EVALUATING VARIETIES OF RICE ADAPTED TO LOWLAND RAINFED CONDITIONS IN CENTRAL MYANMAR:

A Farmer Participatory Approach

Khin Swe Hlaing Tun

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Foreword

Rice production in the central dry zone of the Republic of the Union of Myanmar faces uncertain rainfall every year. Owing to traditional farming techniques and uneven rainfall—as well as other unexpected circumstances—rice productivity is low, especially in areas with inherent low soil fertility. Production of rice—integral to the socio-cultural and economic lives of the people—is thus increasingly becoming ever more challenging. This has left the inhabitants of dry land with limited options, especially for small land holders with little access to agricultural inputs. This also makes the majority of the population of the area extremely vulnerable to social insecurity. In this light, interventions to improve the rice production system are a must to provide much needed advancements. If sustainable rice production systems can be designed and implemented, it could have a great socio-economic impact on the dry zone of Central Myanmar.

Given the above facts, this multidimensional research study seeks to understand the socio-economic circumstances of rice farmers in the rainfed lowland areas of the central Myanmar and gain a better understanding of their knowledge and practices. More importantly, the research helps identify rice varieties capable of producing sustained yield under low nitrogen fertilization to help improve the system of rice production. To this end, the research has employed intensive methods, including field work, experiments and on-field experiments. Field work has been conducted with rice farmers to learn about their knowledge and practices, as well as the socio-economic factors affecting rainfed lowland rice production. Three sets of experiments using six different varieties of rice were conducted to identify suitable rice varieties that would be useful in varied climatic and soil conditions. In addition, on-field experiments were conducted with the farmers to take them on board and identify the most suitable variety of rice that meets their selection criteria. Ultimately, it hopes to enable farmers with the knowledge they need to boost rice production and contribute to bettering their human security. Mindful not only of the methodical intervention, but also the farmers' preference for selecting rice varieties in terms of productivity, quality, and marketability, the research in itself is a unique undertaking.

This research is a broad effort to help the farmers of the central dry zone of Central Myanmar improve their rice production by reducing production costs and maintaining sustainable, stable yield through adverse environmental conditions. However, the scope of the research is not limited to just this area, as it might have applications to similar circumstances elsewhere. It is hoped that this research adds not only to the existing knowledge of rice production in rainfed lowland areas, but also contributes in uplifting the lives of the people associated with it.

Chayan Vaddhanaphuti, PhD
Director, RCSD

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Abstract

This study attempts to inform efforts to improve sustainable, rainfed rice production with low external inputs, especially the low use of chemical fertilizers. The study consists of three parts: field survey, farmer participatory varietal selection, and field experiment.

The field survey was carried out at Thekwe, Yamethin Township, Mandalay Region, Myanmar, to collect the knowledge and practices of the local rice farmers and the socioeconomic factors contributing to rainfed lowland rice production. Research was carried out from December 2012 to August 2013. Primary and secondary data were recorded. Primary data was collected through structured questionnaires and in-depth interviews with 40 rice farmers who were selected using a simple random sampling method. Results revealed that farmers are literate and have experience in rice production and domestic farming. Their rice farmlands consist of sandy soil, and rice production mainly depends on seasonal rainfall. They use traditional farming practices and apply a low amount of nitrogen-based fertilizers.

Fifteen participating farmers evaluated rice varieties at tillering, reproductive, and grain filling and maturation stages. *Manawthukha* was the most preferred variety in all evaluation times. *Shwmanaw* was the second-most preferred variety at tillering and reproductive stages, and *Shwepyihtay* was the second-most preferred variety at grain filling and maturation stage.

The experiment was conducted at three sites within one location during the 2013 rainy season to identify rice varieties that are capable of producing sustained yield under low nitrogen fertilization. In each experiment, six genotypes — namely, one early, four medium duration, and one photoperiod sensitive — were grown using randomized complete block design with two replications. In each case, a total of 28.84 N kg/hectare (which is the most commonly applied dose among farmers) was applied at 14 days after transplanting (DAT), 40 DAT, and 50 DAT in three equal applications (of 9–10 kg/hectare each). The 34-day- old seedlings were transplanted for experiment 1, 41-day-old seedlings for experiment 2, and 47-day-old seedlings for experiment 3. The genotype, environment, and genotype x environment interaction effects were observed on grain yields. Regression coefficient (b_i) was used to estimate adaptability. *Shwemanaw* (early duration), *Sinthukha* (medium duration), and *Tunthukha* (photoperiod sensitive) were suitable to grow in the favorable rainfed rice production area, and *Shwepyihtay* (medium duration) was suitable in the unfavorable rainfed rice production area.

The on-farm farmer participatory research approach provides an effective learning platform for generating and disseminating context-relevant information directly to benefit rainfed lowland rice farmers.

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INTRODUCTION

Rice production in the central dry zone of the Republic of the Union of Myanmar depends primarily on seasonal rainfall. In the low-lying areas of Thekwe in Yamethin Township (20˚ 25′ N latitude, 96˚ 9′ E longitude and 178 meters above mean sea level), rice farmers mostly cultivate rice under rainfed conditions. These central Myanmar farmers are smallholders and lack capital for agricultural inputs. They do not invest much in chemical fertilizers for rice production. Rice yield is low, especially in areas with low inherent soil fertility.

Farmers select their rice varieties with multiple objectives: they seek to reduce production costs but maintain stable yield. Available varieties include ones that are adapted to low temperature stress and tolerant of mid- and late-season drought, which are conditions farmers have experienced in the last decades. The traditional rice variety *Manawthukha*, which was released by the Central Agricultural Research Institute in Yezin in 1978, is still preferred by these local farmers. It possesses good grain quality and consistently brings a higher price. The variety can produce a higher yield with moderate-to-high input systems.

Rice is not only the main staple food in the region, but is also an economic crop for farming households. Farmers in this area continue to use traditional practices that depend on labor with low chemical input. The drought experienced in 2012 caused severe yield reduction and in some cases, a complete crop failure.

Thus, these farmers have been experiencing increased concerns about the stability of rice production in the rainy season. Any crop failure has social and economic implications for farmers' livelihoods, and, especially, impacts their food security.

The present study is therefore intended to determine the appropriate production strategies to benefit lowland rainfed rice farmers in central Myanmar. Specifically, the research aims to inform development of sustainable rice production under low external inputs so that farmers can become more self-reliant while faced with environmental risks and uncertainty.

The study consists of three parts: a field survey, a collaborative on-farm experiment, and farmer participation in varietal selection. Research was conducted from December 2012 to December 2013 in Thekwe, Yamethin Township, Mandalay Region, in central Myanmar. The ultimate goal is to improve sustainable rice production practices for rainfed lowland farmers in central Myanmar.

Firstly, a field survey was conducted with 40 rice farmers to learn about their knowledge and practices, as well as the socio-economic factors affecting rainfed lowland rice production. Next, I conducted three experiments using six different rice varieties and three different dates for transplanting rice on the fields of three farmers. I applied equal amounts of nitrogen (N) fertilizer, using the amount of fertilizer that was applied by most farmers based on results from the survey of farmers' practices. Finally, 15 farmers participated in an evaluation of the rice varieties at different stages.

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BACKGROUND INFORMATION

Rice is the primary staple food of more than half of the world's population with Asia representing the largest producing and consuming region (FAO, 2012). Myanmar has a predominantly agricultural-based economy focused on rice production, and it is the sixth largest rice producing country in the world (Lee, 2011). Rice production was 32,579,000 metric tons in 2010–11, comprising 34% of total crop production (MOAI, 2011). In Myanmar between 2009–10, 68% of the total rice sown was sown in favorable environments (20% in irrigated lowlands and 48% in rainfed lowlands), while 32% was sown in unfavorable environments (12% in drought prone areas, 9% in submerged areas, and 5% in uplands).

In the present context of climate change, Myanmar is suffering from storms, floods, and droughts that affect its agricultural production and social security. Thus, current production systems in agriculture must be reviewed. In irrigated areas, where there is a favorable environment for rice growing, rice-after-rice cropping patterns cause soil degradation and pest and disease outbreaks, resulting in yield reduction. In unfavorable environments, high-yielding varieties demonstrate lower yield potential. The use of fertilizer decreases in efficiency and farmers face increasing risks due to incidences of drought, flood, pests, and diseases. Drought prone areas are found in Mandalay, Magwe, and Sagaing divisions (Department of Meteorology and Hydrology et al., 2009).

