JIRCAS International Agriculture Series No. 26 ISSN 1341-3899

Unprecedented and sustainable high-yield rice-ratooning with the lowest use of time and resources

SALIBU RICE RATOON CROPPING SYSTEMS

Perennial rice cultivation using low-position ratoons

Kazumi Yamaoka
Erdiman
Khin Mar Htay
Joseph Ofori
Resfa Fitri
Kyaw Myaing
Naing Kyi Win
Kofi Kutame
Gabriel Owusu
Harjito

JIRCAS Japan International Research Center for Agricultural Sciences

JIRCAS International
Agriculture Series No. 26

ISSN 1341-3899

Unprecedented and sustainable high-yield rice-ratooning
with the lowest use of time and resources

SALIBU Rice Ratoon Cropping Systems

Perennial rice cultivation using low-position ratoons

By
Kazumi Yamaoka
Erdiman
Khin Mar Htay
Joseph Ofori
Resfa Fitri
Kyaw Myaing
Naing Kyi Win
Kofi Kutame
Gabriel Owusu
Harjito

JIRCAS Japan International Research Center for Agricultural Sciences

2 days after the second cutting under the treatment of SALIBU rice ratoon cropping systems
Cultivar: Koshihikari Date: 8 Aug 2018 Place: Tsukuba, Japan

Mr. Erdiman

4 days after the second cutting under the treatment of SALIBU rice ratoon cropping systems
Cultivar: Koshihikari Date: 10 Aug 2018 Place: Tsukuba, Japan

Second cutting by engine mower

Foreword

According to the “"State of World Population 2021” report by the United Nations Population Fund, the world population reached 7,875 million in 2021. It increased by 834 million in 10 years from 7,041 million in 2011, equivalent to the total population of 829 million in 50 countries in Europe, including all of Russia. Thirty years from now, in 2050, the population is projected to increase by 1,860 million, comparable to Europe + North America + Latin America populations, to reach 9,735 million.

We need to find the answer as soon as possible to the main human challenge of finding ways to produce the food required for this population. The year 2050 is not the distant future, but the time when small children today will be in their thirties. Cereals are the most critical staple food for human consumption and, in addition, are required in large quantities as feed for livestock production and other processing use. We have increased primary cereal production for decades by increasing inputs, such as land, water, fertilizer, and energy. However, the resources required for maintaining the current level of cereal production, such as land, water, environmental and genetic resources, appear limited. It is necessary to save the various resource inputs per unit production of cereals to realize a sustainable and carbon-neutral society.

Rice is one of the three major grains in the world, with corn and wheat. The SALIBU rice ratooning developed in Sumatra, Indonesia, is a unique rice cultivation method that enables 3–4 times harvesting continuously during a year under a tropical or sub-tropical, winterless climate. Moreover, it is an epoch-making method of cultivation that allows the harvest of good quality rice every time with the same yield level per acre as the main crop cultivated using the conventional way. This cultivation method can remarkably reduce the land resource required per unit yield per year. In addition, there is no need to prepare seedlings, puddle paddy fields, or transplant seedlings. The cultivation period is shortened, and the water resource required for each unit yield per year is saved significantly. Simultaneously, reducing labor and fertilizer input per unit yield may be possible.

It is a technology that realizes sustainable rice production increase while reducing resource input, and its further development may provide a farming method that would save the future world from food shortage. In addition, poor small-scale rice farmers in developing regions can save on seed costs and transplanting labor costs and expect an increase in income, in terms of both opportunity frequency and amount, without additional investment.

Describing the progress and results of research on the technology explained in this book, we aim that the stakeholders will show a renewed interest in the technology and that efforts to expand research and disseminate the technology are strengthened. We hope that the spread of the technology will directly increase the income of poor small-scale rice farmers in developing countries, improve their livelihoods, and promote sustainable rice production, minimizing the input of resources and energy. Our sincere hope is that this can lead to the beginning of another Green Revolution, which can provide an answer to the main challenge of human beings.

We would appreciate your frank opinions and constructive suggestions for further improvement of the promising technology.

Osamu Koyama
President
Japan International Research Center for Agricultural Sciences

Acknowledgment

The Japan International Research Center for Agricultural Sciences (JIRCAS), to which I belong, permitted me to engage in research that covered fields outside my expertise, and thus, I have traveled to Indonesia eight times during my ten years at work. JIRCAS also allowed me to make 20 business trips to Myanmar and 17 business trips to Ghana. These repeated overseas field survey trips led me to gain a deep understanding of actions on SALIBU rice ratoon cropping systems. I am deeply grateful to JIRCAS.

A field survey in Indonesia would not have been feasible without the tremendous cooperation of Mr. Rusman Heliawan, the Deputy Minister of Agriculture of the Republic of Indonesia, and the Agricultural Infrastructure Facilities Division of the Ministry of Agriculture of Indonesia. In the field survey process, I encountered SALIBU for the first time, which paved the way for subsequent research. I express my deep gratitude to the Ministry of Agriculture of Indonesia and all people concerned, including the Water Users' Associations, who cooperated in the field surveys in various parts of the country. In addition, I conducted a joint field survey with, and a National Seminar on "Development of Perennial Tropical Rice (SALIBU) Technology for Sustainable Food Security in Indonesia" was organized by the Faculty of Economics and Management (FEM), Bogor Agricultural University (IPB: Institut Pertanian Bogor). I express my deep gratitude to the people involved, especially Prof. Yusman Syaukat, Dean of FEM.

