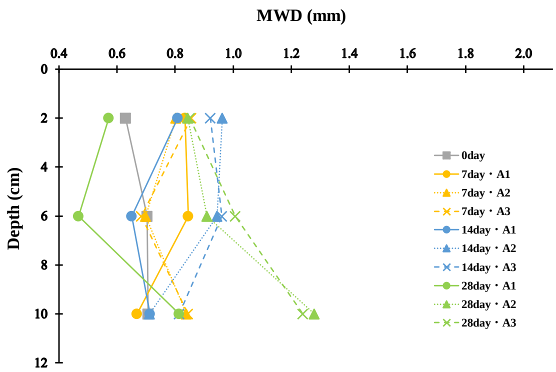


Fig. 9 Periodic changes of MWD content in A1 to A3

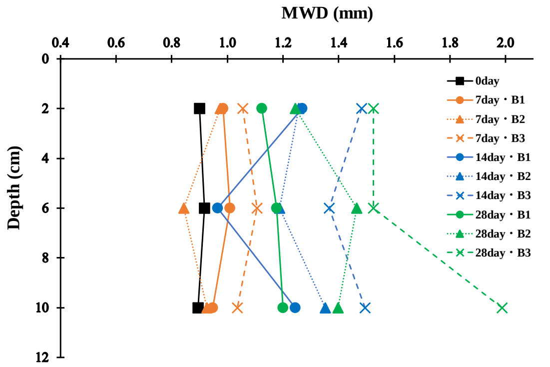
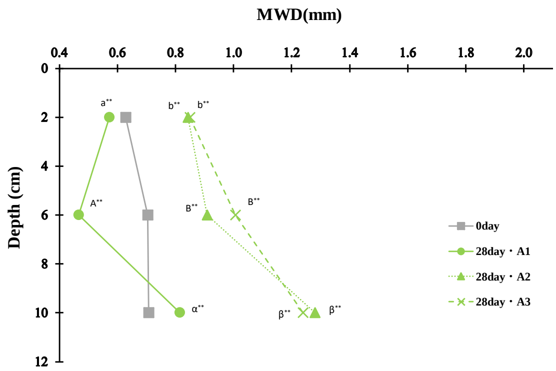
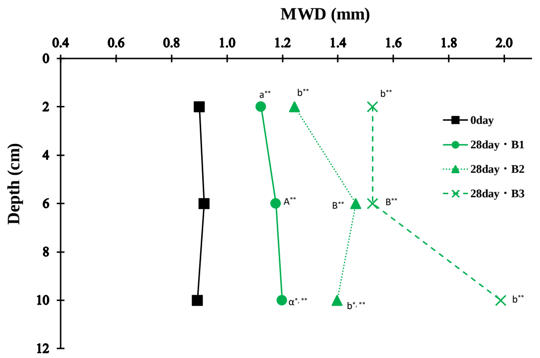


Fig. 10 Periodic changes of MWD content in B1 to B3



Significant difference at ** p<0.01, * : p<0.05

Fig. 11 MWD content in A1 to A3 at 0 and 28 days



Significant difference at ** p<0.01, * : p<0.05

Fig. 12 MWD content in B1 to B3 at 0 and 28 days

Periodic Changes in Nitrate Nitrogen Content

The nitrate nitrogen content became higher in all three layers of treatment A2 and A3, with A3 showing comparative high nitrate nitrogen content as shown in Fig. 13. Similarly, the nitrate nitrogen content in 5% added litter treatment B3, increased with time (Fig. 14). Nitrate nitrogen content was highest in treatment B3 in 28 days of experiment (Fig. 16). The highest value was observed in layer of 0 to 4 cm in B3. This increase of nitrate nitrogen content could be explained by nitrification of organic matter enhanced by microbial action present in casts of earthworms. As, B3 had the highest amount of organic matter, it is speculated that earthworm activity was highest in this treatment, resulting in excretion of casts and higher microbial activity. In this process, organic nitrogen gets converted to NH_4-N to NO_2-N, which further changes into NO_3-N. NH_4-N is converted to NO_2-N by the action of ammonia oxidizing bacteria. Whereas, NO_2-N is converted into NO_3-N by the action of nitrite oxidizing bacteria. Nitrifying bacteria are aerobic microbes and are active near surface of soils (Ward, 2008) which supports the result of this study where nitrate nitrogen content was high in upper layer of soil compared to lower layers. According to Su et al., 2017, *Amynthas corticis* from Megascolicidae family has nitrifying bacteria in casts. The results with high nitrate nitrogen content in treatment with high litter content can be discussed with the fact that nitrifying bacteria gets attached in the surface of the litter.

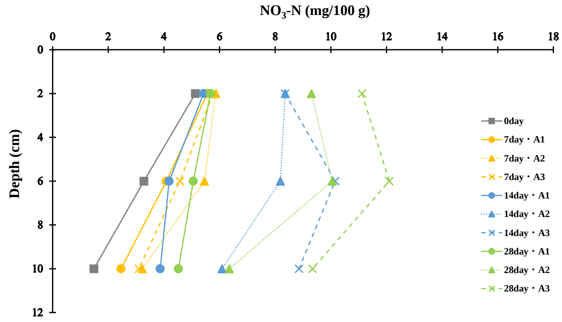


Fig. 13 Periodic changes of NO_3-N content in A1 to A3

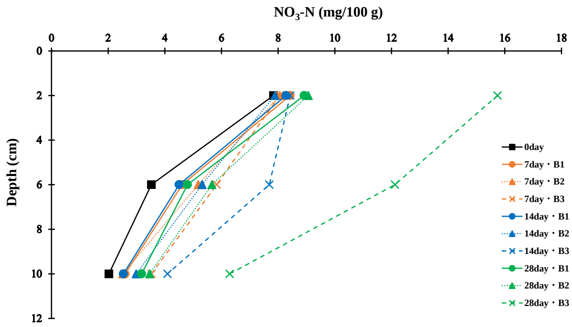
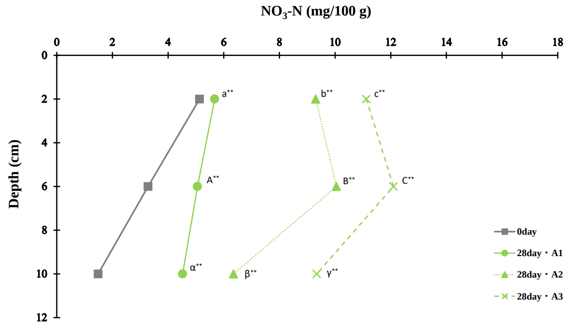
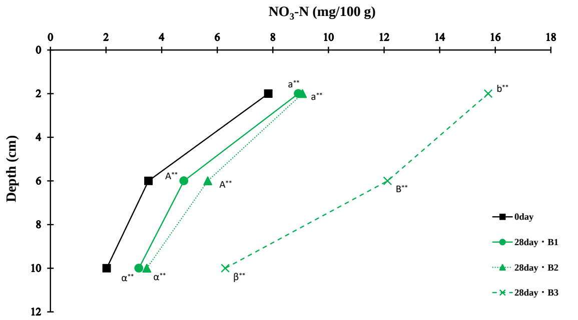


Fig. 14 Periodic changes of NO_3-N content in B1 to B3



Significant difference at ** : p<0.01, * : p<0.05

Fig. 15 NO_3-N content in A1 to A3 at 28 days



Significant difference at ** : p<0.01, * : p<0.05

Fig. 16 NO_3-N content in B1 to B3 at 28 days

Periodic Change in Total Available Phosphorus

High content of total phosphorus in lower layers of column was observed for treatment A3 and B3 contrasting to the results of nitrate nitrogen (Figs. 17 and 18).

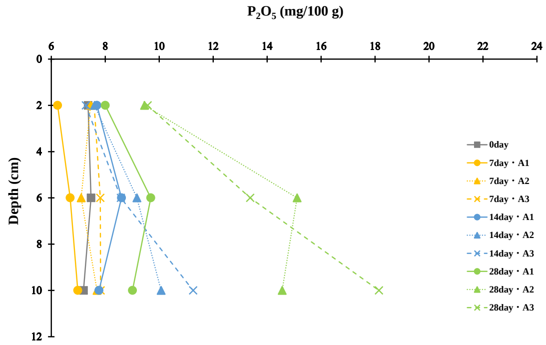


Fig. 17 Periodic changes of P_2O_5 content in A1 to A3

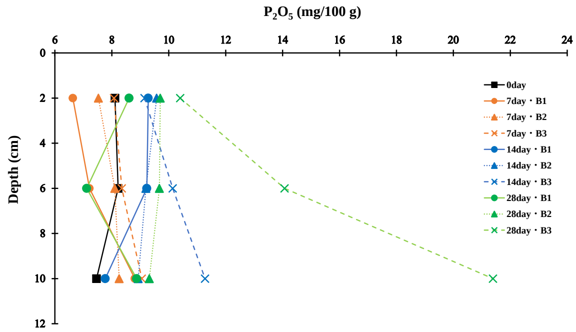


Fig. 18 Periodic changes of P_2O_5 content in B1 to B3

This tendency can be linked with high presence and activity of earthworm in lower layers. It is speculated that high phosphorus content is caused by high phosphatase activity in earthworm casts. High phosphatase activity results in increased inorganic phosphorus released by mineralization of organic phosphorus. Satchell and Martin, 1984 reported high level of phosphatase activity in earthworm casts of *Aporrectodea trapezoide*s, an earthworm from Lumbricidae family. The results of laboratory experiments conducted by Matsumoto and Taniguchi, 1995, hypothesized high phosphatase occurrence in earthworm leading to high phosphatase activity in earthworm casts and surrounding soils.