Manawthukha is a popular, high yield variety of rice. It was introduced as a pedigree variety of Mahsuri-M from the International Rice Research Institute (IRRI) of the Philippines in 1975. Its origin is Malaysia. It is a breeding line developed by crossing *Japonica* and *Indica* rice. The Rice Division of the Central Agricultural Research Institute released this high yield variety as "*Manawthukha*" in late 1978. It has a 135-day growing period with medium plant height, and produces 10–12 productive tillers per hill under normal planting spacing. It possesses good milling quality and yields 5–6 tons/hectare in favorable environments with good management practices.

Manawthukha is grown in all rice cultivating areas throughout Myanmar, especially in Mandalay, Sagaing, Magwe, and central Myanmar, because of its high amylose content, quality grains, and cooking characteristics. However, the variety is not resistant to bacterial leaf blight disease in the monsoon season. Nonetheless, farmers are satisfied with its performance despite its reduction in yield due to disease infection. It has stable local market. This is perhaps the most important incentive for farmers to continue growing this specific variety all around Myanmar.

For food security and income stability from rice production, it is commonly recommended to farmers to select adaptive varieties and to have good management practices. Since rice farmers in Myanmar are smallholders with less access to capital for agricultural inputs, this research project aims to find opportunities and identify tactical solutions for sustainable rice production under low external inputs, especially low use of chemical fertilizers.

Objectives

The research has three objectives, namely

1. To understand the socioe-conomic circumstances of rice farmers in the rainfed lowland areas of the central Myanmar;

2. To gain a better understanding of farmers' knowledge and practices regarding rainfed lowland rice production systems; and

3. To identify rice varieties that are capable of producing sustained yield under low nitrogen fertilization.

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RESEARCH METHODOLOGY

Selection of Study Site

The dry zone in the central part of the Republic of the Union of Myanmar was selected as a study site. The area is rainfed lowland rice growing region lying between the Yangon-Mandalay railway line and highway (Figure 1). In this area, the 10 years average annual rainfall (2002-2011) is 900 mm (Table 1), which is considerably lower than that of the rice growing areas in the Ayeyarwaddy Delta region. It is anticipated that if sustainable rice production systems can be designed and worked out, it would have great impact on the dry zone of the Central Myanmar.

Socio-economic Circumstances and Rice Cultivation Practices of Farmers in Rainfed Lowlands

Data collection

A simple random sampling technique was used to select rice farmers for this study. The sample size was 40 rice farmers from Thekwe village. Formal and informal surveying as carried out from December 2012 to August 2013. Primary and secondary data were collected. Primary data were collected through structured questionnaires and in-depth interviews. Nutrient management, cropping patterns, and socio-economic characteristics of farmers such as age, education, and land holding size were emphasized in the questionnaires. Secondary data, such as facts about rice growing, land use patterns, rainfall, and population, were gathered from government organizations including the Department of Agriculture, Settlement and Land Record Department and the Agro Metrological Station and Emigration Department.

Data analysis

The data from the formal survey were analyzed using descriptive statistics.

On-Farm Experiment

Experimental site and design

Three experiments were established on rainfed fields around Thekwe village. Six rice genotypes were tested using randomized complete block design with three replications for each experiment. The six tested genotypes are listed in Table 2. Soil sampling from each experiment was conducted before sowing and the available N, P, K, organic matter, soil texture, and soil pH were analyzed (Table 3). The mean minimum and maximum temperatures and total rainfall during crop growing season were reviewed (Table 1).

Crop management of three experiments

The six tested varieties were seeded on June 25 and 34-day-old seedlings were first transplanted on July 29. The experimental size was 841 m^2 and each plot size was 60 m^2 (24 rows x 12 m length). Hill spacing was 20 cm x 17 cm with 3 to 4 seedlings per hill. The plot was supplemented with water as required from a nearby pond. Nitrogen fertilizers at the rate of 28.84 N kg/hectare were split-applied three times at: 14 days after transplanting (DAT), 40 DAT, and 50 DAT with equal amounts. Hand weeding was done one time at 40 DAT. During the experiment, we did not observe any significant incidence of pests or disease. The plot was kept weed-free.

The second transplanting was done with the 41-day-old seedlings on August 5. Transplanting was late due to delayed rainfall in the area. The experimental size was 84.85 m^2 and each plot size was 5.45 m^2 (8 rows x 4.47 m length). Similar crop management practices were carried out as with the first transplanting.

The third transplanting was carried out with the 47-day-old seedlings on August 11. The experimental size was 164.11 m^2 and each plot size was 8.67 m^2 (8 rows x 7.11 m length). The same crop management practices were followed as with the first and second transplantings.

All three transplantings were carried out in collaboration with local farmers. The third planting date was considered to be relatively late in comparison with local practices. However, it was included to account for an extreme case when rainfall is delayed or when there is a prolonged dry spell in July (Table 1).

Data collection

The inner rows of each plot were used for data collection and the outer rows were used as the border rows. The five hills were randomly selected from the inner rows and data was collected for agronomic characteristics: plant height, productive tillers per hill, panicle length, the total spikelets per panicle, filled grains per panicle, and thousand grain weight (Table 4). The fertility percentage was calculated using the total spikelets per panicle and filled grains per panicle. The plot yield was obtained from 1 m^2.

Data analysis

Statistical computations and estimates were carried out using CROPSTAT, version 7.0. Combined ANOVA was performed on grain yield and the mean comparison of grain yield and agronomic traits such as plant height, productive tiller, panicle length, fertility percentage and thousand seed weight, was done using least significant difference (LSD). To determine varietal adaptability, the grain yields of six varieties were tested across three planting dates that were treated as varying environments using regression coefficient (b_i) (Finlay and Wilkinson, 1963).

Farmer Participatory Varietal Selection

Fifteen farmers were selected based on age and experience with rice production. They were invited to evaluate tested rice varieties at tillering, reproductive, grain filling, and maturity on site 1 (transplanted on July 29). The experimental design, the purpose of exercise, and the evaluation procedures were explained and discussed with the farmers. Each variety was clearly labeled. Farmers were given four ballots and asked to walk through the field to choose the two most promising varieties and the two worst varieties. After voting, I facilitated a group discussion to determine how and why the individual farmers made their selections, making a note of their responses. The preference score (PS) for each genotype was calculated as follows:

$$PS = \frac{\text{number of positive votes} - \text{negative votes}}{\text{total number of positive and negative votes}}$$

(Paris et al., 2011)

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RESULTS

Description of Study Area

As mentioned, Thekwe village, Yamethin Township, is in Mandalay Region in the central part of the Republic of the Union of Myanmar (20˚ 25′ N latitude, 96˚ 9′ E longitude) at 178 meters above mean sea level (Figure 1).

The land area of Yamethin Township is 323 sq. km with a population of 324,735 (in 2012). There are five wards in the urban area, and 63 village tracts comprising 246 villages in the rural area. The urban and rural populations are 46,476 and 278,259, respectively, with 86% of the total population living in the rural area and surviving on agriculture as their main livelihood system. The land use pattern of Yamethin Township can be seen in Table 5. The net sown area is 74,982 hectare and lowland (*Le*) is 32,491 hectare (43.3% of the net sown area). Rice is grown in the lowland (*Le*) with 900 mm average annual rainfall over the last ten years (Table 1) with supplementary irrigation from four dams and five ponds.

In Thekwe village, there are 495 people in 110 households. About 85% of the households earn their living in agriculture. They grow rice as their staple food, together with various kinds of crops, such as field crops and horticultural crops. There is a primary school and the community uses generators and solar energy for electricity. They get access to news, information, and entertainment through radio and television broadcasts.

Socio-economic Circumstances and Cultivation Practices of Farmers in Rainfed Lowlands

Demographic information: Age, family size, and education level

Farmers engaged in rainfed lowland rice production who participated in this research had an average age of 49 years and from five to 43 years of experience. The average family size was five members per household.

Among the selected 40 rice farmers, 20% had only attended primary school. A larger number (42.5%) had attended middle school, while 17.5% had gone to high school, and 15% to a private school (i.e., a monastery). The remaining 5% had college education. The sampled farmers were all literate, and all apparently have the capacity for self-learning and improvement if proper agricultural knowledge delivery systems are designed and implemented.

Land holdings and on-farm activities

Households own different amounts of land. All sampled farmers were landowners with both lowland (*Le*) and upland (*Yar*) fields. Farm households were classified into three groups according to land holding size. The households with less than 2.0 hectares (ha) were classified as small farm households. Some small farm households possess farmland and also practice domestic farming on rented land. The households with between 2.0 and 4.0 hectares of land were classified as medium holders, and those with more than 4.0 hectares were considered large holder households (Table 6). Some medium and large holder households were able to expand their holdings with income from farming and other activities such as cattle brokering.