The Ministry of Agriculture, Livestock, and Irrigation (MOALI) of the Republic of the Union of Myanmar signed a joint research agreement with JIRCAS, and a series of collaborative research on SALIBU rice ratoon cropping systems have been conducted at the Department of Agricultural Research (DAR), MOALI in Yezin, Naypyitaw, Myanmar. Many of the results of the joint research are included in this book. I express my deep gratitude to everyone involved. In Myanmar, political instability has continued due to the army coup d'etat that broke out in February 2021. We sincerely hope a peaceful society and life will return as soon as possible.

The Directorate of Agricultural Extension Services (DAES), the Ministry of Food and Agriculture, The Republic of Ghana, and JIRCAS signed a joint research agreement. Several field surveys were conducted in villages located tens of kilometers outside the second-largest city of the country, Kumasi, nearly 6 h drive from the capital of the country, Accra, and in villages in the Kpong irrigation scheme area in the eastern part of the country with the cooperation of DAES. I also received a great deal of cooperation from the local officers and extension workers of DAES. Specifically, I express my sincere appreciation for Eugene Oduro, Agricultural Extension Agent in the Ahafo Ano South-East district, and his invaluable efforts in organizing and energizing the farmers' groups for the project. Furthermore, the cooperation of Yoshiken Travel and Tours, a

Japanese company located in Ghana, and the Ohayo Ghana Foundation, a related organization, provided great encouragement. We take the opportunity to express our deep gratitude to everyone involved in Ghana.

Finally, I thank my family, especially my wife Masami, for her devoted support.

Kazumi Yamaoka

Table of contents

Introduction — SALIBU rice ratoon cropping systems defeat the common knowledge of conventional ratooning

Our mission for ensuring to feed the future world population sustainably

Target 2.1 of Sustainable Development Goals seeks to end hunger and ensure access by all people, particularly the poor and people in vulnerable situations, including infants, to safe, nutritious, and sufficient food throughout the year by 2030. To achieve this target, we must concentrate our efforts on Sub-Saharan Africa and South Asia, where the target of eradicating hunger in the Millennium Development Goals remains unattained. The report "How to Feed the World in 2050," released by the Food and Agriculture Organization (FAO) in 2009, stated that by 2050 the population of the world will reach 9.1 billion, 34 percent higher than today and food production, excluding food used for biofuels, will have to increase by 70 percent due to accelerated urbanization and higher income level of people. The organization also expects that globally 90 percent, or 80 percent in developing countries, of the growth in crop production is expected to come from intensification, such as higher yields per acre and increased cropping intensity, implying that in developing countries, only 20 percent of the growth in crop production will come from the expansion of arable land. However, the growth rate in yields of major cereal crops in the world has been steadily declining, dropping from 3.2 percent per year in 1960 to 1.5 percent in 2000.

In contrast, the agricultural production and distribution of food have been primary contributors to greenhouse gas emissions. The enormous increase in the use of nitrogen fertilizers to produce crops like corn, which happened hand in hand with the Green Revolution since the 1940s, has dramatically increased nitrous oxide emissions, a powerful greenhouse gas. The gasoline and diesel fuel consumed by tractors and trucks is also an enormous source of carbon dioxide emissions. Additionally, resources such as land, water, fossil oil, and minerals available worldwide are limited. We need a considerable increase in food production in the future, but simultaneously, we need to reduce using various resources related to food production, in terms of reducing both carbon emissions and the use of limited natural resources.

The challenge for technology is to reverse the decline of the rate of growth in yields of the major cereal crops at a global level. In addition, we need to feed the massive world population in the future, saving resources and deploying sustainable agricultural technologies.

Role of rice in the world

Rice is one of the three major crops in the world and a staple food for people worldwide, cultivated in general as a monocarpic annual plant on over 164 million ha in over 110 countries in 2020. Global annual rice production exceeds 756 and 504 million tons for paddy and milled rice, respectively (FAOSTAT, 2022), and 3.5 billion people consume rice worldwide. The importance of rice in Asia, which comprises nearly 60% of the global population, cannot be understated, and recent increases in rice consumption in Africa are also noteworthy. The consumption of rice in Sub-Saharan Africa, where the population is growing faster than anywhere else, was estimated to increase from 19.8 million tons in 2010 to 34 million tons in 2020. Rice has year on year replaced existing coarse grains, such as sorghum and millet, and starchy root vegetables, such as taro, cocoyam, and cassava, as a primary source of dietary calories (Africa Rice Center, 2011; Mustapha, 2004). In developed countries, as consumption of edible cereals is declining due to people favoring vegetables and meats, rice is a delicious and healthy food component. Further, technological progress, such as whole crop silage, makes super high-yield rice, such as hybrid rice, more feasible feed for livestock.

The consumption or domestic supply of rice in Sub-Saharan Africa recorded a radical increase of 9.8 million tons from 2003–2013, while its domestic production did by 6.8 million tons. Many countries in the region are boosting domestic rice production as one of the major national economic issues because they are forced to spend precious foreign currency wastefully importing bulk rice from Asian countries to fill the rapidly increasing gap between domestic production and consumption. Increased rice production is incredibly desirable in the future, and rice is believed to be a promising food crop for feeding the next generation.