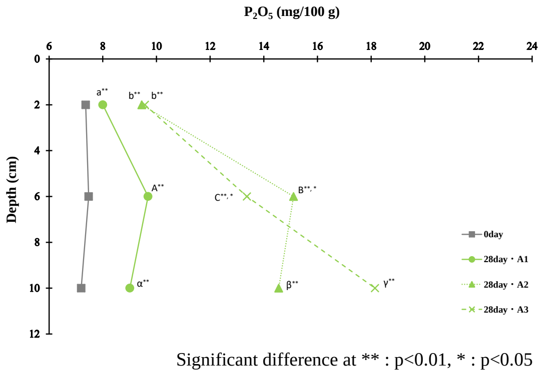


Fig. 19 P_2O_5 content in A1 to A3 at 0 and 28 days

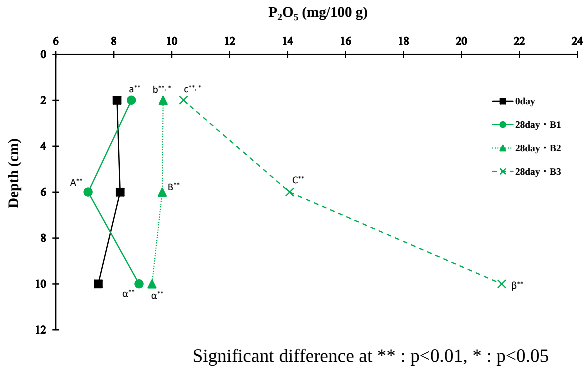


Fig. 20 P_2O_5 content in B1 to B3 at 0 and 28 days

CONCLUSION

This study was conducted to clarify the effects of epigiec earthworm from Megascolicidae family on soil aggregates, nitrogen and phosphorus content with their ecological behavior in subsurface soil using column treatment in incubator. Survival rate of earthworm at different layers resulted in high earthworm number between 4 to 8 and 8 to 12 cm deep, irrespective of litter content. Water resistant aggregates (larger than 2 mm) and MWD increased with time, where the earthworm numbers were high. Similarly, available phosphorus content was high in the layer with high earthworm numbers. This increase can be explained with phosphatase activity in earthworm casts. High phosphatase activity results in increased inorganic phosphorus released by mineralization of organic phosphorus. Whereas, nitrate nitrogen was high in the upper layer having less number of earthworm. The results of nitrate nitrogen content would be due to the presence of nitrifying bacteria in earthworm's casts, which are aerobic microbes and are active near surface of soils. With the obtained results, earthworm activity and movement showed potential for growth and development of plant by enhancing soil structure, increasing nitrogen and phosphorus content.

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Research article

Postharvest Management Options to Improve Tomato Value Chain in Cambodia

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Received 23 April 2020 Accepted 12 December 2020 (*Corresponding Author)

Abstract Tomato (cv. Mongal) value chain practices of a farmers' cooperative as pilot model in Siem Reap, Cambodia, were assessed and improved through the introduction of postharvest technologies and best practices. The existing value chain (EVC) practices included harvesting tomatoes at the breaker stage, use of harvesting container with smooth surface (plastic pail), use of plastic crate in hauling harvested tomatoes to the farmers' house where packaging in ordinary plastic bags at 10 kg fruit per bag was done. No sorting and special storage were practiced except for overnight storage at ambient when harvesting was done in the afternoon. The packed fruit were then transported to the city market about 12 km from the farm or 30-45 minutes ride using a motorcycle-driven carrier (locally named 'TukTuk'). Marketing tomatoes usually took half day. Using the cooperative's simple packhouse which linked farm production and marketing, improved value chain (IVC) practices were introduced, including sorting to ensure more uniform quality and damage-free fruit, sanitizing with 0.01% calcinated calcium (non-chlorine sanitizer) by dipping fruit in the solution for 3 minutes, modified atmosphere packaging (MAP) using perforated 50 µm thick low-density polyethylene bag at 10 kg fruit per bag, and transporting and direct retailing in ice box using a dedicated motorcycle-driven carrier. In another set of trials, three-day storage simulating extended period of distribution and marketing was included using ambient condition in the EVC while in the IVC, three storage options were introduced: ice box (3 kg ice per box with about 25 kg fruit replenished every day); low-cost cold storage using the Coolbot chamber; or evaporative cooler (EC). Results revealed that without storage (direct marketing after harvest) total postharvest loss was about 14% in the EVC; this was remarkably reduced to 4% in the IVC. IVC fruit were also firmer, had higher soluble solids and much reduced microbial load than EVC fruit. No pesticide residue was detected in both EVC and IVC fruit. With the three-day storage, the three storage options in the IVC did not differ much in reducing postharvest loss to about 3-6% from 22% in the EVC. IVC fruit also ripened slowly resulting in higher firmness than EVC fruit. Other quality attributes were not affected. Vitamin C content was slightly higher in IVC fruit than in EVC fruit. From the results, there is potential for integrating postharvest management options in value chains to reduce postharvest loss and enhance quality of tomatoes.

Keywords *Solanum lycopersicum*, value chain improvement, farm-packhouse-market model, postharvest loss reduction

INTRODUCTION

Tomato (*Solanum lycopersicum*) is a major fruit-vegetable in Cambodia with production continually expanding as a result of the introduction of improved varieties and production techniques as well as increased market demand and entry of modern market outlets (e.g. supermarkets, hotels and restaurants) due to the flourishing tourism industry (Buntong et al., 2012). However, poor postharvest practices are a serious problem resulting in poor quality perception and high postharvest losses (Genova et al., 2006; AVRDC-The World Vegetable Center, 2016). Postharvest losses vary with type of produce, location, growing season and the value chain stage (Weinberger and Acedo, 2011; Acedo and Easdown, 2015). Postharvest losses of tomato in Cambodia were estimated at 11-35% in Kandal province (Genova et al., 2006), 23% in traditional and modern supply chains in Kandal and Kampong Speu provinces (Buntong et al., 2012) and 26% in Battambang and Siem Reap provinces (AVRDC-The World Vegetable Center, 2016). Aside from poor postharvest practices and the perishable nature of fresh produce, other factors contributing to losses include the fragmented and unorganized supply chains and the hot and humid tropical climate. Postharvest losses are often absorbed by farmers as reduced farm gate prices and by consumers through an increased purchase price. Postharvest losses contribute to Cambodia's high dependence on vegetable imports from Vietnam and Thailand estimated at about 80% of domestic consumption (Millar, 2017). As part of Cambodia's strategic priorities to achieve inclusive and sustainable development, domestic production and marketing of all kinds of vegetable are being promoted in order to substitute imports (Royal Government of Cambodia, 2018).

Postharvest losses have significant economic, social, and environmental consequences. Globally, food loss amounts to about one-third of total production valued at almost one trillion US dollars in annual economic losses; contributes to hunger and malnutrition; represents about 25% of water used by agriculture; requires cropland area the size of China; and generates about 8% of global greenhouse gas emissions (GHG) which is the third largest after China and USA (FAO, 2013; HLPE, 2014). Reducing postharvest losses is a global agenda embedded in the United Nations Sustainable Development Goal (SDG) 12.3 which targets reducing food waste including postharvest losses by 50% by 2030 (https://sustainabledevelopment.un.org/). About half of the global food losses can be prevented with a more efficient supply chain and the saved food can feed about one billion extra people, thereby reducing the pressure to raise more food to feed an additional two billion people by 2050. Postharvest technologies play a vital role toward this end and can enable developing countries to improve the quality and competitiveness of their horticultural produce in domestic and international markets as they integrate into the world economy and global value chains proliferate. Additionally in Cambodia, reducing postharvest losses could potentially contribute to vegetable import substitution and self-sufficiency.

Postharvest management (PHM) is vital to reduce postharvest losses and contribute to improved food and nutrition security through three different pathways: (1) increasing the availability of food at farm-gate and market level, (2) reducing the price of food and thus enhancing potential access, and (3) reducing the volatility and quality of food availability (Van Gogh et al., 2017). PHM also contributes to food safety which is the most critical dimension of food quality. If the quality has deteriorated to a level that the food is no longer safe for human health, the food needs to be removed resulting in quantitative food loss (Bin Liu, 2016). Economic revenues of improved PHM include both efficiency (positive benefit-cost ratio) and effectiveness (incentives for supply chain stakeholders to engage in PHM activities). Furthermore, PHM increases employment as farmers and other value chain agents are engaged in postharvest loss reduction activities. PHM can also reduce GHG emission and global warming.

A value chain approach on PHM is important to effectively reduce postharvest losses (Batt and Cadilhon, 2007; Van Gogh, 2017). It should target smallholders who are the dominant players in supply chains in developing countries including Cambodia; otherwise, they would be further disadvantaged and marginalized (Van der Meer, 2006; Chan, 2009). PHM can overcome the underperformance in postharvest chains in terms of the loss of quantity and quality of the harvested produce, and hence the loss of revenues and resources. Postharvest losses are not caused by one or two specific links in the chain but are the result of an entire value chain. Tackling these losses therefore requires a value chain approach rather than actions from a single stakeholder or a single solution approach. The value chain approach specifies that the costs incurred in specific parts of the chain to create the added value will be sufficiently compensated by the revenues from the entire value chain. PHM measures are stimulated when there is good prospect of obtaining the revenues in exchange for the costs and risk of investment.