The livelihoods of these three groups of farmers are characterized by farming-based activities with various degrees of diversification, as shown in Table 7.

The smallholder farmers (those with holdings of less than 2 ha) planted only photoperiod-sensitive rice varieties in the rainy season. Such varieties are known to be more flexible, as varying planting dates do not jeopardize yields. Thus, they are better fit with a variable rainfall environment. The smallholder farmers also diversified their upland fields into field crops and horticultural crops. Among the field crops, farmers gave high priority to green gram (also known as mung bean) (84%), followed by cotton (11%) and chili (5%). Green gram is a short maturing crop, about 65–75 days, so farmers have less risk with green gram under rainfed conditions. These three crops also enabled farmers to have better labor distribution, as cotton is a medium maturing crop (120–150 days), and chili is a late maturing crop.

The smallholder farmers also allocated their land to grow horticultural crops, mainly watermelon (89%) and long bean (11%). Both of these crops are labor intensive and require good management practices, as they are susceptible to diseases and pests, respectively. In the post-monsoon and summer season, a few farmers with access to water grew eggplant, onion, and watermelon. One farmer from this group reported that he was able to grow watermelon throughout the year.

Cattle raising was also found to be a source of additional income among smallholder farmers. In addition, some households derived incomes from various sources, such as on-farm wage labor and wage earning in nearby governmental offices.

The medium-holding households (with 2-4 ha of land) grew modern, non-photoperiod sensitive rice varieties, as well as more flexible, photoperiod-sensitive rice varieties. On the upper terraces where water does not flood, farmers grew similar field crops as the first group, but with the addition of sesame and groundnut. Farmers allocated their land for green gram (65%), chili (20%), cotton (5%), sesame (8%), and groundnut (2%). The field plots used for horticultural crops were mainly planted with watermelon (87%) and long bean (13%). In the post-monsoon summer season, only a few farmers were successful with summer crops as water was limited. For instance, it was observed that only one farmer grew tomato (0.08 ha), and three farmers grew onion on small scale (0.24 ha).

All the farming households earned their livings from crop-based farming systems, while a few also raised cattle similar to the smallholder farmers.

The large farming households (with access to more than 4 ha) had more options for rice cultivation. They typically include flexible, photoperiod-sensitive varieties along with modern, photoperiod-insensitive varieties. Farmers selected rice varieties to fit the topographical features of their rice fields. For instance, on the upper terraces where there is the possibility of water shortage, farmers would plant a photoperiod-insensitive variety (with a duration to maturity of 125 days) in order to avoid drought. Some broadcasted and transplanted with these modern, photoperiod insensitive varieties. Additionally, some farmers broadcasted photoperiod sensitive varieties (again, in an effort to avoid drought). It can be seen that farmers had multiple objectives when they selected their rice varieties and their planting strategies (broadcasting, transplanting, or both).

For production of field crops during the rainy season, the large-holder farmers had cropping patterns similar to the first two groups, giving highest priority to green gram (59%), followed by cotton (20%), chili (16%), sesame (4%), and groundnut (1%). Regarding horticulture, watermelon, covering about 96% of the area allocated for horticultural crops, was grown twice a year by pumping in underground water. One household was able to grow three crops of watermelon in a year. Long bean occupied about 4% of the allocated land.

In the post-monsoon season, two farmers grew onion and one farmer grew eggplant using pumped underground water. The majority of the large farmers earned their incomes from crop-based farming systems and only a few from raising cattle. One farmer received household income from crops, from raising livestock, and from trading as a cattle broker.

The three groups of farmers, regardless of their land holding size, developed integrated rice-based farming systems with similar field and horticultural crops during the rainy season. In addition, where water was available, a few farmers engaged in cash cropping of vegetables such as onion, eggplant, and tomato. All the rice farmers made full use of their land by allocating rice to the lower terraces, and field crops and horticultural crops on the upper terraces where drainage is much improved so that waterlogging would not damage crops. The large farmers with better access to resources were able to invest in water pumps and hired labor, so they were able to grow more high value cash crops that require more labor and other agricultural resources.

From the farming activity perspective, it can be argued that these rice farmers in rainfed lowlands are very efficient in their land use management. They have been able to diversify their farming systems to mitigate agricultural risks under rainfed conditions and they have selected specific cropping patterns to fit their varying farming environments. The smallholder farmers were more subsistence-oriented, planting their rice to achieve household food security. Meanwhile, the medium and large holder groups were more commercialized. They were better able to diversify their rice varieties, planting varieties for home consumption and for market. However, all farmers relied on income from cash cropping and from raising cattle.

Farmers' design of rice-based cropping systems

In Thekwe village, most farmers possess both lowland (*Le*) and upland (*Yar*) plots. They practice diversified farming by growing different crops on their farmlands. In the years 2012 and 2013, the main cropping patterns on the lowland plots were rice-fallow, rice-sunflower, and green gram (mung bean)-rice. On the upland plots, horticultural crops such as groundnut, sesame, green gram, chili, and cotton were cultivated (Figure 2).

Most farmers in the study area relied on seasonal rainfall for cultivation and did not grow any crops after harvesting the monsoon paddy. There were three types of cropping patterns: rice-fallow (62.5% of total sampled farmers), rice-sunflower (12.5%), and green gram-rice (25%). Green gram-rice was practiced by three of the ten smallholder farmers; three of the 23 medium holder farmers, and four of the seven large holder farmers. One of the smallholder farmers, three of the medium holder farmers, and one of the large holder farmers grew sunflower after rice for edible oil. Farmers reported that, five years ago, they grew green gram before rice to earn income to invest for the next crop production. This practice improved physical properties of the soil.

Rice production systems

For the year 2013, rice production depended on seasonal rainfall (82.5%), a combination of seasonal rainfall and irrigated water (12.5%), and seasonal rainfall and supplemental water in the small pond (5%). The rice farmers who depended solely on seasonal rainfall for their production faced many production risks, and would commonly grow rice with low inputs, even when they had supporting capital. Rice production is important not only as a staple food but also to generate income for education, clothing, living, and general household expenses, as well as religious donations. Rice crop failure led to widespread food insecurity and poverty in 2012.

Farmers' soil types for growing rice

Farmers in the studied site have rice fields with varying soil types. Fifteen farmers (37% of the sample) have a field with sandy soil characteristics, such as poor water holding capacity, so rice has a high probability of facing water stress. Eight farmers (20%) possess clayish soils, four (10%) have black cotton soils, two (10%) have sandy loam, and one (2.5%) has silty soil. Nine farmers (22.5%) have farms with sandy and clay soils, and one (2.5%) has sandy and black cotton soils. The rice productivity is expected to be low to moderately low, since more than 50% of farmers' paddy fields have sandy soil, or sandy soil characteristics. It is recommended that farmers begin to apply organic matter available on their farms, such as cow dung, composted kitchen scraps, and humus of tamarind and other plant materials as nutrient supplements for their fields to improve the physical and chemical properties of the soils.

Farmers' selection of rice varieties

The lowland rice farmers in the study area grew rice for consumption with the surplus being sold in the village. Four major rice varieties were commonly selected by farmers for planting, namely *Manawthukha*, *Tunthukha*, *Yeanelo*-1 and *Shwepyihtay* (Table 8). All are high yielding varieties with the exception of *Tunthukha*, which is a photoperiod-sensitive variety. Farmers' criteria for selecting rice varieties were productivity, quality, and marketability. Farmers grow at least two varieties. For instance, it was found that 27.5% of farmers grew *Manawthukha*, a modern and popular variety (that is photoperiod insensitive), and *Tunthukha*, a photoperiod-sensitive variety. *Tunthukha*, being photoperiod-sensitive, is adapted well and persistent under variable rainfall conditions. When the growing season is short due to delayed rainfall, or long dry spell, *Tunthukha* can still grow, develop, and produce grain yield when the rain comes. Farmers usually sow the variety by direct seeding which requires less labor. Farmers do not have to prepare a nursery, which requires water and care, or pull the seedlings. The seedlings are not subjected to water stress as they would be if pulled from the soil of the nursery. However, the direct seeding has certain disadvantages. The seeds are exposed to birds, there is greater competition between rice and weeds, and direct seeding requires higher seeding rate, as there is less root anchorage. *Tunthukha* produces a high straw yield even in drier years. Even when the grain yield is poor, farmers can still harvest the straw and use it for livestock feed. Thus the variety is valued for straw yield as well as grain yield.

Two other varieties, *Yeanelo*-1, and *Shwepyihtay*, which are medium maturing varieties (but earlier than *Manawthukha*), were grown by 5% and 2.5% of farmers, respectively. *Yeanelo*-1 is known to have better drought tolerance, but it possesses lower amylose content than *Manawthukha* and is more sticky, so it is less preferred by rice farmers.