However, rice plants thrive in a warm and humid climate, and high-yield varieties are cultivated where paddy fields are flooded and, therefore, these often need abundant irrigation water. Considering limited global water resources and more regions where future climate change may make water increasingly scarce, the need to use water more efficiently for rice production grows. Rice production technology that dramatically improves water productivity is critical and may pave the way for another Green Revolution to feed future global citizens, provided its applicability to various rice production areas worldwide.

Another mission: ending hunger and eradicating poverty in developing regions

Most rice production in Asia and Sub-Saharan Africa depends on innumerable small-scale rice farmers, for whom rice is a critical source of nutrients and income. However, it is difficult for such farmers, who lack investment capacity, to increase cultivated area, and unrealistic for them to target large-scale rice farming. Despite increasing their yield per acre roughly by 20 or 30% within a limited cultivation area, they cannot expect a substantial increase in their income.

Note that hunger can persist amid adequate aggregate supplies because of lacking stable income opportunities for the poor and the absence of sufficient social safety nets.

Half a century ago, the "Green Revolution" dramatically increased grain production by developing high-yielding varieties. However, the biggest beneficiaries were consumers who could buy foods at lower costs compared to the pre-revolution era due to increased production and large-scale farmers in developed countries who could actively introduce high-yielding varieties into farm management. The answer to the question of whether the "Green Revolution" has enriched small-scale poor farmers in developing countries lies in the fact that still 736 million poor people in 2015 and 690 million malnourished people in 2019 are left behind worldwide. We assume that most are small-scale poor farmers in developing countries worldwide.

According to the formula, "Green Revolution = water availability (irrigation development) × introduction of high-yielding varieties × fertilizer input," we have undoubtfully realized and achieved an increase in yield per unit area, which can be explained by Figure 0-1. One can see that the high-yielding varieties, under plenty of available water and enough fertilization, make maximum use of their abilities to increase grain yield. The yield of high-yielding varieties far exceeds that of conventional types under such conditions. However, if the water available is limited, the outputs of high-yielding rice varieties are reduced significantly, and below a certain amount of irrigation water, the yields of both rice varieties are reversed. The high-yielding rice varieties are fragile and susceptible to mortality under water scarcity conditions. Therefore, introducing high-yielding rice varieties is risky unless provided with a stable supply of sufficient water.

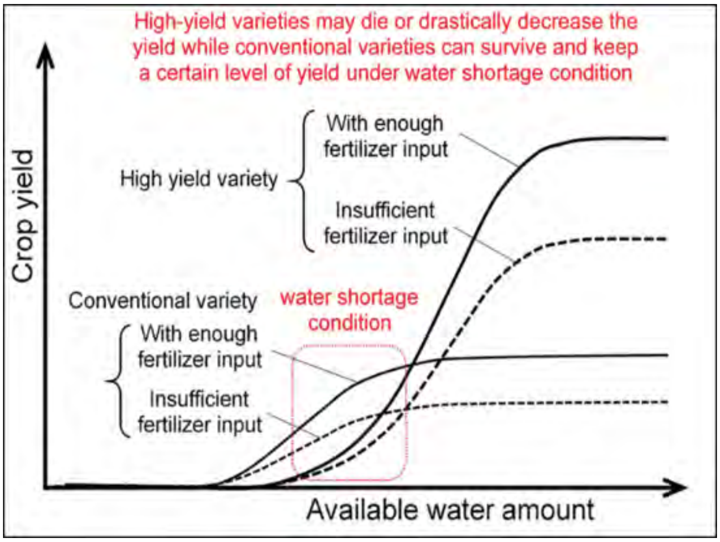


Fig. 0-1. Crop yield response of rice to available water (conceptual diagram in case of rice)

As seen from Figure 0-1, if high-yielding varieties are planted in areas where irrigation facilities are not in place, the yield will drop significantly under water shortages. For poor rice farmers, failed investments in seeds and fertilizers imply their families will face starvation which is extremely risky. Therefore, particularly in Sub-Saharan Africa, the increase in rice production has relied on expanding the production area of conventional rice in rain-fed paddy fields, of which the yield per unit area is low.

Many poor farmers in developing countries such as the Sub-Saharan Africa region are still overly fearful of the introduction of new varieties and new farming methods that claim to increase yield and associated investments. If the cash income of a farmer dependent on rice harvesting only twice a year accounts for most of the annual income, unlike people paid a monthly salary, making a bold investment becomes difficult. Under these circumstances, when one invests a portion of their income, they cannot afford to fail. Researchers want to devote themselves to developing technologies that increase yields per unit area. However, local small farmers want to increase sales by 30% without handling risks, not by introducing a new high-yield variety aiming for a 30% increase in yield per unit area but by increasing the planted area of existing rice varieties by 30%. It is a life-span dream for them to get a second-hand cultivator and increase the planted area by 50% or so.

We need to tackle the multifaceted challenges such as developing technology to increase yields, saving both carbon emissions and the use of resources, and directly increasing the income of smallholder farmers, effectively ending hunger and securing their investments.