Reducing postharvest losses is context specific, and strategies to developing competitive and sustainable value chains have to be tailored to the socioeconomic and ecological environment in which the value chain operates. The root causes of postharvest losses can be generalizable; however, the magnitude and causes of losses and the measures to reduce losses will differ with supply chain. Attempting one-size-fits-all approaches can create more challenges than they address. In improving value chains, PHM measures need to be tested before commercialization. For example, in the cabbage supply chain in Central Philippines, postharvest loss in the traditional chain was estimated at 34% and introduction of 3-4 wrapper leaf retention and plastic crate packaging at the farm level; 2-3 wrapper leaf retention, 15% alum treatment for bacterial soft rot control and plastic crate packaging prior to transport to market; and 15% alum treatment prior to retail reduced losses to 3%, 6% and 11%, respectively, or a total loss of 20% (Gonzales and Acedo 2016). In the modern chain involving supermarkets, total loss was 25%, and introduction of 3-4 wrapper leaf retention and plastic crate packaging at the farm level; 2-3 wrapper leaf retention, 15% alum treatment and plastic crate packaging prior to transport to market; and 15% alum treatment and individual plastic film wrapping prior to supermarket display reduced losses to 3%, 7% and 6%, respectively, or a total loss of 16%. With the introduction of the different PHM measures, net income and return on investment increased. In Cambodia's tomato traditional chain in Kandal province, improved packaging (20 kg capacity plastic crate with modified atmosphere packaging or MAP using 50 µm-thick low density polyethylene or LDPE), precooling (5 min dip in 5°C water) and sanitizing (2 min dip in 200 ppm chlorine solution) at the farm level decreased fruit damage at the wholesale and retail stages and reduced weight loss at the retail stage by about two-fold compared to that of fruit conventionally packed in 20 kg capacity 50 µm-thick high density polyethylene (HDPE) and without precooling and chlorine treatments (Buntong et al., 2013). In the tomato modern chain in Kampong Speu province wherein only one intermediary (collector-wholesaler) was involved between farmers and supermarkets, MAP was only required, with 11 µm-thick film overwrap being more effective than LDPE in reducing weight loss and retarding fruit ripening.

In the present study, the existing value chain of tomato in Siem Reap province was improved by introducing selected PHM techniques in two scenarios, with and without storage options to simulate temporary holding prior to marketing and immediate marketing after harvest, respectively. Postharvest loss was quantified and fruit quality (physicochemical and food safety attributes) was determined.

OBJECTIVE

The study aimed to determine the effectiveness of selected PHM techniques in improved value chain in reducing postharvest loss and enhancing physicochemical quality of tomato and assess the comparative advantage of improved value chain over the existing value chain with and without a storage component.

METHODOLOGY

Tomato fruits cv. Mongal at the breaker to turning stage were sourced from local farms of farmer-members of a cooperative in Siem Reap. The harvested fruit were placed in plastic crates and hauled either to the farmers' house representing the existing value chain (EVC) or to the cooperative's simple packhouse located nearby representing the improved value chain (IVC). Ten kg fruit were used for each treatment per replicate. Three replications were used.

Experimental Trials Without Storage Component

In the EVC, after arrival at the farmers' house, tomatoes were packed in ordinary plastic bags at 10 kg fruit per bag without sorting or grading as usually practiced. The bags of fruit were then transported to Siem Reap city wet market using 'TukTuk' (motorcycle-driven rickshaw) about 12 km away or 30-45 min travel time. After the usual half day marketing period, the fruit were assessed for losses and quality attributes.

In the IVC, after arrival at the simple packhouse, the fruit were sorted and only defect-free fruit were used. The sorted fruit were sanitized by dipping for 3 min in 0.01% (100 ppm) calcinated calcium (CCa) solution which was followed by rinsing in clean water and air-drying. The fruit were then packed in MAP (50 µm-thick LDPE) at 10 kg fruit per bag and placed in 25-kg (30 x 30 x 40 cm) Styrofoam box with 1 kg ice (ice box) for transport to Siem Reap in dedicated 'TukTuk' for direct retailing and after half day, the fruit were assessed for losses and quality attributes. All treatments were replicated three times.

Experimental Trials with Storage Options

The same procedure as in trials without storage component was followed except that a 3-day storage period was included prior to transport to Siem Reap market to simulate temporary holding before marketing. In the EVC, the 3-day storage period was done at ordinary ambient condition. In the IVC, three storage options were tested; low-cost cold storage using the Coolbot chamber, storage in evaporative cooler, and storage in 25-kg ice box with 1 kg ice per box per day. All treatments were replicated three times.

Data Gathered

Postharvest loss: This was determined as the sum of percent outright volume loss, percent weight loss and percent loss of damaged fruit which were still marketable. After the half day marketing period and storage (for trials with storage component), non-marketable fruit due to rotting, breakage and/or over-ripening were weighed and expressed as percentage of the initial weight to represent the outright volume losses. Weight loss was also taken as percentage of the initial weight. For damaged fruit that were still marketable, they were subjected to evaluation of price reduction by 5 trained panelists. The magnitude of price reduction was expressed as percentage of the price of sound or undamaged fruit to represent equivalent loss of damaged but still marketable fruit.

Fruit quality attributes: Red-ripe fruit were counted and expressed as percentage of the total number of fruit samples per replicate. Firmness was measured non-destructively using the Fruit Hardness Tester (TR Turoni, Italy). Total soluble solids of the fruit juice was determined using a digital refractometer while juice pH was measured using an electronic pH meter (Hanna Instruments). Vitamin C was analyzed following the 2, 6-Dichloroindophenol Titrimetric method and the result reported as mg/100g of tomato fruit (AOAC, 2006).

Food safety attributes: Pesticide residue analysis was performed using the GT Rapid Pesticide Test Kit (Bangkok, Thailand). Microbial analysis determined the total bacteria (total plate count), coliform and E. coli counts. Triplicate 25g fruit samples were placed in Stomacher for 2 min and then subjected to serial dilution using sterile distilled water under aseptic condition in a laminar flow cabinet. Triplicate aliquot of 0.1 ml was aseptically micropipette and placed in a petri dish with plate count agar. The petri dishes were then placed in an incubator at 35ºC for 24 hours and colony forming units (CFU) were counted. For coliform enumeration, violet red bile agar (VRBA) was used. The plates were incubated in 35 ± 2 ◦C for 24 hours and red colonies were counted. For E. coli analysis, 25g fruit samples were mixed with 225 ml saline water and placed in Stomacher for 2 min and added with 9 ml EC broth before serial dilution. Aliquots of 0.1 ml were aseptically pipetted out and placed in E. coli agar plates followed by incubation at 44ºC for 24 hours. Microbial counts were determined using dilution plates with 15–300 colonies expressed as colony forming units per ml ($CFUml^{-1}$). When CFU exceeded 300 per plate, counts were taken from four 1-cm squares per plate. Logarithmic values of counts ($logCFUml^{-1}$) were computed for every plate.

Storage conditions: Temperature and relative humidity (RH) during storage were measured using an Infrared Temperature-RH meter.

Statistical Analysis

All experimental trials were conducted in completely randomized design with three replications. Data were subjected to analysis of variance and treatment mean comparison by least significant difference (LSD) test using the SAS Statistical Package.

RESULTS AND DISCUSSION

Value Chains without Storage Component

Postharvest loss: Postharvest loss in both EVC and IVC was due to the combination of weight loss, outright volume loss and equivalent loss of price reduction of damaged but still marketable fruit (Table 1). However, EVC had much higher weight loss (3.7%), outright volume loss (4.8%) and equivalent loss of damaged fruit (5.1%) compared to that of IVC (1.6%, 1% and 0.9%, respectively). Overall, the total postharvest loss in the EVC was 13.6%, which was about four times higher than that in the IVC (3.5%). Several factors contribute to the reduction of postharvest loss in the IVC. The temperature of the ice box (21ºC) used during transport of tomatoes to market was much lower while RH (100%) was much higher than that in the EVC (ambient, 29ºC and 60% RH). Low temperature and high humidity are known to reduce water loss which is mainly responsible for weight loss (Nunes, 2008; Holcroft, 2015). The ice box in the IVC may have also protected the fruit from damage more effectively being a more rigid container than the plastic bag in the EVC during transport and marketing. In addition, sorting, CCa sanitizing and MAP in IVC may have contributed to postharvest loss reduction as previous reports indicated (Kumar et al, 2015; Arah et al., 2016). Specifically in tomato, MAP has been found to be very effective in reducing weight loss (Gautam et al., 2017; Rahman et al., 2017; Seng et al., 2017).