Most farmers have had experience growing medium maturing varieties and photoperiod-sensitive varieties, but they have had no experience growing early maturing varieties. Generally, high yielding varieties are highly responsive to nutrient management, while photoperiod-sensitive varieties, which have a long duration, usually utilize large amounts of water to produce rice. *Yeanelo*-1 can recover even when midseason drought occurs. It has the ability to escape terminal drought. Therefore, early and moderately early rice varieties provide better opportunities to fit the rainfed cropping pattern and greater potential for improving land use efficiency, and mitigating climatic risk.

Farmers' cultivation practices with rainfed lowland rice

Farmers practiced both direct seeding and transplanting. Direct seeding was of two types: dry land preparation (dry seeded rice) and wetland preparation (wet seeded rice). About 90% of farmers transplanted their rainy season rice. However, the medium and large holder farmers reported that they could not grow transplanted rice in all of their fields. Instead they practiced direct seeding in some fields. The cost of production when transplanting rice is higher than with direct seeding. The former requires land preparation and labor costs for pulling rice seedlings and transplanting. Under erratic rainfall distribution, farmers do not want to invest more than they have to, and they want to reduce risks by reducing production costs as much as possible. Direct seeding was usually practiced if water availability was delayed or the arrival of the monsoon season was late. Ten percent of the farmers interviewed said that they intended to grow direct wet-seeded rice in the coming planting season.

The elderly farmers are accustomed to assessing weather conditions by observing how the wind blows on the first, second, and third day of last month of the Myanmar year (the month of Tabaung). They assume that higher wind speeds correlate with higher precipitation, and that wind speeds on these three days indicate the amount of precipitation to come in the early, middle, and late period of the monsoon season, respectively. These traditional weather forecasting practices of elderly, experienced farmers have never been scientifically evaluated.

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DISCUSSION

Transplanted Rice

Seed rate and seedling age

The average seed rate used in the nursery plot for rice transplanting was 90 kg/hectare (ha). Most farmers used 77 kg/ha. The highest seed rate was 155 kg/ha and the lowest seed rate was 52 kg/ha (Table 9). Some farmers seeded more than the required amount because of the possible damage from rodents, cattle, and natural hazards. In direct-seeded rice, most farmers broadcasted seeds at the rate of 77 kg/ha, while some farmers used a low seeding rate because they intended to reduce their seed cost.

About 90% of the farmers grew 30-day-old seedlings. A small number of farmers (2.5%) began to transplant younger seedlings at 25 days old. These farmers (2.5%) reported they grew three seedlings per hill if the seedling age was 25 days' old, or they grew five seedlings per hill if the seedling age was 28 days' old. Younger seedlings produce more tillers, but when the farmers have to delay their rice transplanting due to unforeseen events, they plant more seedlings per hill to improve the number of tillers per unit area.

Some farmers (5%) reported they grew 45-day-old seedlings in 2013. This is not very common under normal circumstances. Usually, farmers who have less access to rice seed choose to save seed and thus save costs by controlling plant density. However, the laborers (including hired labor and exchange labor) who help with the transplanting might plant more seedlings per hill with younger seedlings in order to save time. Farmers have to use 40-day-old (or older) seedlings if the rainfall is delayed and they cannot afford to prepare a new nursery. Farmers use these older seedlings in problem areas where pink snails or crabs are widespread as older seedlings with their hardened culms are more resistant to pest damage.

Nursery preparation

There are three methods of seed preparation for nursery planting depending on the method of seed conditioning, namely: using dry (or rinsed) seed, soaked seed, or germinated seed. Once the rice seed is broadcasted in the nursery, water management is more or less the same regardless of the initial seed preparation method.

About 90% of the farmers practiced the traditional method, which involves broadcasting dry seed in the nursery. Before broadcasting, farmers may run the rice seed through water to remove floating, unfilled seed. The dry or lightly rinsed seeds are broadcasted in the puddle soil (*thaman*). Three or four days after broadcasting, when the seeds have germinated, the field is drained. Approximately 7–10 days later, when the soil surface becomes dry and cracked, it is irrigated with water and then completely drained, either immediately or overnight (*pyo-khin-kyin-ye-tait*). The nursery is irrigated in this way once every 7–10 days whenever the soil surface becomes dry and cracked.

A second method was recommended and demonstrated to the farmers by the agricultural extension workers and 5% of the farmers (those with access to supplemental water sources) practiced this method. In this method, seeds are soaked in water for one day, and then incubated one day using materials such as straw and fully decomposed cow dung. Germinated seeds are broadcasted in the puddle soil (*thaman*). About 1–2 days later, the field is completely drained. When the soil surface becomes dry and cracked, the field is irrigated. Later, the field is irrigated again depending on the water requirements of the seedlings.

The third method, a modification of the traditional method, was used by 5% of the farmers in the study. In this method, seeds are soaked in water for one night and then broadcasted in the puddle soil. About 2–3 days after broadcasting, when the soaked seeds have germinated, the field is completely drained. When the soil surface becomes dry and cracked, it is irrigated and then it is drained again, either immediately or overnight. Approximately 5–7 days after draining, the field is irrigated again.

In all three methods, urea fertilizer is applied at the rate of 600-2,400 gm per 21 kg seed about 7–8 days before transplanting to speed up new root growth and to enable easy uprooting at transplanting.

Crop management

Land preparation

In the transplanting fields, there are two types of land preparation depending on the soil type. In the sandy fields, soil preparation is done with a plough and a harrow. Leveling instruments are not used to avoid compacting the soil surface. In the fields with other soil types (clay, sandy loam, silt, and black cotton soils), a plough, harrow, and leveler are used to prepare the land.

Water management

In the sandy fields, water is not drained from the field at time of transplanting. A shallow water depth of about 7.5–10 cm for two weeks after transplanting provides optimum conditions for tillering under good rainfall conditions. However, if there is a poor distribution of rainfall, farmers maintain the water level at around 15–20 cm during the growing season, even though they know that deep water causes poor tiller production. They would rather have too much water than risk having too little. The fields are drained to provide uniform maturity, to facilitate the manual harvest, and to avoid grain germination when the panicles droop.

Nutrient management

Chemical fertilizer application

It is recommended to apply urea, triple-super phosphate, and murate of potash in order to increase rice yields. However, almost all the lowland rice farmers I studied applied only urea as a main source of nitrogen to increase their rice yields. Most applied low amounts of urea fertilizer and said they had access to insufficient capital to purchase the recommended amounts of fertilizer. The farmers were also not convinced of the effectiveness of chemical fertilizer for improving yield, especially when droughts occur frequently.

On average, farmers applied urea at a rate of 24 nitrogen (N) kg/ha. However, some farmers (10%) grew rice without N application, while a few farmers (2.5%) used a higher rate at 66 N kg/ha on transplanted fields (Table 9). Some farmers who grow rice with residues of crop-weed biomass as a source of nutrient reported that they could not afford external inputs, and some claimed that their fields already had high soil fertility. With direct seeding of rice, farmers applied N fertilizer and cow dung at the average rates of 15 N kg/ha and 7 ton/ha, respectively. They each raised two–10 heads of cattle (minimum two, maximum 10, and average four) and used cow dung for nutrient replenishment, especially on low fertility soil or poor soil.

I found that the farmers had different practices with respect to the timing of fertilizer application. About 42% of the farmers applied N fertilizers twice during the growing season: first at the tillering stage, and then at panicle initiation. The rest applied fertilizers only once: about 30% of the farmers applied at the tillering stage, and 28% at panicle initiation. Theoretically, the split application (at tillering and panicle initiation) should provide favorable nutrients for rice growth. Apparently farmers have good knowledge about the timing of fertilizer application, even if they can only afford to apply fertilizer once. Farmers' decisions about using fertilizer in rice farming, including the rate and timing of application, need to be further explored regarding both transplanting and direct seeding of rice.

Manure application

Almost all the lowland rice farmers applied cow manure to improve the fertility and enhance the water-holding capacity of their soil. On average, farmers applied cow dung at the rate of 4.9 ton/ha (ranging from zero to 10.6 ton/ha). Most farmers applied cow dung at the rate of 4.3 ton/ha (Table 9). However, some farmers could not apply cow dung every year. They applied cow dung based on the soil fertility status of their fields. Farmers who did not have enough dung from their own cattle would use whatever was available for their horticultural and upland crop production.

As previously mentioned, all farmers in this study owned cattle. Seventy-five percent of them raised cattle for multiple purposes. Cattle are used as draught animals for land preparation, weed control, post-harvest processing, and transportation of farm products. They also generate income by producing milk. Animal waste is used for soil nutrient improvement. The remaining 25% of the farmers in my study raised cattle only for farming activitives and fertilizer.