Solving the two missions and many problems at once — SALIBU rice ratoon cropping systems

When we can cultivate rice as a perennial plant that can be harvested many times a year once planted under limited water resources, and when the yield is maintained at a high level each time, the multifaceted challenges are solved at once. A farming method that requires only once to puddle the paddy fields and transplant the seedlings from the nursery and allows repeated harvesting after field management annually increases the land utilization rate and saves irrigation water resources. It will increase farmers' incomes directly and possibly reduce carbon emissions per unit yield. It ends hunger and eradicates poverty in rice-growing areas, increases rice supply to urban areas where its consumption is rising rapidly, and reduces rice imports in sub-Saharan African countries, contributing to their national finance. Simultaneously, rice may supply livestock feed and play such a role as a prominent grain that feeds the world population in the future.

Such a dream-like rice cultivation method is becoming a reality with the farming method developed in Sumatra in Indonesia, i.e., the SALIBU regenerated rice cultivation method. The epoch-making rice ratooning method is a new technology developed by Mr. Erdiman, a researcher who worked at the branch office of the local agricultural technology evaluation test site with the desire to help farmers. It was named SALIBU rice ratoon cropping system using the term SALIBU, originally a word coined by combining the Indonesian words "SALIN," meaning "reproduction," and "IBU," meaning "mother," and local farmers used to call rice ratoon SALIBU. However, no one has taken the new technology straight into research, and is unknown outside

Indonesia. Therefore, the author consulted with him and started the activity in 2016 to study the technology in Myanmar and make it known to the world.

Double cropping is standard practice for rice cultivation in the tropics, but each cropping requires sowing, puddling, transplanting, irrigation, fertilization, and harvesting activities. The SALIBU rice ratoon cropping system requires sowing, puddling, and transplanting for the first crop, but after that, sowing, puddling, and transplanting can be skipped, and the number of days from germination until harvest can be shortened by 10–30 d compared to a fresh start from sowing. It is possible to harvest nearly seven times in two years with the same yield levels as the first rice harvest by repeating irrigation with half the amount of water and fertilizers. Compared to the case of standard double cropping, the annual yield of SALIBU rice ratooning is nearly doubled because double cropping is harvested four times in two years. (See **Figure 0-2**)

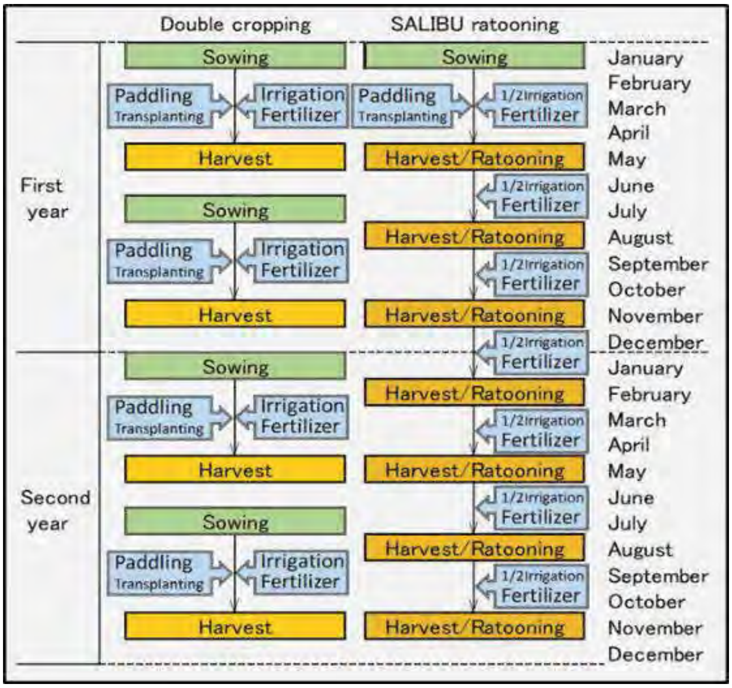


Fig. 0-2. Crop calendar for double cropping and SALIBU

Erdiman's Challenge

Conventionally, rice-ratoon cultivation can be labor-saving, but the yield is overly low, approximately 20–50% of that of rice grown from transplanted seedlings and, thus, after the harvesting of ratoon, farmers return to traditional cultivation systems of sowing and transplanting. In the village of *Matur*, located at an elevation of 1100 m near *Bukittinggi*, West Sumatra in Indonesia, farmers have been cultivating rice-ratoon for a long time, but the yield was still low, and only for one generation. Despite being just below the equator, the altitude is high, and the climate is cold, due to which farmers cultivated cold-tolerant rice varieties called *Kurik Kusuik* and *Lumut Kurik Kusuik*, late ripening varieties that need 145 d from sowing to harvesting. They grew and harvested additional rice ratoon in a few paddy fields to disperse the risk if the regular crops failed.

Rice-ratoon cultivation is not standard practice because the conventional ratoon farming method has two primary drawbacks. One is that the number of panicles and grains that grows on one panicle is small, and the yield per unit area is overly low. The other is that there is a difference in the growth rate of ratoons growing in one stubble or ratoons between stubbles, and the timings of heading and optimum harvest are different. Therefore, if one harvests all at once, a lot of immature and overripe grains are mixed, necessitating the selection of appropriately ripe panicles and harvesting them separately 2–3 times. It significantly reduced the efficiency of the work and was unpopular with farmers.