Table 1 Postharvest loss of tomato in existing value chain (EVC) and improved value chain (IVC) without storage component

Parameter	EVC	IVC	ANOVA1
A. Weight loss, %	3.7	1.6	**
B. Outright volume loss, %	4.8	1.0	**
C. Damaged fruit, %	23.8	4.2	**
D. Price reduction of damaged fruit, %	21.0	21.0	
E. Equivalent loss of damaged fruit, %	5.1	0.9	**
F. Total postharvest loss (A+B+E), %	13.6	3.5	**

Fruit quality: No fruit turned full ripe in both EVC and IVC as transport and marketing were done on the same day of harvest (Table 2). Vitamin C content and pH were also statistically similar between EVC and IVC fruit. However, IVC fruit were significantly firmer than EVC fruit. Total soluble solids content was also significantly higher in IVC fruit than in EVC fruit. These responses suggest slowed metabolic activity in the IVC fruit which could have been induced by low temperature in the ice box and MAP as also found in earlier studies (Beckles, 2012; Facundes et al., 2015; Gautam et al., 2017; Rahman et al., 2017; Seng et al., 2017).

Food safety: No pesticide residue was detected in both EVC and IVC fruit (Table 2). However, microbial load was remarkably reduced in IVC fruit with aerobic bacteria (total plate count) of 2.95 log CFU/g and non-detectable level of coliform bacteria and E.coli. In contrast, EVC fruit had 4.02 log CFU/g aerobic bacteria, 2.85 log CFU/g coliform bacteria and 1.48 log CFU/g E. coli. Acceptable levels for food safety include <4.0 log CFU/g aerobic bacteria, <2.0 log CFU/g coliform and no E. coli. IVC fruit met these acceptable microbial levels for food safety while EVC fruit did not. This result can be attributed to the CCa sanitizing treatment in the IVC fruit. The effectiveness of CCa sanitizing in reducing the microbial load on tomato and other vegetables was obtained in previous studies (Ahmed et al, 2017a, 2017b; Rahman et al., 2017).

Table 2 Quality attributes of tomato in existing value chain (EVC) and improved value chain (IVC) without storage component

Parameter	EVC	IVC	ANOVA1
Full-ripe fruit, % of total	0	0	
Firmness, nondestructive, Shore	122	133	*
Total soluble solids, %	5.2	5.8	**
pH	4.3	4.4	ns
Vitamin C content, mg/100g FW	9.3	9.3	ns
Microbial load			
Total plate count, log CFU/g	4.02	2.95	**
Coliform, log CFU/g	2.85	<1.0 (0)	**
E. coli, log CFU/g	1.48	<1.0 (0)	**
Pesticide residue, GT Rapid Test	negative	negative	

Value Chains with Storage Options

Postharvest losses: Total postharvest loss was very high in the EVC (21.6%) due to high weight loss (11.1%), outright volume loss (7%) and equivalent loss of damaged fruit (3.5%) (Table 3). In the IVC, total loss was comparable among the three storage options and ranged from 2.5-6.1% consisting of 1.9-2.8% weight loss, 0-2.8% outright volume loss and 0.6-0.9% equivalent loss of damaged fruit.

Table 3 Postharvest loss of tomato in existing value chain (EVC) with 3-day ambient storage and improved value chain (IVC) with 3-day storage in ice box, Coolbot chamber or evaporative cooler (EC)

Parameter	EVC-ambient	IVC-ice box	IVC-Coolbot	IVC-EC
A. Weight loss, %	11.1a	2.4b	1.9b	2.8b
B. Outright volume loss, %	7.0a	2.8b	0.0b	0.0b
C. Damaged fruit, %	17.4a	4.7b	3.2b	3.0b
D. Price reduction of damaged fruit, %	21.0	21.0	21.0	21.0
E. Equivalent loss of damaged fruit, %	3.5	0.9	0.6	0.6
F. Total postharvest loss (A+B+E), %	21.6a	6.1b	2.5b	3.4b

Table 4 Temperature and relative humidity (RH) during 3-day storage at ambient in existing value chain (EVC) and in ice box, Coolbot chamber or evaporative cooler (EC) in improved value chain (IVC)

Value chain and storage option	Temperature (°C)	RH (%)
EVC – ambient storage	28-33	58-78
IVC – ice box storage	20-23	85-100
IVC – Coolbot storage	14-17	73-100
IVC – EC storage	21-26	79-100

Weight loss reduction in the IVC can again be attributed to the use of MAP as well as the lower temperature and higher RH in the three storage options (Table 4), which are conducive to fruit water retention as water loss is the primary cause of weight loss of fruit and vegetables. Other metabolic activities, particularly respiration rate are also reduced under MAP and low temperature conditions. Earlier, MAP and Coolbot storage were found to reduce weight loss of tomatoes (Gautam et al., 2017a; Rahman et al., 2017; Seng et al., 2017). The reduced outright volume loss and damage incidence in IVC fruit were due to fewer fruit that turned overripe and diseased during storage and lower incidence of mechanical damage compared to that of EVC fruit.

Fruit quality: The three storage options in IVC slowed the rate of ripening depicted as much lower number of fruit that fully ripened after storage (3.9-10.5%) as compared to EVC fruit (40.9%) (Table 5). Fruit firmness was higher in IVC with Coolbot or EC storage relative to that of EVC fruit and IVC with ice box storage. High firmness indicates lower degree of ripening in which softening is a major indicator. Total soluble solids, pH and vitamin C content did not significantly differ with value chain and storage option (Table 5). Total soluble solids ranged from 3.8-4.4%, pH from 4.3-4.4, and vitamin C content from 17.7-23.4 mg/100g fresh weight. The results show the remarkable effect of IVC with storage options was on the retardation of fruit ripening. Earlier studies showed that MAP in combination with Coolbot storage delayed ripening of tomatoes (Seng et al., 2017). MAP atmosphere of low oxygen and high carbon dioxide together with low temperature are known to inhibit physiological process including ripening in harvested produce.

Table 5 Quality attributes of tomato in existing value chain (EVC) with 3-day ambient storage and improved value chain (IVC) with 3-day storage in ice box, Coolbot chamber or evaporative cooler (EC)

Parameter	EVC-ambient	IVC-ice box	IVC-Coolbot	IVC-EC
Full-ripe fruit, % of total	40.9a	3.9b	3.9b	10.5b
Firmness, nondestructive, Shore	83.3b	96.9b	113.7a	114.2a
Total soluble solids, %	3.8	4.0	3.9	4.4
pH	4.3	4.4	4.3	4.4
Vitamin C content, mg/100g FW	17.7	20.7	23.4	21.9

CONCLUSION

Improving tomato value chains with the infusion of postharvest technologies and best practices, such as sorting, non-chlorine sanitizing using CCa, MAP, storage techniques, and cold packing for transport and marketing, proved to be highly promising in reducing postharvest losses and enhancing fruit quality and food safety. Considering that postharvest loss reduction is context specific, it is important to examine existing value chains and know the deficiencies in order to identify, test and adopt postharvest management measures.

ACKNOWLEDGEMENTS

This research is made possible by the generous support of the American People provided to the Center of Excellence on Sustainable Agricultural Intensification and Nutrition (CE SAIN) of the Royal University of Agriculture through the Feed the Future Innovation Lab for Collaborative Research on Sustainable Intensification at Kansas State University funded by the United States Agency for International Development (USAID) under Cooperative Agreement No. AID-OAA-L-14-00006. The contents are the sole responsibility of the authors and do not necessarily reflect the views of USAID or the United States Government. Many thanks also go to The World Vegetable Center-USAID Packehouse project for research site support.

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Research article

Assessing the Yield of a High Yielding Rice Variety, Byaw Htun, Planted Using the Cut-stem Transplant Method and Cultivated in a Deep-water Area, Bago Region, Myanmar

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Received 20 January 2020 Accepted 12 December 2020 (*Corresponding Author)

Abstract Among the five rice ecosystems in Myanmar, submerged and deep-water areas occupy 13.5% of the total cultivated area. If flooding occurs, most rice varieties elongate and lay flat after the water recedes. In such a situation, the lodged stems are cut and transplanted without roots. This cut-stem transplant (CST) method is practiced locally in Ywa Houng village, Thanatpin Township in the Bago Region, using deep-water rice (DWR) varieties such as Pawsan and Yoesein in deep-water areas. However, a high yielding variety, Byaw Htun, is cultivated in the shallow-water areas by using direct seeding (DS) or the normal transplanting (NT) method. Unusual levels of flooding in 2018 resulted in almost all of the fields being subject to deeper water conditions than normal in Ywa Houng village. The highest flood level occurred on 19th July, with a 45cm depth recorded, in what is normally a shallow area (normally less than 25cm depth) and the flood peaked for about 25days. Hence, transplanting of Byaw Htun was delayed until the 10% heading stage in the nursery. Thus, farmers tested the CST method in place of NT method in Byaw Htun. This study examined to clarify the growth and yield of CST method for the Byaw Htun variety. Byaw Htun CST plants exhibit plant growth and yields comparable to those of DS plants. In addition, the yield of Byaw Htun CST was similar to, or higher than those of Pawsan and Yoesein CST. However, the harvesting of Byaw Htun CST took place far later than that of DS areas. Consequently, it was found that CST can be applied for Byaw Htun varieties when the plants were damaged by flooding, but due to delays in harvesting, the application of this method should be considered in relation to any subsequent crops to be cultivated.

Keywords cut-stem transplant, deep water rice, direct seeding, high-yielding rice variety, submerged and deep-water areas

INTRODUCTION

Rice is cultivated on over 7 Million ha in Myanmar, which is more than half of the arable land. There are five rice ecosystems that have been described for Myanmar. These are lowland rain-fed and irrigated, flooded, deep-water, upland and sea water intrusion areas (MOALI, 2015). Among them, flooded and deep-water areas occupy 13.5% of the total area under rice cultivation (Rice Division, 2016). Therefore, construction of flood protection measures, the growing of flood tolerant rice varieties and/or the development of climate resilient cultural practices are necessary to sustain rice production in these areas.