Weed control

Over 80% of farmers practiced weed control in rice production. About 64% of the farmers manually controlled weeds; 8% controlled weeds using a toothless harrow or leveler at the tillering stage if there was water in the field; and 14% practiced both weed control methods. The remaining 14% of the farmers did not control weeds (Table 10). Some claimed that their fields had no or low weed infestation. Others had fields infested with barnyard grass (*Echinochloa crus-galli L*), which has a stem color similar to the *Yeanelo*-1 variety rice plants at the seedling stage. Farmers in this situation find it difficult to distinguish weeds from rice seedlings, and so do not practice weed control. Farmers planting *Yeanelo*-1 variety for low N tolerance should be aware of this limitation. As it is less distinguishable from weeds during the seedling stage, planting *Yeanelo*-1 may lead to lower yield potential.

Pest and disease control

Farmers reported incidence of rice stem borer, green leaf hopper (*Nephotettix virescens*), leaf folder (*Cnaphalocrocis medinalis*), and bacterial blight (*Xanthomonas oryzae pvoryzae*). However, the incidence of these pests and diseases was not significantly widespread. Yield reduction occurs, but complete crop failure due to pest and disease has never been encountered.

When pest and disease incidence occurs, only a small proportion of the farmers controlled pests by using insecticides and/or by picking larva and pupa by hand (manual control). The majority did not practice any control measures (Table 11), perhaps allowing the plant-pest-predator ecosystem to regulate itself.

About 10% of the farmers reported bacterial blight disease in their fields, but only 2.5% mitigated bacterial blight incidence by reducing the field water level. Moisture on foliage or standing water in the rice fields is thought to provide enabling conditions for the occurrence and development of fungal and bacterial diseases.

Harvesting

Harvesting was done manually and threshing was done mechanically or using a bullock.

Rice yield

In rainfed rice production in 2012, there was only 291 mm of total rainfall during the growing season (June to November) and most of the farmers, because they grow medium maturing, photoperiod-sensitive varieties, faced crop failure. Five percent of the farmers grew a variety with drought-tolerant characteristics (i.e., 10 days earlier to maturity), and while they did have crops, they were able to produce only 0.26 metric ton/ha.

In 2012, rice was seeded in the nursery in the second and third weeks of June and transplanted from the last week of July to the first week of August. The rainfall was 70.87 mm in June, 52.07

mm in July, and 96.01 mm in August (Table 1). The drought incidence occurred at the maximum tillering stage and the panicle initiation stage, resulting in yield reduction and crop failure. From this experience, it is evident that early maturing rice would provide better potential for farmers' varietal choice to escape drought.

Production constraints

The major constraints farmers faced in rice production were: drought (97.5%), poor soil (35%), unsuitable variety (30%), and lack of capital for inputs (17.5%). Other constraining factors such as pest and disease damage, weed infection, and labor scarcity were 5%, 5%, and 2.5% respectively. Some farmers encountered more than one constraint in rice production.

Most farmers grow *Manawthukha*, which is a fertilizer-responsive and high yielding variety. They sow seed from their own harvest or from neighboring farms. By using their own seed or known seed sources, farmers are able to reduce certain production costs and be more self-reliant. However, interventions for improving the farmers' seed quality, such as pure line selection, and post-harvest handling to enhance purity and high germination, could provide additional improvement to the production system.

On-Farm Experiment

The mean performance of yield and agronomic traits of six rice varieties grown on three planting dates (i.e., different environments) in Thekwe village

The on-farm experiment was designed in collaboration with farmers in Thekwe village to identify rice varieties that are suitable for low nitrogen management in the rainfed lowland ecosystem. It was assumed that three planting dates covering pre-optimal and post-optimal planting seasons would generate and represent three varying environments with respect to the availability of rainwater. Varieties with a high mean yield across the three environments and with regression coefficient equal or close to 1 would represent varieties with high productivity and stability. Six rice varieties were tested, namely: *Yeanelo*-1, *Shwemanaw*, *Sinthukha*, *Shwepyihtay*, *Manawthukha*, and *Tunthukha*. The varieties were planted on three planting dates, and each planting date was located in a different field site in the village. Therefore, the combination of planting date and farmer's field site was treated as a single environment.

The genotypes tested in environment 1 (planting date June 29, 2013) exhibited a highly significant difference in plant height, productive tiller, fertility percentage, 1,000 seed weight, and grain yield but a non-significant difference in panicle length. *Tunthukha* was significantly higher than other genotypes in plant height while *Shwemanaw* had the shortest plant height. *Shwemanaw* possessed the highest productive tiller, followed by *Shwepyihtay* and *Sinthukha*. Panicle length ranged from 18.7 cm to 21.1 cm. The mean panicle length was 20.1 cm. The highest fertility percentage was observed in *Tunthukha* and followed by *Shwemanaw*, and the lowest in *Manawthukha*. *Tunthukha* had a significantly higher 1,000 seed weight compared to other genotypes. *Shwemanaw* had the lowest thousand seed weight. *Shwemanaw* showed the highest grain yield, followed by *Tunthukha* and *Sinthukha*. *Shwepyihtay* possessed the lowest grain yield (Table 12).

Among the varieties tested on site 2 (planting date August 5, 2013), there was a highly significant difference in plant height, as well as a significant difference in fertility percentage and 1,000 seed weight. A non-significant difference was observed in grain yield. *Tunthukha* was significantly taller than other genotypes in plant height. It ranged from 5.9 cm to 7.9 cm in productive tiller, 18.9 cm to 21.7 cm in panicle length, and 134.9 gm to 248.2 gm in grain yield. The mean values of productive tiller, panicle length, and grain yield were 7.0 cm, 19.7 cm, and 189.0 gm, respectively. *Shwemanaw* and *Tunthukha* had the highest fertility percentage and were significantly higher than other genotypes. The highest 1,000 seed weight was observed in *Yeanelo*-1 and the lowest 1,000 seed weight was observed in *Shwemanaw* (Table 13).

There was a highly significant difference in plant height, fertility percentage, and 1,000 seed weight with the genotypes grown on site 3 (planting date August 11, 2013), but there was a non-significant difference in productive tiller, panicle length, and grain yield. *Tunthukha* was significantly higher than the other genotypes in plant height. *Manawthukha* exhibited significantly higher fertility percentage compared with the other genotypes. *Tunthukha* showed the highest 1,000 seed weight, followed by *Yeanelo*-1. The ranges were from 7.5 cm to 9.9 cm in productive tiller, from 18.9 cm to 22.3 cm in panicle length, and from 165.9 gm to 315.5 gm in grain yield. The mean values of productive tiller, panicle length, and grain yield were 8.8 cm, 1.9 cm and 235.8 gm, respectively (Table 14).

The combined analysis of variance and partitioning of the sum of squares of components in relation to grain yields for the six varieties tested on three sites

The genotype, environment, and genotype x environment (GE) effect were highly significant sources of variation in grain yield (Table 15). The genotype x environment (GE) interaction complicates the selection of genotype. DAS et al. (2011) also report genotype, environment, and genotype x environment interaction effects in rice grain yield.

Table 15 shows the partitioning of sum of squares of components to determine the percentage of contribution of each component for the grain yields for each of the six genotypes. Variation due to the genotype (G) was 22.3% of the total variation, while variation due to the environment (E) component was 45.9%, and variation due to the genotype x environment (GE) component was 23.7%. The presence of GE interaction contributes to the unreliability of rice yields over the three tested environments, making the selection of a superior rice variety for the target environment difficult. Finlay and Wilkinson's (1963) regression analysis for estimating the stability of genotype was adopted to compare the performance of the set of rice varieties grown at three sites. It is well noted that the design and methods used in the analysis are limited by the range of rice varieties and environments.

For each variety, a linear regression of an individual rice variety on the mean of all varieties was computed. The mean of all varieties grown in the environment (site) was used to assess environmental performance. This allowed the grading of environments from the lowest yielding to highest yielding. The coefficient of regression (b_i) and the mean yield over all three environments were used to classify the stability of variety.

Regression coefficient (b_i)

Site 1 of the first planting date with highest mean yield of six rice varieties (325.0 gm) was graded as the highest yielding environment, while site 2 of the second planting date with lowest mean yield (189.0 gm) was graded as the lowest yielding environment. The first planting date was nearly the same as that of farmers' traditional practice in the area. The delayed planting in August resulted in a lower rice yield.