Researcher Erdiman, who visited the village of *Matur* in 2007, his wife's hometown, was asked by farmers to improve the shortcomings of rice-ratoon cultivation. The researcher spent two years observing the cultivation and growth of rice-ratoon. After the observation, the researcher came up with the idea that stems should be trimmed to the limit of the ground surface after harvesting, keeping the soil moist without flooding for a certain period. The cutting height is shorter than that of the mainstream practice at the time in which farmers cut stems at 15–20 cm above the ground surface. After that, cultivation tests were continued, improvements were repeated, and when the author first visited the site in *Pariangan* village, located 500–600 m above sea level, in *Tanah Datar,* West Sumatra, in 2014, the procedure of SALIBU rice ratoon cropping cultivation was almost established.

Outline and purpose of this book

This book aims to introduce the SALIBU rice ratoon cropping system, invented by Mr. Erdiman, to the world. The primary readers of this book are expected to be agricultural extension workers advising rice cultivation to farmers, researchers investigating rice cultivation, particularly regenerated rice cultivation methods, and paddy field irrigation engineers working to develop water-saving irrigation technology. In addition, ways have been devised, such as describing the author's story of encountering the SALIBU rice ratoon cropping system on Sumatra Island to generate interest among general readers. Part 1 is set as a valuable technical guidebook for those who want to practice the SALIBU rice ratoon cropping system, and Part 2 presents the results of research on the SALIBU rice ratoon cropping system from various aspects in Myanmar, Indonesia, and Ghana as a document collection for rice researchers and paddy field irrigation engineers.

Part 1 of the book deals with the technological introduction to SALIBU rice ratoon cropping systems. Chapter 1 of Part 1 looks back on the research and development of rice ratoon cropping technology as challenged by many researchers for more than half a century, followed by a description of the differences between traditional ratoon and SALIBU rice ratoon cropping systems. The differences in common knowledge shared between established conventional ratooning, i.e., basal shoot cultivation, research and the new idea of SALIBU rice ratoon cropping systems are summarized in the form of a list, enabling one to compare and understand the differences specifically in the table.

Next, Chapter 2 describes the author's encounter with the SALIBU rice ratoon cropping system and its inventor, Mr. Erdiman, on the island of Sumatra, Indonesia, and the launch of the research project on this cultivation method. The chapter describes the process leading to the initiation of research on SALIBU in Myanmar, focusing on the report on the first visit to the site of SALIBU rice ratoon cropping in Sumatra, Indonesia, during a business trip in 2014.

Chapter 3, the last chapter of Part 1, explains how Mr. Erdiman, who was begged by farmers in a village on the island of Sumatra, Indonesia, to find ways to improve the rice ratoon cropping, approached the improvements in the cropping and solved the problem. In this chapter, the basic concept of "a rice ratoon cropping system that raises the yield equivalent to that of the main crop," which he arrived at, is described in the form of "key technology" and "other indispensable technology." Furthermore, it represents the local situation understood through a joint field survey in Sumatra in 2016 with the Department of Agricultural Research (DAR), Ministry of Agriculture, Livestock, and Irrigation in Myanmar, and Faculty of Economy and Management, Bogor Agricultural University in Indonesia.

Part 2 introduces studies on the SALIBU rice ratoon cropping systems in three countries. Chapters 4–7 describe a series of studies in Myanmar, Chapter 8 notes a study in Indonesia, focusing on economic analysis of the SALIBU rice ratoon cropping systems, and Chapters 9–11 describe studies conducted in Ghana to apply the SALIBU rice ratoon cropping systems in the sub-Saharan region of the African continent.

Studies on the SALIBU rice ratooning were conducted jointly with DAR of the Ministry of Agriculture, Livestock, and Irrigation in Myanmar. Step-by-step research and development involved cultivation tests in large open-air pots, water productivity comparison using field tests, tests to compare ways of cutting stems at harvests, comparative field tests of 33 rice varieties, the introduction of combine harvester into field trials for 11 rice varieties, and a supplementary cultivation test in the fields of farmers. Chapter 8 illustrates research on profitability and labor productivity improvement using SALIBU rice ratooning conducted in Indonesia. Chapters 9–11 present a series of studies on the SALIBU rice ratooning and related research conducted in Ghana, West Africa, in collaboration with the University of Ghana and the Directorate for Agricultural Extension Services, Ministry of Food and Agriculture, Ghana. First, we present a comparative analysis of water productivity using cultivation tests in a test field at the University of Ghana, then cultivation tests used by farmers in rain-fed paddy fields, and field research and policy recommendations on setting up a rice farmers organization.

While sharing these experiences, this book aims to explore the possibilities of SALIBU rice ratoon cropping systems from diverse angles.

PART ONE: Technological introduction on the SALIBU rice ratoon cropping systems

Chapter 1: Review of studies on rice ratooning

Rice is cultivated as a monocarpic annual plant in traditional agricultural systems. In reality, it can survive as a perennial plant in the tropics and continue producing grains of ratoon crops for generations. The *japonica* and *javanica* subspecies of *Oryza sativa* rice species have more robust characteristics as perennial plants than its *indica* subspecies and the subspecies of the African variety *Oryza glaberrima* (Sakagami et al., 1999a and 1999b). In this book, though the tests in Myanmar, Indonesia and Ghana used local cultivars considering practicality, SALIBU ratoon cropping systems showed satisfactory performance.