The conventional rice crop establishment methods used throughout the world are direct seeding (DS) and transplanting (NT). In the deep-water areas, dry seeding is fairly common, but transplanting or double transplanting is practiced in some flooded area in Asia (De Datta, 1981**).** Likewise, there is a locally used and adapted method in accord with flooded conditions employed in Ywa Houng village, Thanatpin Township in the Bago region (Mon et al., 2019a). Ywa Houng is situated at the Sittaung River basin area, and monsoon flooding occurs frequently. Therefore, a high yielding variety (HYV) such as Byaw Htun, also a moderate flood tolerant variety, is cultivated in shallow-water areas and photoperiod sensitive deep-water rice varieties (DWR) such as Pawsan and Yoesein in the deep-water areas.

Normally, DS and NT are undertaken in shallow-water areas. Seeding is done after land preparation, which starts when the soil moisture content is sufficient for land preparation. Transplanting in NT method will be carried out when the seedlings are about 35-40 days old. However, seeding time will vary from field to field and depends on the water availability in the nursery field, adjustments being made to coincide with a suitable depth of water in the fields for transplantation, and expected moisture availability for a second crop such as legumes, which require sufficient residual soil moisture. If a second crop will not be cultivated, seeding time will likely be postponed until the water recedes, to escape the possibility of flood damage.

For deep-water areas, dry seeding is done in April-May after the first flash of monsoon and water levels start to increase when the seedlings are 1.5 months old. If the plants are not damaged by flooding, NT is followed. However, if flooding occurs, the plant will respond by elongation of the stem and laid flat after the water recedes. In such a case, the lodged stems are cut and transplanted by using a transplanting fork and the cut-stem transplant method (CST) is practiced (Mon et al., 2019a).

Due to torrential rain in the 2018 monsoon season, abnormal flooding occurred even in relatively higher-level fields, and transplanting had to be delayed until the growth of Byaw Htun in the nursery field reached the late booting stage. Hence, farmers tested the CST on this variety in 2018. Previously CST had only been applied to the DWR varieties such as Pawsan and Yoesein in 2016 and 2017 (Mon et al., 2019a and b), but a HYV, Byaw Htun was planted with the CST method in that 2018 monsoon season. Hence, this survey was conducted with the following objectives.

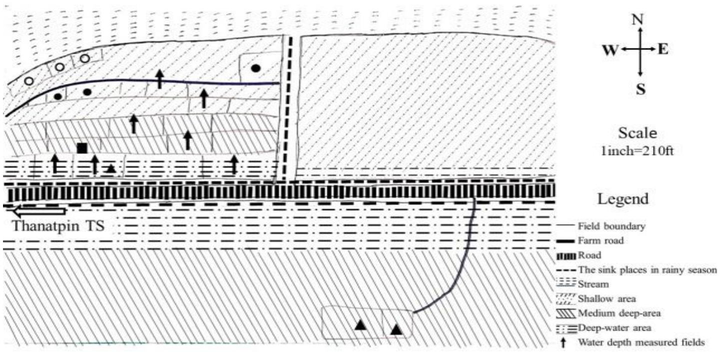
OBJECTIVE

The objectives of this study are (1) to clarify the growth and yield performance of CST comparing with DS planting for Byaw Htun and (2) to compare the yield of CST for Byaw Htun with DWR yields for Pawsan and Yoesein.

METHODOLOGY

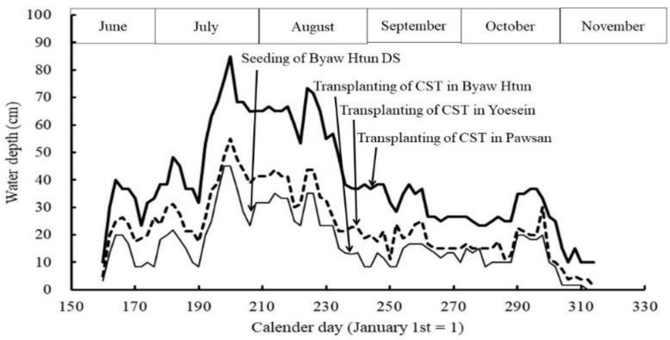
The survey was conducted in Ywa Houng village, Thanatpin Township where the CST method is locally practiced. The location of each harvested field is shown in Fig 1. The water depth was recorded at 2 days intervals, starting from 9th June to the 10th November 2018, by setting of three marking posts at the diagonal of each field. The water depths were measured in 2, 2 and 3 fields for shallow, medium-deep and deep-water areas respectively (Fig 1). Changes of water depth are shown in Fig 2. The water depth was 3, 5 and 10cm in the shallow, medium-deep and deep-water areas at the beginning of June (9th June) (160 calendar days). The water level gradually increased and the peak flooding occurred on 17-19th July (198-200 calendar days) with depths of 45, 55 and 85cm respectively, in each area. Flooding was stagnant for 25 days until 14th August (226 calendar days) and after that, the water depth gradually decreased and finally receded by the end of October (304 calendar days). The seeding date, transplant date and the harvest date of all varieties are shown in Table 1. Although the seeding of Byaw Htun CST was 67 days earlier than that of DS, harvesting was 7 days later. Moreover, the seeding of Byaw Htun CST was 25 days and 18 days later while the harvest date was 26 days and 15 days earlier than those of Pawsan and Yoesein CST. In terms of fertilizer application, Byaw Htun DS and CST fields were applied with urea at 62 days after seeding, and 14 days after transplanting (DAT) with the rate of 21 kg ha^{-1} and 42 kg ha^{-1}, respectively. Similarly, Pawsan and Yoesein CST were applied with urea at 15 DAT and 16 DAT with the rate of 63 kg ha^{-1} and 42 kg ha^{-1}, respectively.

Sampling was done at harvest in farmers' fields by sampling seven 1m^2 plots in each field along the transverse of the field's diagonal to determine the yield rates, and hill density was recorded at these plots. In addition, samplings of 10 hills for each 1m^2 plot in the DS fields and 5 hills each for the CST fields were randomly excavated near each plot, to measure the growth and yield components.



○ Byaw Htun DS ● Byaw Htun CST ▲ Pawsan CST ■ Yoesein CST

Fig. 1 Map of the sampling plots situated in north west part of Ywa Houng village



Continuous thick line: deep-water area, Dotted line: medium-water area, Continuous thin line: shallow-water area.

Fig. 2 Changes of the water depth at three locations of the paddy fields in Ywa Houng village, Thanatpin Township, Bago Region, Myanmar (2018)

Table 1 Outline of cultivation methods of Byaw Htun, Pawsan and Yoesein

Varieties	Cultivation method	Seeding			Seedling age (days)	Transplant date	Growth stage at transplant	Harvest date	Growth duration (days)*
		Method	Date	Rate (kg/ha)					
Byaw Htun	DS	WSR	27-Jul	103	-	-	-	20-Nov	116
	CST	WSR	20-May	103	96	24-Aug	10% heading	27-Nov	191
Pawsan	CST	DSR	25-Apr	224	129	1-Sep	Tillering	23-Dec	242
Yoesein	CST	DSR	2-May	103	117	27-Aug	Tillering	12-Dec	224

**: days from seeding to harvest, WSR: Wet seeded rice, DSR: Dry seeded rice, DS: Direct seeding, CST: Cut-stem transplant*

The plant samples were washed for removing the soil and hung for one week. After that, the growth parameters and yield components were measured. When measuring the growth parameters in CST, the two types of plants were observed; the main stem existing, and the main stem died and only the tillers existing. About 25% of the plant samples in Byaw Htun CST were the main stem died. The plants of which the main stem died were skipped to count the number and the length of elongated nodes. For statistical analysis, the average value of each fields resulting from 7 harvested plots was regarded as one replication. The data were analyzed by using Statistix version 8.0 and mean separation was done at Least Significant Distance (LSD) at a 5% level.

RESULTS AND DISCUSSION

Comparing the Growth and Yield of CST and DS in Byaw Htun

The internode elongation patterns of CST and DS in Byaw Htun are shown in Fig 3 (A). In both CST and DS, the basal internodes (1st to 3rd) were almost the same length and after that there was an increase from 4th internode to succeeding nodes. However, the basal internodes' lengths of DS were shorter than comparable nodes of CST plant. It showed that a DS plant was not affected by flooding at the vegetative stage. Because, the DS fields were located on the river bank, drainage of excess water was easier (Fig 1) and seeding was done after flooding.

The growth parameters of Byaw Htun DS and CST are shown in Table 2. The plant length, culm length, panicle length, the number of elongated nodes and the number of roots per hill of CST were similar and not significantly (*$p<0.05$*) different than those for DS plants. All the shoot dry weight (g) showed no significant difference except the shoot dry weight per stem. Yields and yield components are shown in Table 3. The hill density of CST (29.2) was about half of DS (63.6). However, the number of panicles per hill was higher in CST. The number of grains per panicle was not statistically different between the two methods. In addition, filled grain (%) and 100 grains weight were not significantly different, as well. Finally, the yield (g/m^2) of CST (412.7 g/m^2) was not significantly different from that of DS (400.3 g/m^2). Although, the grain yield of Pawsan DS was lower than that of CST in Ywa Houng village (Mon et al., 2019b), similar yield in Byaw Htun DS and CST were due to the field location and cultivated condition. DS in this experiment was cultivated in the shallow area, not affected by flooding and being able to apply fertilizer during the plant development. Therefore, it could produce the plant growth and yield comparable to that of CST.