The lowest yield was observed with *Manawthukha*. *Manawthukha* was significantly lower than *Shwemanaw*, *Sinthukha*, *Shwepyihtay*, and *Tunthukha*. *Tunthukha* was the highest grain yield, followed by *Sinthukha*, *Shwemanaw*, *Shwepyihtay*, and *Yeanelo*-1 (Table 16). Finlay and Wilkinson (1963) report that a genotype that has a slope of b_i=1.00 is the most stable over the different environments in their trial. A genotype that has a slope significantly greater than 1.00 is specifically adapted to a good environment, while a genotype with a slope less than 1.00 is adapted to a poor environment.

Tunthukha and *Sinthukha* showed similar regression coefficients, b_i=1.56 and b_i=1.61, respectively, and with high mean yields across all environments of 324.6 gm and 260.7 gm, respectively. The two varieties provided relatively high yields as environmental conditions were improving. *Manawthukha* (b_i=0.56), *Yeanelo*-1 (b_i=-0.073), and *Shwepyihtay* (b_i=-0.13) were adapted to poor or unfavorable conditions such as delayed rainwater (late transplanted fields). However, *Shwepyihtay* which has a higher mean yield and is more stable than *Manawthukha*, and provides a better choice under unfavorable conditions. *Shwemanaw* (b_i=2.48), on the other hand, with the highest b_i value, was less stable. It responded well is a favorable environment, but performed poorly in an unfavorable environment (Table 16).

Evaluation of Rice Varieties by Farmers

The fifteen participating farmers evaluated the rice varieties at tillering, reproductive and grain filling, and maturity stages. The result of the varietal evaluation by farmers was that *Manawthukha* was the most preferred variety in all evaluation times. *Shwemanaw* was the second most preferred variety at tillering and reproductive stages, and *Shwepyihtay* was the second most preferred variety at grain filling and maturity stages (Table 17). The farmers evaluated the varieties based on several characteristics, such as tiller production, plant height, panicle length, spikelet per panicle, preference for consumption, reasonable price, and ease of marketing. They observed that *Shwemanaw* produced grain yield even when late season drought occurred, and so they wanted to grow *Shwemanaw* (early duration) to escape late season drought. They reported that they would select *Manawthukha* and *Shwepyihtay* (medium duration) to grow under normal rainfall conditions.

6

CONCLUSION

The lowland rice ecosystem of the dry zone of central Myanmar offers under-rainfed growing conditions. In Thekwe village in Yamethin Township, average annual rainfall is about 900 mm, which is considered to be below optimum for paddy rice production. The rice farmers often encounter dry spells and late season drought, and the year 2012 was hard hit by severe drought when annual rainfall totaled only 290 mm. Farmers manage their rice production with low external inputs, especially with respect to nitrogen (N) application. In the study, about 25% of the farmers were small land holders with an average farm size of 1.8 hectares (ha), 58% were medium farm holders with an average farm size of 2.0 ha, and the rest (17%) were large farm holders with an average farm size of 4.1 ha. All the farmers adopted rice-based diversified farming systems with inclusion of livestock. Green gram (mung bean) and watermelon were two important cash crops grown on upland or upper terraces. A few farmers with access to supplemental water were able to do summer cropping.

Rice farmers practiced both transplanting and direct seeding (wet and dry) and adopted both photoperiod-sensitive rice varieties, such as *Tunthukha*, and modern varieties (photoperiod-insensitive) of rice, notably *Manawthukha*. With relatively low and irregular rainfall and frequent drought incidence, farmers adopted low cost and low external input production systems and selected varieties to fit their rice ecosystems. The main source of N fertilizer came from low amounts of urea and animal manure. Weed control was done manually, and only a small proportion of farmers used chemical pest control. The incidence of destructive pest infestation was not serious, according to the farmers.

The on-farm experiment was carried out in collaboration with Thekwe farmers. Six rice varieties with three planting dates were utilized in three sites, where each site was used for a distinct planting date. A low rate of N fertilizer (at 28.8 N kg/ha) was given equally in three split-applications. Combined analysis of variance showed significant GE interaction, and the stability and adaptability of the rice varieties were further analyzed using Finlay and Wilkinson's (1963) linear regression analysis.

Shwemanaw, *Sinthukha*, and *Tunthukha* performed better in the favorable rainfed rice production area, while *Shwepyihtay* was suitable in the less favorable rainfed rice production area, especially where rainfall was delayed for transplanting.

Fifteen farmers participated in assessing the performance of six rice varieties at different growing periods. The farmers used multiple selection criteria to determine suitable rice varieties and preferred *Manathukha* (high quality, high market demand), *Shwemanaw* (early maturing and low N tolerance), and *Shwepyihtay* (medium maturing).

The on-farm experiment and farmer participatory varietal selection offered an opportunity for the farmers and the researcher to interact and create an effective learning process. The on-site co-learning provided a meaningful platform for strengthening lowland rice farmers' ability to improve their sustainable rice production system, and for the researcher to develop a better context-relevant research agenda.

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Table 1 Climatic Data of Yamethin Township

Month	Rainfall (mm)			Temperature (°C)		Relative Humidity (%)
	10-Year Average (2002–2011)	2012	2013	Minimum 2013	Maximum 2013	
January	5.84	3.05	1.02	13.40	31.70	64
February	2.29	-	-	17.30	36.30	50
March	5.33	-	-	21.40	38.50	46
April	30.23	49.02	-	25.20	40.10	51
May	140.21	19.05	150.88	23.10	35.60	64
June	114.05	70.87	165.10	22.20	34.00	79
July	83.82	52.07	51.05	21.60	33.00	78
August	123.7	96.01	183.90	22.10	31.40	87
September	167.13	-	219.96	20.80	32.20	85
October	170.18	-	150.88	21.10	31.40	86
November	37.08	-	21.08	19.30	31.30	82
December	20.83	-	1.00	14.00	27.80	76
Total	**900.69**	**290.07**	**944.87**			

Source: Agro Metrological Station, Yamethin

Table 2 List of Tested Varieties

No.	Genotype	Days to Maturity	Remarks
1	*Yeanelo*-1	125	low N tolerance (Su Su Win et al., 2011)
2	*Shwemanaw*	110	low N tolerance (Su Su Win et al., 2011)
3	*Sinthukha*	138	bacterial blight resistant
4	*Shwepyihtay*	127	-
5	*Manawthukha*	135	-
6	*Tunthukha*	145	photoperiod-sensitive

Table 3 Physical and Chemical Properties of Soil on Three Sites

Site	pH	Available			Organic Matter (%)	Soil Texture (%)		
		N (mg/kg)	P (mg/kg)	K (mg/kg)		Sand	Silt	Clay
Site 1	6.60	60	1	59	0.19	84.40	7.20	8.40
Site 2	8.29	61	3	78	0.28	79.70	8.20	12.10
Site 3	6.14	61	2	94	1.42	54.60	27.1	18.30

Source: Soil Science Section, Soil Science, Water Utilization and Agricultural Engineering Division, Department of Agricultural Research (Myanmar)

Table 4 Measurement of Characteristics of Rice Plant and Yield

No.	Characteristic	Measurement	Time of Data Collection
1	plant height (cm)	- the height from the ground level to the tip of the highest panicle	physiological maturity
2	productive tillers/hill (No.)	- the total number of grain bearing tillers/hill	physiological maturity
3	panicle length (cm)	- the length from basal node of main axis to highest tip of the main panicle	physiological maturity
4	total spikelet/panicle (No.)	- counts of total number of spikelet (including filled and unfilled grains/panicle)	physiological maturity
5	filled grains/panicle (No.)	- counts of well-developed or filled grains/panicle	physiological maturity
6	thousand-grain weight (gm)	- weight of the random sample of 1,000 filled grains	adjusted at 14% moisture content of grain
7	grain yield (gm)	- grain yield was obtained from $1m^2$	adjusted at 14% moisture content of grain

Table 5 Land Use Patterns in Yamethin Township

No.	Description	Area (ha)	%
1	**Net Sown Area**	**74,981.79**	**44.24**
	lowland (*Le* land)	32,490.89	43.33
	upland (*Yar* land)	41,952.25	55.95
	garden land	244.84	0.33
	taungya land	293.81	0.39
2	**fallow land**	**1,313.64**	**0.78**
3	**uncultivable Land**	**54,440.00**	**32.12**
4	**virgin land**	**38,764.87**	**22.87**
	Total	**169,500.30**	**100**

Source: Settlement and Land Records Department, Yamethin

Table 6 Types of Farming Households, Their Numbers, and Size of Land Holdings

Household Group	No.	Average Farm Size (ha)	Minimum Farm Size (ha)	Maximum Farm Size (ha)
small farm households	10	1.80	1.21	2.02
medium farm households	23	2.01	2.23	4.04
large farm households	7	4.07	4.45	8.09