Ratooning is a method of harvesting crops growing from stubble, leaving the roots and bottom of the plant. For a few crops, such as sugar cane, bananas, and sorghum, ratooning is considered an established agricultural method with reasonable yields. However, rice ratooning generally yields only 20–50% of the main crop, the previous generation plant grown from seed in the usual cultivation method. Thus, it is considered merely an auxiliary cropping system (Krishnamurthy, 1988).

There are so many arguments on the rice ratooning cropping system, but no article affirmed that the yield of the rice ratoon crop could be stably equivalent to or more than that of the main crop. The lower yield of rice ratoon crops has been common knowledge and brought researchers to assume that perennial rice cultivation may be useless to attempt. Therefore, the rice ratoon crop has always been treated as a one-generation supplementary crop with no successors. Existing knowledge and assumption also have made researchers ignore the study on saving irrigation water in rice ratoon cropping systems. Nonetheless, farmers may reduce their use of irrigation water compared to usual cropping methods because ratooning makes the cultivation period shorter and omissible water use for seedling nursery, puddling, and transplanting.

Rice ratooning has been researched since the 1950s and analyzed for characteristics, including the morphology, physiology, ratoon-development speed, varietal potentiality, tiller-making capacity, growth duration, plant height, land preparation and spacing of crop, harvest timing, cutting height, fertilizer and water management, temperature, and light intensity. In 1986, the International Rice Research Institute (IRRI), Philippines, alongside abundant knowledge accumulated to date, started work to systematically synthesize research outputs with 26 researchers working in the field worldwide and compiled the text "Rice Ratooning" in 1988 as a cornerstone for all subsequent research in this field. Since then, many further studies have been conducted by researchers worldwide to date, but generally concluded that the grain yield of rice ratooning, i.e., ratoon crop, was within the range of 20–50% of that of the main crop (Krishnamurthy, 1988). Excerpts from Oad et al. (2002) and comments from the authors of this book follow.

Morphology, physiology and ratoon development earliness

Plant height is usually lower (Balasubramanian et al., 1970), and effective tillers are fewer in ratoon crops compared to main crops (Bahar and De Datta, 1977). It seems to be common sense, however, as is reaffirmed later, where a case of plant height of SALIBU ratoon crop demonstrated 68.2–119.9 cm (first to the sixth generation) and 93.6 cm over an average of six generations of ratoon crops as opposed to 92.7 cm for the main crop. Regarding the number of effective tillers, it demonstrated 16.0–49.4 (first to the sixth generation) and 33.0 over an average of six generations of ratoon crops and 10.0 for the main crop. The stem thickness is correlated with higher carbohydrate content in the stubble, spawning more vigorous regeneration of ratoon tillers and grain yield (Palchamy and Purushothaman, 1988). Cultivars and cultural practices, including cutting height and fertilizer management, which provide abundant harvest reserves, may boost rice ratooning (Ichii, 1984). SALIBU rice ratoon cropping systems also require fertilizer to be applied one week before harvest. High cutting of main crop stubble helps boost total available carbohydrate (TAC) in stubble, and the ratoon growth of rice depends upon the amount of TAC in the stem base, which spawns many tillers (Ichii and Ogaya, 1985). SALIBU rice ratoon cropping systems requiring a two-step cutting system, at 25–40 cm above ground level for harvest and 3–5 cm for the second cutting one week after harvest, may allow a higher TAC in the stubbles. Several studies showed that ratoon tiller development depends upon the carbohydrates that remain in the stubble and root after the main crop is harvested (Cuevas Perez, 1980; Ichii and Sumi, 1983; and Samson, 1980).

Ratoon tiller regeneration and growth depend on the buds remaining on the stubble and existing at various development stages (Nair and Sahadevan, 1961). In the Kagi Ban2 cultivar, C:N ratio was 17.0, 13.88, and 10.80 in tillers from upper nodes, those from the base, and those below the soil, respectively, and tillers from upper nodes with high C:N matured faster like old seedlings and were shorter in culm than those emerging from lower nodes, which behaved like young seedlings (Iso, 1954). SALIBU rice ratoon cropping systems encourage tillers to emerge from the lowest node by the second cutting of stems at a height of 3–5 cm from ground level. Its tillers grow just like conventional transplanted rice.

Varietal potentiality, tillering capacity, and main crop growth duration

Ratooning ability has been shown as a varietal in character (Bahar, 1976, Balasubramanian et al., 1970, Bahar and De Datta, 1977; Haque, 1975; Nadal and

Carangal, 1979). Nadal and Carangal (1979) identified three rice selections without tillering capacities and high ratoon yields under varying soil moisture regimes. A suitable variety selection under SALIBU rice ratoon cropping systems is critical for researchers. However, the authors of this book believe that more important is using cultivars familiar to farmers and have been evaluated by the market to help such technology spread widely, provided the cultivars have the right potential.

Tillering ability is probably the critical genetic factor affecting the ratoon performance of grasses. In ratoon crops, despite fewer effective tillers than the main crop, the actual number of tillers in the ratoon crop may exceed that in the main rice crop (Balasubramanian et al., 1970). However, almost all tillers produced by the SALIBU rice ratoon cropping systems are effective. Many findings suggest that the ratoon crop thrives when the main crop stubble is cut with 2–3 nodes left (Oad et al., 2002). However, tillers regenerated from the node at ground level by cut stubbles without other nodes left are ideal under SALIBU rice ratoon cropping systems.