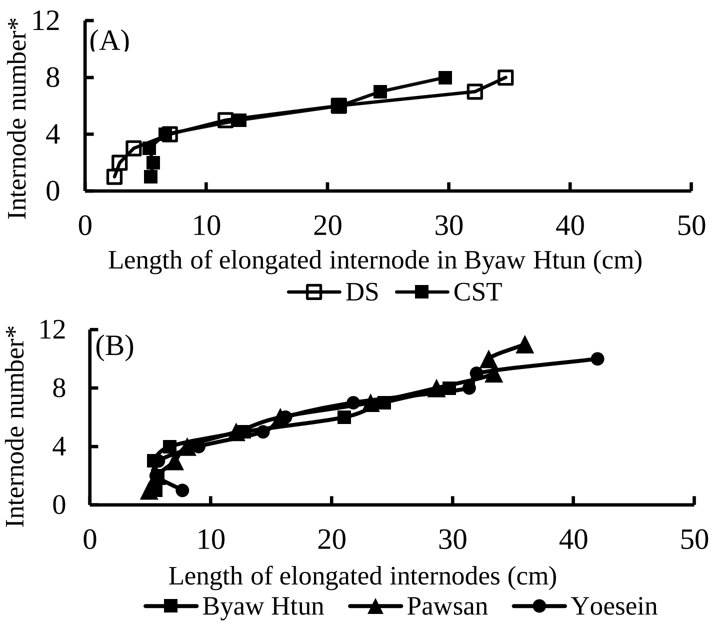


Fig 3 Internode length of each elongated internodes of DS and CST in Byaw Htun (A) and CST in Byaw Htun, Pawsan and Yoesein (B)

** Node number count from the stem base*

Despite the yields of these two methods were similar, the growth duration of CST was 75 days longer than that of DS (Table 1). Because, Byaw Htun was photoperiod insensitive HYV and maturity was depended on the growth duration. After transplantation, some of the main stem died and the tillers were produced from the remaining nodes of the stem. CST plants reset the growth from the tillering stage although it was transplanted at 10% heading stage. Therefore, the growth duration was longer than that of DS. In addition, CST needed high cultivation cost especially transplantation cost than that of DS. Therefore, in consideration of the cost and labor for the CST transplantation and the effective use of the paddy field, CST in Byaw Htun would not be applicable in the area where the flooding is not use to occur.

Table 2 The plant growth parameters of Byaw Htun cultivated with direct seeding and cut-stem transplant method

Cultivation method	Plant length(cm)	Culm Length (cm)	Panicle Length (cm)	No. of nodes	No. of roots per hill	Shoot dry weight (g)		
						(/stem)	(/hill)	(/m^2)
DS	108.5a	84.0a	24.5a	7.2a	252.1a	6.9a	28.6a	1038.1a
CST	98.7a	76.6a	21.4a	6.9a	474.9a	4.6b	19.1a	816.2a

**DS: Direct seeding, CST: Cut-stem transplant, Values followed by the same letter within each column do not different at $p<0.05$ by using statistix version 8.0*

Table 3 Yields and yield components of Byaw Htun cultivated with direct seeding and cut-stem transplant method

Variety	Hill density	No. of panicle per hill	No. of grains per panicle	Filled grain (%)	100 grains weight (g)	Yield (g/m^2)
DS	63.6	2.8	166.2	63.78	2.34	400.3
CST	29.2	6.7	138.6	72.06	2.26	412.7

**DS: Direct seeding, CST: Cut-stem transplant, Values followed by the same letter within each column do not different at $p<0.05$ by using Statistix version 8.0.*

Comparing the Growth and Yield of Byaw Htun CST with those of Pawsan and Yoesein

The pattern of internode elongation among CST is shown in Fig 3 (B). The internode elongation patterns of Byaw Htun, Pawsan and Yoesein CST were similar in that the internode length from the 1st to 3rd nodes were short and then the length gradually increased from the 4th to the higher nodes. It showed all CST developed under similar field condition. However, the number of elongated nodes in Byaw Htun (6.9 nodes) was less than those of Pawsan (8.2 nodes) and Yoesein (8.7 nodes) and it could depend on the plant type. Byaw Htun was a photoperiod insensitive HYV while the other 2 varieties (Pawsan and Yoesein) were photoperiod sensitive DWR. There was a correlation between the number of elongated internodes and the vegetative growth period in DWR and local rice varieties, while no correlation was found in the semi-dwarf cultivar (Hamamura, 1978). Hence, the number of elongated nodes of Byaw Htun might be expected to be less than those of Pawsan and Yoesein. In addition, the younger seedling age and the shallower field condition in Byaw Htun causes a smaller number of elongated nodes than DWRs.

The growth parameters of Byaw Htun and Pawsan are compared in Table 4. Among the plants following CST method, plant length, culm length and number of nodes of Byaw Htun were the lowest while those of Pawsan and Yoesein showed a very similar value. However, the panicle length (cm) of Byaw Htun was not significantly different from those of Pawsan. The number of roots per hill of Byaw Htun was the lowest, although it was not significantly different from Pawsan. The shoot dry weight per stem and per hill of Byaw Htun were significantly less than those of Pawsan, though the shoot dry weigh per m^2 of Byaw Htun was not significantly different due to higher hill density in Byaw Htun. The yields and yield components are shown in Table 5. Among the varieties, the hill density of Byaw Htun was the highest followed by Yoesein and Pawsan. In contrast to that, the number of panicles per hill of Byaw Htun was significantly lower than other varieties. Whereas, the number of grains per panicle of Byaw Htun was statistically higher than that of Pawsan. Filled grain (%) of Byaw Htun and Yoesein was higher than that of Pawsan. Because the grain filling period of Byaw Htun was earlier than those of Pawsan and Yoesein by 26 days and 15 days, the availability of soil moisture for grain filling of Byaw Htun was higher than those of Pawsan and Yoesein. However, the 100 grains weight of Byaw Htun was the lowest due to small grain size. Yields (g/m^2) of Byaw Htun (412.7) was the highest, followed by Yoesein (291.9) and Pawsan (286.7) although this did not represent a significant difference between Byaw Htun and Pawsan. Because of the earlier maturity in Byaw Htun, the moisture availability at grain filling would be higher than those of Pawsan and Yoesein. In some years, the rainfall finishes early and moisture deficit affecting the grain yield occur in the late harvested varieties especially Pawsan. Under such condition, Byaw Htun would produce significantly higher yield than that of Pawsan particularly in Ywa Houng village where no irrigated water was available for grain filling. Therefore, Byaw Htun can be followed with CST in the deep-water area if the flood damage occurred.

Table 4 The growth parameters of Byaw Htun, Pawsan and Yoesein cultivated with cut-stem transplant method

Variety	Plant length (cm)	Culm Length (cm)	Panicle Length (cm)	No. of nodes	No. of roots per hill	Shoot dry weight (g)		
						(/stem)	(/hill)	($/m^2$)
Byaw Htun	98.1b	76.6b	21.5a	6.9b	474.9a	4.6b	28.6b	816.1a
Pawsan	141.5a	117.4a	24.1a	8.2a	561.5a	7.0a	66.1a	867.3a
Yoesein*	152.5	127.5	24.2	8.7	566.9	5.9	41.6	842.3

*Analysis was done for Byaw Htun and Pawsan only by using statistix version 8.0, * No replication. value followed by the same letter within each column do not different at $p< 0.05$.*

Table 5 Yields and yield components of Byaw Htun, Pawsan and Yoesein cultivated with cut-stem transplant method

Variety	Hill density	No. of panicles per hill	No. of grains per panicle	Filled grain (%)	100 grain weight (g)	Yield (g/m^2)
Byaw Htun	27.1a	6.7b	138.6a	72.06a	2.26b	412.7a
Pawsan	13.4b	11.6a	94.3b	61.17b	3.24a	286.7a
Yoesein*	20.4	6.7	105.2	69.05	2.97	291.9

*Analysis was done for Byaw Htun and Pawsan only by using statistix version 8.0, * No replication, value followed by the same letter within each column do not different at $p<0.05$*

CONCLUSION

Although CST in Byaw Htun can be transplanted, it took longer growth duration than that of DS. Therefore, CST in Byaw Htun should not be followed in the area where no flood damage occurs and the second crop such as legume will be cultivated after rice harvest. However, Byaw Htun CST produce the yield comparable to those of Pawsan and Yoesein CST. Moreover, it can harvest earlier than those of Pawsan and Yoesein. Therefore, CST in Byaw Htun could be practiced in the area where the flood damage occurred.

ACKNOWLEDGEMENTS

This research was financially supported by the YAU-JICA Technical Cooperation Project.