Source: Field survey

Table 7 Land Allocation (Farming Land) for Different Cropping Patterns for the Three Groups of Farmers in Thekwe Village, Yamethin Township

	Smallholder Farmers (land less than 2 ha)	**Medium Farmers (land 2-4 ha)**	**Large Farmers (land more than 4 ha)**
Rainy Season Crops		**% Land Area**	
rice	photoperiod-sensitive, modern variety (135 days to maturity)	photoperiod-sensitive, modern variety (135 days to maturity)	photoperiod-sensitive, modern varieties (125 and 135 days to maturity)
green gram (mung bean)	84	65	59
cotton	11	20	20
chili	5	5	16
sesame	-	8	4
groundnut	-	2	1
Horticultural Crops		**% Land Area**	
watermelon	89	87	96
long bean	11	13	4
Post-Monsoon and Summer Crops	eggplant, onion, watermelon	tomato, onion	eggplant, onion
all farmer groups raise cattle			

Source: Field survey

Table 8 History of Rice Varieties Used by Thekwe Farmers

No.	Variety	Origin	Farmers' Access to Seed
1	*Manawthukha*	released from Central Agricultural Research Institute, Yezin, Myanmar in 1978	farmer to farmer
2	*Tunthukha*	unknown, farmer selected	farmer to farmer
3	*Yeanelo*-1	released from Department of Agricultural Research, Yezin, Myanmar in 2007	Department of Agricultural Research
4	*Shwepyihtay*	released from Department of Agricultural Research, Yezin, Myanmar in 2007	farmer to farmer

Table 9 Seed Rate and Fertilizer Dosage Applied on Transplanted Field (n=40)

No.	Item	Average	Mode	Minimum	Maximum
1	seed rate	89.70 kg/ha	77.32 kg/ha	51.55 kg/ha	154.64 kg/ha
2	urea fertilizer	24.22 N kg/ha	28.84 N kg/ha	0.0 N kg/ha	66.47 N kg/ha
3	cow dung	4.87 ton/ha	4.25 ton/ha	0.0 ton/ha	10.63 ton/ha

Table 10 Farmers' Weed Control Practices in Rice Production

No.	Item	Percentage (based on *n*=40 farmers)
1	by hand	64%
2	harrow	8%
3	both by hand and harrow	14%
4	without control	14%

Table 11 Farmers' Pest Control Practices in Rice Production

No.	Item	Percentage (based on *n*=40 farmers)
1	without incidence	65%
2	incidence	35%
	- insecticide	10%
	- manual	2.5%
	- without control	22.5%

Table 12 Mean Performance (Yield and Agronomic Traits) of the Six Rice Varieties Grown on Site #1

Variety	Plant Height (cm)	Productive Tiller (No.)	Panicle Length (cm)	Fertility (%)	1,000 Seed Weight (gm)	Grain Yield/m^2 (gm)
Yeanelo-1	84.50	6.35	19.85	81.91	21.10	226.03
Shwemanaw	76.50	12.33	21.00	91.88	16.00	456.00
Sinthukha	85.86	10.50	20.17	83.55	20.00	378.05
Shwepyihtay	83.25	10.70	19.88	76.66	20.00	221.35
Manawthukha	82.76	9.70	18.73	72.52	20.00	231.82
Tunthukha	110.80	8.90	21.07	92.71	23.80	437.60
mean	87.28	9.74	20.12	83.20	20.15	325.14
CV%	4.75	8.50	5.20	1.90	3.40	19.80
LSD (0.05)	12.21	2.12	2.71	4.17	1.76	82.15
Pr>F	0.0087	0.0098	0.3779	0.0007	0.0021	0.0025

Table 13 Mean Performance (Yield and Agronomic Traits) of the Six Rice Varieties Grown on Site #2

Variety	Plant Height (cm)	Panicle Length (cm)	Fertility (%)	1,000 Seed Weight (gm)	Grain Yield/m^2 (gm)
Yeanelo-1	85.13	21.66	73.66	22.95	248.15
Shwemanaw	75.64	18.95	94.35	16.55	134.90
Sinthukha	72.82	18.98	76.08	19.25	155.90
Shwepyihtay	72.30	19.63	80.10	19.95	227.60
Manawthukha	65.21	18.91	78.17	17.10	146.55
Tunthukha	111.50	20.00	90.83	21.65	220.85
mean	80.43	19.69	82.20	19.58	188.99
CV%	3.50	4.70	5.60	6.50	18.40
LSD (0.05)	7.25	2.35	11.74	3.28	89.10
Pr>F	0.0004	0.1507	0.0295	0.0232	0.0803

Table 14 Mean Performance (Yield and Agronomic Traits) of the Six Rice Varieties Grown on Site #3

Variety	Plant height (cm)	Productive Tiller (No.)	Panicle Length (cm)	Fertility (%)	1,000 Seed Weight (gm)	Grain Yield/m^2 (gm)
Yeanelo-1	85.51	8.50	22.27	80.20	21.90	180.15
Shwemanaw	76.82	9.90	20.14	85.33	15.60	165.90
Sinthukha	74.50	8.40	20.45	82.72	19.95	248.10
Shwepyihtay	80.27	9.50	20.57	76.69	19.55	284.65
Manawthukha	70.95	9.20	18.87	92.18	18.65	220.35
Tunthukha	102.38	7.50	21.53	85.56	22.95	315.45
mean	81.74	8.83	20.64	83.78	19.77	235.77
CV%	5.30	13.40	3.60	2.20	2.60	15.90
LSD (0.05)	11.12	3.04	1.90	4.66	1.30	96.57
Pr>F	0.0076	0.4674	0.0514	0.0049	0.0007	0.0553

Table 15 Combined Analysis of Grain Yield Variance for the Six Rice Varieties Tested on Three Sites in Thekwe Village

Source of Variation	d.f	S.S	S.S %	Mean Square
genotype	5	55648.34	22.27	11129.67*
environment	2	114814.12	45.94	57407.06*
genotype x environment	10	59165.79	23.67	5916.58*
rep within sites	3	2098.11	0.84	699.37
pooled error	15	18198.08	7.28	1213.21
Total	**35**	**249924.44**	-	-

* = highly significant difference

Table 16 Mean Yield (g/m^2) and Regression Coefficient (b_i) Estimate of the Six Varieties Tested on Three Sites in Thekwe Village

No.	Variety	Site 1	Site 2	Site 3	Mean	Regression Coefficient (b_i)
1	*Yeanelo*-1	226.03	248.15	180.15	218.11	- 0.07
2	*Shwemanaw*	456.00	134.90	165.90	252.27	2.48
3	*Sinthukha*	378.05	155.90	248.10	260.68	1.61
4	*Shwepyihtay*	221.35	227.60	284.65	244.53	-0.13
5	*Manawthukha*	231.82	146.55	220.35	199.57	0.56
6	*Tunthukha*	437.60	220.85	315.45	324.63	1.56
	mean	325.14	188.99	235.77	249.97	-
	CV%	19.80	18.40	15.90	13.93	-
	LSD (0.05)	82.15	89.10	96.57	42.85	-
	Pr>F	0.002	0.080	0.055	0.002	-

Table 17 Farmers' Preference Scores for the Six Rice Varieties

No.	Variety	Farmer Participant		Preference Score (tillering)	Farmer Participant		Preference Score (reproductive)	Farmer Participant		Preference Score (GFM* stage)
		+ vote	-vote		+ vote	-vote		+ vote	-vote	
1	*Yeanelo*-1	-	8	-0.13	6	2	0.07	4	5	-0.02
2	*Shwemanaw*	10	2	0.13	9	-	0.15	1	9	-0.13
3	*Sinthukha*	4	5	-0.02	-	14	-0.23	-	6	-0.10
4	*Shwepyihtay*	-	12	-0.20	4	-	0.07	8	1	0.12
5	*Manawthukha*	10	1	0.15	11	1	0.17	14	-	0.23
6	*Tunthukha*	6	2	0.07	-	13	-0.22	3	9	-0.10