Main crop growth duration has been reported to influence ratooning ability (Bardhan Roy et al., 1982; Cuevas Perez, 1980), with growth duration strongly correlating with grain yield. Varieties with longer growth duration tended to have a more powerful ratooning ability than varieties with shorter growth duration. However, very early maturing cultivars were recommended for ratoon crops in temperate areas because they do not require early seeding and allow a favorite growth period for the ratoon crop. Zandstra and Samson (1979) observed a significant correlation between ratoon crop yield and duration ($r = 0.71$) and between the crop duration of ratoon and main crops ($r = 0.65$). However, the relatively early-maturing Myanmar variety Thee Htat Yin, with 115 d to maturity under conventional transplanting cultivation, achieved a yield of 6.9–11.5 t/ha from the first to the sixth generation and 9.2 t/ha on average for ratoon crops, whereas it achieved a yield of only 5.3 t/ha in the main crop.

Harvest timing of the main crop and cutting height of the stubble

The best time to harvest the main crop for raising good ratoons is when culms are still green (Parago, 1963), and harvesting before the crop is matured fully helps maximize ratoon yield (Nagai, 1958; Balasubramanian et al., 1970). The optimal cutting height should be 30–40 cm above the ground (Zhand Jing Guo, 1991). SALIBU ratoon cropping systems recommend the timing of harvest of the main crop and ratoon crops to be at the physiological maturity period, one week before expected ordinary harvest, when stems are still greenish and roots still vital for successive rice ratooning.

Numerous arguments have been put forward in favor of the height of cutting stems at harvest. Cutting height determines ratoon tiller origin and the growth duration of the ratoon crop (Sun Xiaohui et al., 1988). The effect of the height of cutting stem on ratoon vigor varied. A few cultivars ratooned from high nodes, whereas others produced basal ratoons unaffected by the height of cutting stem (Volkova and Smetanin, 1971). Bardhan Roy and Mondal (1982) reported that cutting height did not markedly affect ratooning ability, reproductive tillers, and ratoon yields. Andrade et al. (1985) evaluated ten irrigated rice cultivars at cutting heights of 10, 20, and 30 cm. They observed that a cutting height of 30 cm elicited optimal results, including plant height in all cultivars. In Japan, ratoons stand with varied cutting heights, although these did not affect grain yield (Ishikawa, 1964). The effects of the height of cutting stem vary based on reports, but no study refers to a two-step cutting method, i.e., the first cutting at harvest and the next at a shorter height a few days after harvest.

In the Philippines, ground-level cutting has been suggested to prevent the growth of unproductive tillers (Parago, 1963). Heavy rainfall is reported to occur during the wet season in the Philippines, implying that cutting close to ground level may risk a high tiller mortality rate and inadequate ratoon crop stand density (Zandstra and Samson, 1979; Samson, 1980; Chauhan et al., 1985). The risk of stubble perishing due to being submerged under heavy rain immediately after the second cutting is minimized in the case of SALIBU rice ratoon cropping systems. It is achieved not only by cutting stems at 3–5 cm above ground level rather than 0 cm but also by making farmers focus on soil moisture. They will strive to keep soil moisture conditions within field capacity after the second cutting, resulting in a decline in mortality accordingly, as is reaffirmed later.

Water and fertilizer management

Water management before and after the main crop harvest affects ratooning ability (Votong, 1975; Haque, 1975), and the field needs to be moist but not flooded for weeks after the main crop ripening to promote ratooning. In addition, the draining of the crop field several days after harvest encourages ratooning. Irrigation water must be kept shallow in the early ratooning stages, and it is essential to apply irrigation immediately after applying the first fertilizer. The fields are drained during the harvest of the main crop to promote tillering at ground level, generally suggested as a means to encourage ratooning and prevent the death of hills due to flooding (Oad et al., 2002). On the other hand, SALIBU rice ratoon cropping systems require the soil to be kept as moist as possible without standing water on the ground surface for four weeks, between two weeks before and after harvest, which concurs with the findings of earlier studies.

Soil fertility may directly or indirectly affect ratoon crop growth and yields (Plucknett et al., 1978). At IRRI in the Philippines, grain yield soared with increasing N application rate, the optimal level of which was determined at 60 kg/ha (Bahar and De Datta, 1977). Applying N to the main crop postharvest consistently increased ratoon crop yield. In addition to the amount of N applied, the application method in the main crops also affects the ratoon crop (Quddus, 1981; Samson, 1980). Palchamy and Purushothaman (1988) reported that N split application at maximum tillering and panicle initiation increased the ratoon crop grain yield up to 86.6% of the main crop. As mentioned above, the SALIBU rice ratoon cropping systems require fertilizers to be applied one week before harvest, concurring with the findings of earlier studies.

Differences between the traditional ratoon cropping and SALIBU rice ratoon cropping systems

The most important difference between the SALIBU rice ratoon cropping and traditional rice ratoon cropping is whether cropping aims for continuous cultivation between the generations of ratoon crops. For continuous cultivation between ratoon crop generations to be economically satisfactory enough for farmers, the yield of ratoon cultivation must be comparable or at least 70% or more to that of ordinary conventional farming. In traditional rice ratoon cropping, yields are generally less than half that of conventional farming yield, approximately 20–50%. Therefore, it was considered natural to return to the traditional cultivation methods of transplant farming after harvesting once from ratoon.