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Research article

Physiological Variables Associated with Yield of Improved Rice (*Oryza sativa* L.) Genotypes in Normal and Late Growing Seasons

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Received 20 January 2020 Accepted 12 December 2020 (*Corresponding Author)

Abstract Genotypic selection for higher total dry weight has become a key method of research and experimentation to increase grain yield. Therefore, this experiment was carried out to determine the relationship of leaf area index (LAI) and yield and its components for ten genotypes of improved rice, for normal and late growing seasons. The experiments were conducted in the experimental fields of the Department of Plant Breeding, Physiology and Ecology, Yezin Agricultural University. The study was undertaken from December 2016 to May 2017 for testing normal growing season plants and March 2018 to July 2018 for late growing season plants. A randomized complete block design with three replications was used. For the relationship among all the traits tested, positive associations were found ($R^2 > 0.5$) for LAI at harvest and yield ($R^2 = 0.574$), for panicle weight at harvest and yield ($R^2 = 0.558$), and for harvest index (HI) and yield ($R^2 = 0.61$). The study showed that yields increase along with an increase in LAI and panicle weight, for the improved rice genotypes that were tested. There was a positive and significant correlation found between LAI at heading stage and percent of filled grains in normal season, and LAI at heading and number of panicles per meter square in late season. In late season, the correlation between LAI at harvesting stage and yield was significant; HI was also significantly correlated with percent of filled grains and yield. As LAI and harvest index contribute to yield and yield component characters, breeders may successfully attempt to boost potential yields by increasing growth traits such as plant foliar surface and harvest index.

Keywords yield, LAI, correlation

INTRODUCTION

Rice is the most important food crop in the world and serves as a staple food for more than one third of the world's population (Singh and Singh, 2008). About 90% of the world' rice growing area is on the Asian continent (Salim et al., 2003). It is estimated, farmers in the world need to produce about 60% more rice than at present to meet the food demands of the world population expected by 2025 (Thakur et al., 2011).

In Myanmar, rice is a staple food and is cultivated in an area of 7.28 million hectares. Total production is 28.09 million metric tons, giving a yield of 3.92 ton/ha (Department of Planning, Ministry of Agriculture, Livestock and Irrigation, 2018). Rice makes up 33 % of total area cropped with 84% (6,474,970 ha) of rice grown during monsoon and 16% (1,214,056 ha) grown during summer (Sein, 2014). Okamoto (2004) affirms that rice production is very important for both the economic livelihood and food security for the population of Myanmar.

Increases in rice production have mainly relied on the expansion of the area of cultivable land used to grow rice, and increases in yield per unit area (Evans, 1993). Climate change and urbanization can result in decreases in rice cropping areas. Therefore, the increase of yield per unit area has become the focus to achieve increases in production. The grain yield of rice is a complex trait, controlled by many genes and highly affected by the environment (Jennings et al., 1979). Grain yield is also related to other characteristics, such as plant type, growth duration, and yield components (Yoshida, 1981). In comparing semi-dwarf and traditional rice cultivars, the increase in harvest index is the contributing factor improving yield potential, rather than any increase in production of biomass (Takeda et al., 1983; Evans et al., 1984). However, modern cereal breeding programs have provided evidence of the possibility of boosting grain yields by selecting genotypes exhibiting higher biomass production (Boukerrou and Rasmusson, 1990; Damisch and Wiberg, 1991). The efficiency with which dry matter is accumulated and allocated to harvestable organs, the grains in rice, determines the size of yield components and final yield (Fageria et al., 2006).

There are two rice growing seasons in Myanmar; summer and monsoon or dry and wet. The summer (dry) rice growing season is from December to May and the monsoon season (wet) from June to November. Sometimes summer rice growing is delayed because of labour scarcities, delays in obtaining irrigation water or due to a late harvesting time for the previous crop.

OBJECTIVE

The aim of this research is to determine the relationship of LAI and yield, and yield related traits of improved rice genotypes, under normal and late growing seasons.

MATERIALS AND METHOD

The experiment was carried out in the experimental fields of the Department of Plant Breeding, Physiology and Ecology, Yezin Agricultural University from December 2016 to May 2017 for normal season rice and March 2018 to July 2018 for late growing rice. Experimental field is located at longitude 19º 10′ N and latitude 96º 07′ E with the elevation of 102 meters (m) above sea level. Ten improved rice genotypes which were preliminary selected based on agronomic traits and yield, were grown and yield estimated (Table 1) by using randomized complete block design with three replications. Each plot was (4m × 4m) with a spacing of 20cm × 20cm. Each genotype was planted with 20 rows, and 20 plants per row (total 400 plants per plot). Twenty-one-day-old seedlings were transplanted with one seedling per hill. Other agronomic practices were followed as required by using recommended cultural practices.

Table 1 List of tested improved rice genotypes in this study

No.	Improved Genotype
1	YAU- 1201-1-2-1
2	YAU-1201-202-1-2
3	YAU-1214-183-3-1-1-1-1
4	YAU-1214-183-35-1-1-1-1
5	YAU-1215-S-S-S-40-2-1
6	YAU-1215-S-S-S-41-1-1
7	YAU-1211-116-3-4
8	YAU-1211-71-1-1
9	YAU-1201-151-1-1
10	YAU-1201-151-1-3

In this study, LAI and dry weight were measured at heading stage and at harvesting stage. Heading stage was defined as the time when the main stem panicle had emerged and the harvesting stage was defined as the stage of the plants' physiological maturity. Two rows in border areas were left out of the sample collected to avoid the border effect. Three representative hills (hills with a mean value of tillers per hill) from each plot were sampled for the determination of dry weight. All plant samples were separated into green leaf blades (leaf), culm plus sheath (stem), and panicles. All samples were oven-dried at 80°C for 72 hours to obtain a constant weight. At the time of harvest, five representative hills were selected to measure yield and yield component traits. The weight of filled spikelets was adjusted for a moisture content of 14%. Leaf area index (LAI) was calculated as the ratio of the sum of the leaf area of all leaves to the ground area of the field where the leaves had been collected (Watson, 1947).

$$\text{LAI}=\frac{\text{Sum of the leaf area of all leaves}}{\text{Ground area of field where the leaves have been collected}}$$

$$\text{Yield per plant (g)}=\frac{\text{1000 grains weight}\times\text{Filled grain \%}\times\text{Spikelet number/panicle}\times\text{Panicle number}}{1000\times100}$$

The data were analyzed with Microsoft Excel (2007) and correlation analysis was also performed by using Statistical Tool for Agricultural Research (STAR) 2.0.1 (2014).

RESULTS AND DISCUSSION

Temperature regimes were different during vegetative, reproductive and ripening stages during two growing seasons (Table 2).

Table 2 Average of daily temperature and total rainfall during different growth stages of rice

Growth stage	Daily temperature (°C) during NS		Daily temperature (°C) during LS		Daily maximum temperature ≥35°C		Total rainfall(mm)	
	max	min	max	min	NS	LS	NS	LS
Vegetative	35.2	18.5	37.3	22.9	50	89	44	311
Reproductive	37.4	24.4	31.8	24.9	24	1	58	264
Ripening	38.4	26.2	31.5	24.7	28	0	93	272

Source: Weather Station of Department of Agricultural Research, Yezin. NS=Normal Season, LS=Late Season

Correlations between physiological variables and yield and yield components for improved rice genotypes in both NS and LS are showed in Table 3. In NS, there was no significant correlation between the variables except LAI at heading and percentage of filled grain. It could be suggested that percentage filled grain correlates with optimum LAI at heading. For LS crops, LAI at heading was positively and significantly correlated with the number of panicles per meter square. Also, filled grains percentage was positively and significantly correlated with harvest index (HI). LAI at harvesting stage, and harvest index (HI) were positively and significantly correlated with yield/m^2. A positive correlation between LAI and yield has been reported in the literature (Xie et al., 2011; Moraditochaee et al., 2014). An increase in harvest index results in an increase in grain yield that produces heavier grain in improved rice cultivars (Kiniry et al., 2001). Yield/m^2 is demonstrably affected by LAI and HI.

Regression analysis showed that yield/m^2 is associated with dry weight at heading stage in LS with an R^2 of 0.027 though this relationship is relatively weak in NS (R^2=0.038) (Fig. 1). The relationship between yield and dry weight at harvesting stage is associated in both NS and LS with R^2s of 0.154 and 0.054 respectively (Fig. 2) . Van der Werf (1996) stated that above-ground total dry matter (ATDM) accumulation (areal total dry weight) along with its partitioning to various parts of the plant determined crop productivity. Under favorable growing conditions, the increased yield of F1 hybrid rice was associated with increased total dry weight (Song et al., 1990; Yamauchi, 1994). Yield/m^2 was positively related with HI in both seasons and this was a strong relationship with an R^2 of 0.61 (Fig. 3). Increasing the harvest index and dry weight can achieve an increase in grain yield.

An association between yield/m^2 and panicle weight in both growing seasons (Fig. 4) was found and there was a moderate relationship with an R^2 of 0.558 in LS. Panicle weight is positively related to increased dry weight from heading to harvesting with an R^2 of 0.223 in NS and R^2 of 0.175 for LS (Fig. 5). Weng et al. (1982) reported a similar result. The result showed that yield can be increased with increased dry weight through the increase of panicle weight.

It was found that yield/m^2 was positively related with LAI at heading stage in both NS and LS (Fig. 6). This indicates that an increase in LAI at heading stage results in an increase in yield. In NS, yield had no relationship to LAI at harvesting stage but there was positive association of yield with LAI at harvesting stage with an R^2 of 0.574 (Fig. 7) for LS. Yield/m^2 was positively related with decreased LAI from heading to the harvesting stage with an R^2 of 0.141 in NS, but there was a negative association for LS (Fig. 8). Moradpour et al. (2013) stated that a strong relationship between yield and LAI was observed. An increase in LAI at harvesting stage contributes to an increased yield for the late season rice.