* GFM = grain filling and maturation

Figure 1 Location of Thekwe Village, Yamethin Township

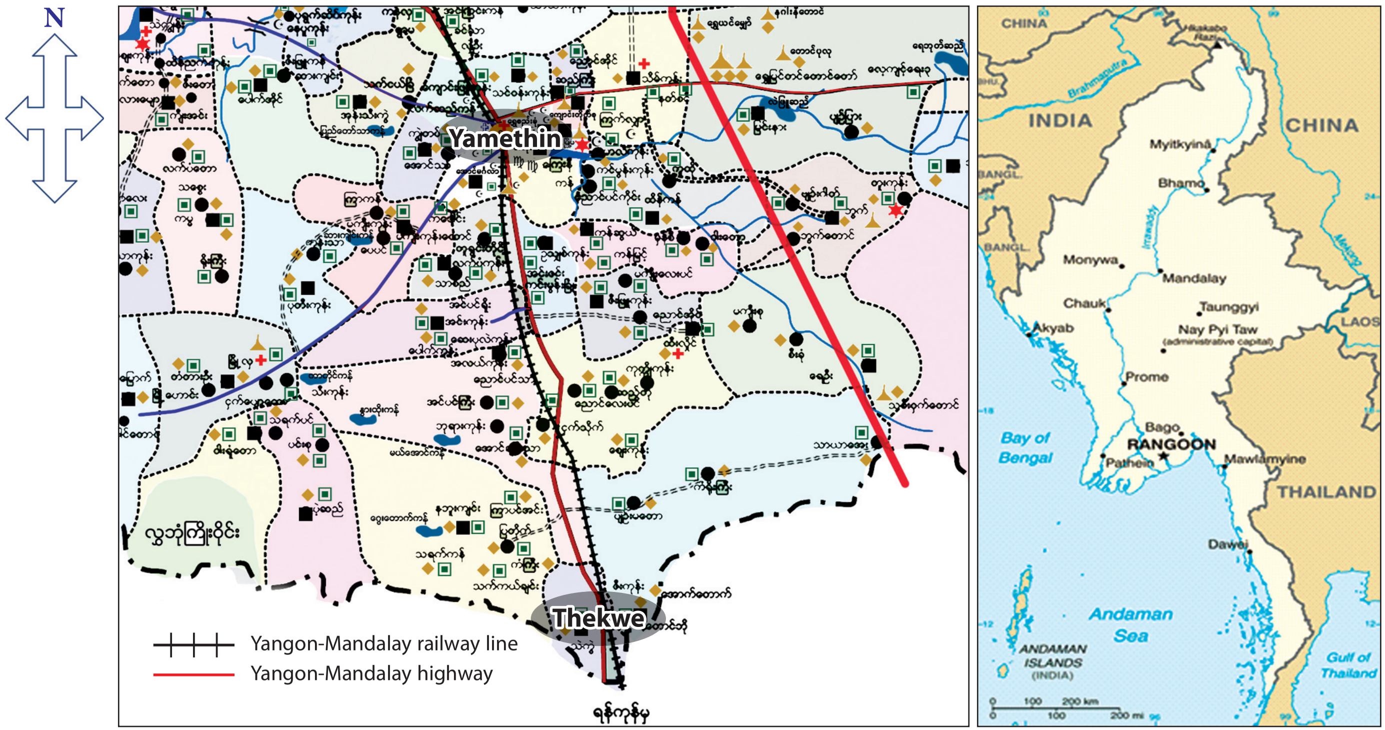
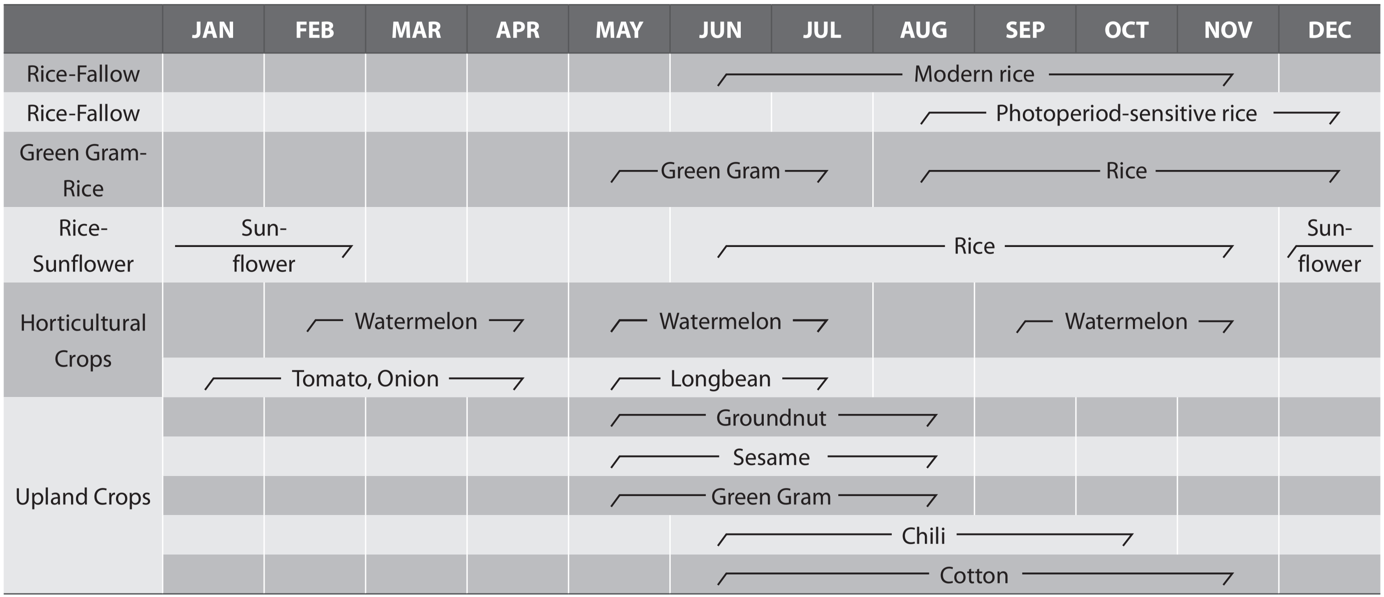


Figure 2 Cropping Pattern of Thekwe Village, Yamethin Township



Appendix Structured Questionnaire to Investigate Socio-economic and Cultivation Practices of Rainfed Lowland Rice Farmers

I. General profile of the respondent

Name of respondent ....
Village ....
Township/District ....
Household information ....

No.	Name	Age	Sex	Education	Remark

II. Farm characteristics

Total Acres	Own (ac)		Rent (ac)		Water Source			Soil Type	Remark
	Lowland	upland	Lowland	Upland	Rain	Dam	Pond		

III. Cropping pattern

.... x .... x ....

IV. Crop calendar

Jan	Feb	Mar	April	May	June	July	Aug	Sep	Oct	Nov	Dec

IV. Rice cultivation

Variety		Method of Sowing					Remark
Name	Age (days)	Transplanted rice			Direct seeded rice		
		Seeding time	Transplanted time	Seed rate/ac	Sowing time	Seed rate/ac	
Land preparation							
- ploughing							
- harrowing							
- levelling							
- Do you plough your field after previous crops was harvested?							
- Why did or didn't you plough?							
Weed infection				Yes/No			
Did you control weed				Yes/No			
Weed control method				By hand/Weedicide/Both			
When did you notice serious weed infection in your field?				(..........) days after sowing/transplanting			
Why do you think there was absence or presence of *weed infection and weed control*?							
Pest and Disease							
Did you encounter pest and/or disease damage in your field? At what growth stages?							
How did you control pest and disease? Please describe.				Picking up infected parts/Pesticide/Both/Other			

	Manure	Inorganic fertilizer
Did you apply?		
Why did or didn't you apply?		
Kind		
Source (own/purchase)		
Manner (method of application)		
Time and rate		
Total amount		

What was the yield of harvested rice? (   )

Major constraints in rice cultivation

Bio-physical constraints
(a) poor soil
(b) drought occurrence
(c) weed
(d) pest and disease
(e) variety

Socio-economic constraints
(a) low investment
(b) labor scarcity
(c) can't get access harvest machine
(d) storage problem
(e) post-harvest

EVALUATING VARIETIES OF RICE ADAPTED TO LOWLAND RAINFED CONDITIONS IN CENTRAL MYANMAR:

A Farmer Participatory Approach

Rice production in the central dry zone of Myanmar faces uncertain rainfall every year. Owing to traditional farming techniques and uneven rainfall—as well as other unexpected circumstances—rice productivity is low, especially in areas with inherent low soil fertility. Rice production—integral to the socio-cultural and economic lives of the people—is thus increasingly becoming ever more challenging. The people of the area are extremely vulnerable and live with constant insecurity. Sustainable systems of rice production systems—if designed and implemented,—could have a great socio-economic impact on the dry zone of Central Myanmar.

This research is a broad effort to help the farmers of Central Myanmar improve their rice production by reducing production costs and maintaining sustainable, stable yield through adverse environmental conditions. It is hoped that this research adds not only to the existing knowledge of rice production in rainfed lowland areas, but also contributes in uplifting the lives of the people associated with it.

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