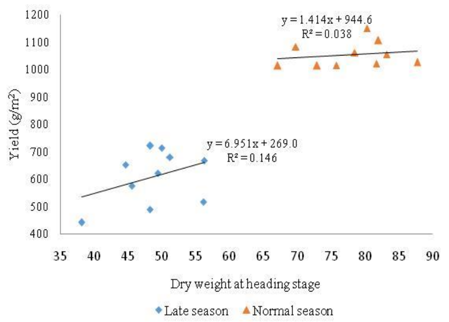

Fig. 1 Relationship between yield/m^2 and dry weight at heading stage in NS and LS

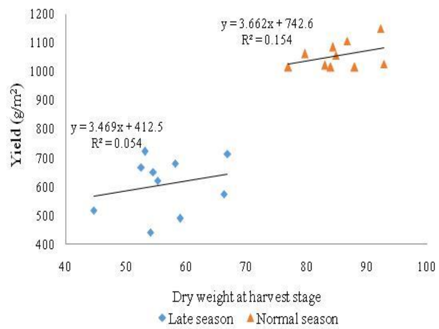

Fig. 2 Relationship between yield/m^2 and dry weight at harvesting stage in NS and LS

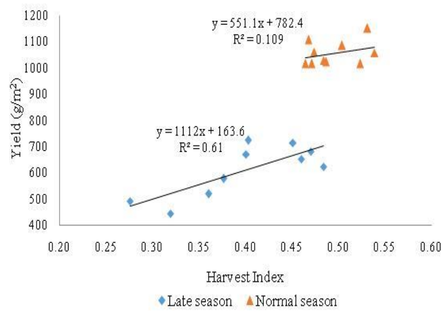

Fig. 3 Relationship between yield/m^2 and HI in NS and LS

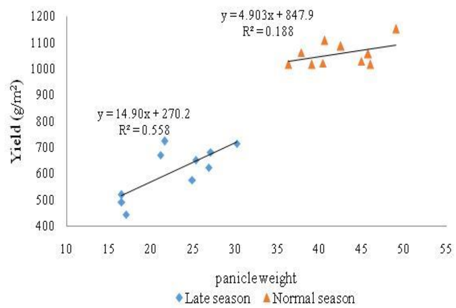

Fig. 4 Relationship between yield/m^2 and panicle dry weight in NS and LS

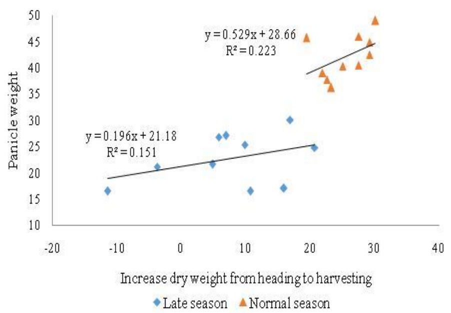

Fig. 5 Relationship between panicle weight and increased dry weight from heading to harvesting in NS and LS

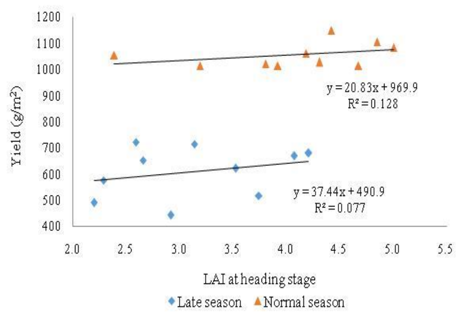

Fig. 6 Relationship between yield/m^2 and LAI at heading stage of in NS and LS

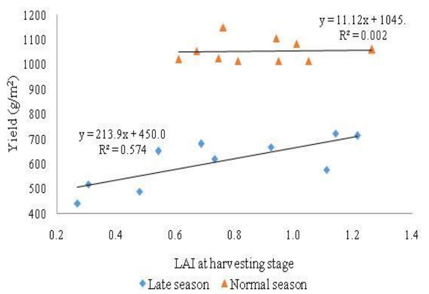

Fig. 7 Relationship between yield/m^2 and LAI at harvesting stage in NS and LS

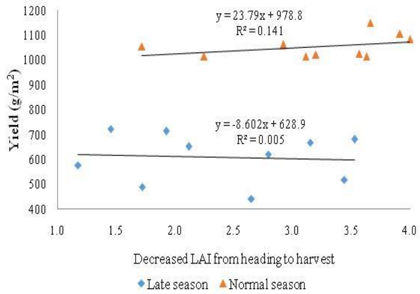

Fig. 8 Relationship between yield/m^2 and decreased LAI from heading to harvesting in NS and LS

Table 3 Correlation between physiological variables and yield and yield components of improves rice genotypes during two seasons

Yield and yield components	No. of panicles (/m^2)		No. of grains (/m^2)		Filled grains percent		Yield (g/m^2)	
	NS 2017	LS 2018	NS 2017	LS 2018	NS 2017	LS 2018	NS 2017	LS 2018
LAI at heading	0.3283	0.7166*	-0.4555	-0.1294	0.6856*	0.4794	0.3581	0.2769
LAI at harvesting	-0.1478	0.13	-0.5454	0.4476	0.5515	0.2231	0.0475	0.7574*
Decrease of LAI from heading to harvesting	0.3966	0.5672	-0.3475	-0.2992	0.596	0.3238	0.3763	-0.0752
Dry weight at heading (g/m^2)	-0.4797	0.5474	0.4413	0.1823	-0.1628	0.5917	0.1963	0.3822
Dry weight at harvesting (g/m^2)	-0.2881	-0.4026	0.1281	0.4363	-0.056	-0.2051	0.393	0.234
Increase of dry weight from heading to harvesting (g/m^2)	0.3093	-0.5767	-0.412	0.1955	0.1439	-0.467	0.1293	-0.0527
HI	-0.1639	0.5034	0.1662	0.2456	0.0683	0.7413*	0.3348	0.6840*

NS= Normal growing season, LS= Late growing season

CONCLUSION

In this study, correlation analysis showed that yield and yield components correlated with LAI, dry weight and HI, especially for late growing season crops. According to regression results, yield increasing was influenced by the increase of HI, LAI and panicle weight, especially in late season and panicle weight was contributed by dry weight. As yield and yield components are correlated with LAI, dry weight and HI, tall varieties of rice, susceptible to lodging rice should not be grown in the late season and breeders should attempt to increase growth traits such as plant foliar surface and HI in order to boost potential yields.

ACKNOWLEDGEMENTS

The authors would like give special thanks to the Japan International Cooperation Agency (JICA), Project for Capacity Development at Yezin Agricultural University for the financial and technical support given in conducting this study.

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International Society of Environmental and Rural Development

Philosophy of ISERD:

Recently, in developing countries, subsistence agriculture is being converted to export-oriented mono-culture, and the amounts of agricultural chemicals applied to the farmland are increasing every year. The applied chemicals in farmland cause serious environmental problems downstream such as eutrophication, unusual growth of aquatic plants, decrease in dissolved oxygen and accumulation of bottom mud in water resources. Also, there seem to be many cases in which people apply agricultural chemicals without understanding its impact to health and food safety. Therefore, it is necessary to promote and enhance understanding of sustainable rural development among local stakeholders including farmers.

Sustainable rural development aims to meet human needs while preserving the natural environment. As it should cover not only social and economic development but also natural environment conservation, no single organization can achieve sufficiently the aspirations of sustainable rural development. Collaboration among international, governmental and non-governmental organizations, together with the academe and scientific sector, is indispensable.

The knowledge and intelligence accumulated in universities and research institutions are also expected to make the programs facilitated by the international, governmental and non-governmental organizations more adequately implemented and meaningful to societal development. However, these cases especially those implemented locally have been scattered without having been summarized well or recorded in annals academic or scientific societies.

So, the International Society of Environmental and Rural Development founded in 2010, aims to discuss and develop suitable and effective processes or strategies on sustainable rural development focusing on agricultural and environmental aspects in developing countries. The ultimate goals of the society are to contribute to sustainable rural development through social and economic development in harmony with the natural environment, and to support the potential or capacity building of local institutions and stakeholders in the rural area with academic background.

Purposes of ISERD:

The primary purposes of ISERD are to contribute to sustainable rural development through social and economic development in harmony with the natural environment and to support the potential or capacity building of local institutions and stakeholders in the rural area with academic background.

In order to enhance the realization of the primary purposes of ISERD, the secondary purposes are;

- to facilitate interaction among international, governmental, non-governmental organizations and local communities,
- to hold conferences or symposia on environmental and rural development,
- to edit the International Journal of Environmental and Rural Development,
- to confer some awards based on scientific achievement, research paper or poster presentation, and
- to encourage and develop local awareness concerning sustainable rural development.

Membership:

There shall be two categories of membership.

(a) Individual

(b) Organizational

An application for membership of ISERD shall be submitted to the secretariat of ISERD, where is located in the Research Center at Institute of Environmental Rehabilitation and Conservation (Japan) by writing or by other appropriate means.

Also, every presenter who attends the International Conference on Environmental and Rural Development (ICERD) is registered as an Individual Member of ISERD.

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All articles and reports published in this journal were accepted through a peer-review process. However, most articles and reports published in this journal were presented at the International Conference on Environmental and Rural Development that was co-organized by United Nations University, Institute for the Advanced Study of Sustainability.

IJERD – Environmental and Rural Development

Vol. 11 No. 2

December 2020