Attempts to identify the most crucial factor that can help obtain yields comparable to yields in conventional farming methods have been pursued for many years in traditional ratoon cropping, i.e., basal shoot cultivation research, but no clear answer has been obtained.

In rice ratoon crops, young panicle formation generally is considered to start almost one week before the expected harvest of the main crop. More precisely, young panicle formation begins immediately after grains in the panicle of the main crop reach physiological maturity. Generally, the main crop is harvested almost one week after physiological maturity, following the custom of fully ripening the grains as food. However, young panicle formation at the bottom of stems begins immediately after physiological maturity such that the young panicle starts to grow before harvesting, ears emerge almost 30 d after the appearance of the young panicle, and vegetative growth ends.

Thirty days is an overly short period to complete vegetative growth. Thus, it is thought that the number of grains per panicle is lower, and the weight of 1,000 grains is also lower than that of the main crop due to inadequate nutrition, and yield is only 20–50% of that of conventional farming. Therefore, when the main crop reaches the physiological maturity stage almost one week before the expected ordinary harvest, the crop needs to be harvested as soon as possible to dissuade young panicle formation.

The leaves of the main crop continue photosynthesis despite grains reaching the physiological maturity stage and try to deliver carbohydrates to grains through stems. However, grains that have reached the physiological maturity stage have no room to accept nutrients sent to them, such that nutrients stay at the point where these enter the bottom of stems from leaves, also close to where the young panicle is about to form. We assume that this pilling up of nutrients triggers the formation of the young panicle.

The main crop harvest removes leaves from stems accompanying with roots, i.e., stubbles, implying no entry of nutrients to the bottom of the stems from leaves nor the formation of young panicles due to any trigger anymore. Consequently, the ratoon crop plant starts young panicle formation 30–40 d after the main crop harvest, and the ears emerge almost 30 d after the appearance of young panicles. Therefore, vegetative growth lasts for 60–70 d and the ratoon crop plant crop grows large leaves necessary to produce nutrients for adequate grain yield. We believe it is vital for SALIBU rice ratoon cropping systems to regulate the physiological environment as described above.

Table 1-1 summarizes the new idea of SALIBU rice ratoon cropping systems compared with common knowledge shared in established ratooning, i.e., basal shoot cultivation research in the following points.

i) Differences in cultivation management before harvesting the main crop
ii) Differences in growth and yield of the ratoon crop compared to the main crop
iii) Benefits of ratoon cropping against the double cropping of conventional transplant farming method
iv) Disadvantages of ratoon cropping against the double cropping of conventional transplant farming method
v) Challenges for future dissemination

Table 1-1. Common knowledge shared in established ratooning research vs. the SALIBU rice ratoon cropping systems

		Common knowledge shared in conventional ratooning research
Differences in cultivation management at around harvesting the main crop	Fertilization just before harvest	Fertilization is **not normally applied** just before harvesting, but some studies have applied fertilizer.
	Harvest time	**Harvested one week after the physiological maturity period** (when 85 to 90% part of the panicles are yellow-ripened and 10 to 15% of greenish part remains at the panicle, and the average grain water content is about 24 to 25%).
	Pre-harvest water management	**Falling the standing water one week before harvest** to dry the soil sufficiently (to increase soil bearing capacity at harvest).
	Post-harvest water management	It is flooded and the soil is saturated with water (**the soil shifts to a reduced condition**).
Differences in growth and yield of the ratoon crop compared to the main crop	Nutritional growth status	**The heading begins about only 30 days after the harvest of the main crop**, and the plant height is short because it finishes the vegetative growth stage, and the leaf blades are fine and the leaf color is light. Plant shape is clearly different from the main crop.
	Reproductive growth status	The number of tillers of one stubble is smaller than that of the main crop, and **the length of panicle is short (1/2 to 2/3 of the main crop**).
	Yield	**Yield stays at 20-50% of that of the main crop.**
	Continuous generations cultivation	**The growth of basal shoots after the main crop is limited to one generation.**
Benefits of ratoon cropping against the double cropping of conventional transplant farming method	Improving farm income	Double cropping is standard in the tropics. Since the income from the ratoon crop is less than half of the main crop, **the annual income is limited to 0.75 times of that of the double cropping of the conventional transplant farming method**.
	Saving farming costs	The ratoon crops do not require sowing, seedling raising,
	Saving agricultural water	The ratoon crops do not require a large amount of water for water is about half that of the main crop.
	Increased income opportunities	Nothing in particular (twice a year, the same as the conventional transplant farming method).
	Equalization of labor allocation	Nothing in particular (same as conventional transplant farming method).

New idea of SALIBU rice ratoon cropping systems and difference from conventional ratooning
Fertilization equivalent to the basal fertilizer of conventional cultivation is performed **one week before harvesting**.
Harvested at the physiological maturity period (when 75 to 80% part of the panicles are yellow-ripened and 20 to 25% of greenish part remains at the panicle, and the average grain water content is about 28 to 29%).
After falling the standing water 2 weeks before harvesting, observe the soil surface every other day, and if it is dry, **irrigate it to the extent that the water will be absorbed into the soil and not flooded.**
For 2 weeks after harvesting, perform the same water management as before harvesting and do not flood (**keep the soil at the root of the plant in an oxidized condition** and promote germination of regenerated ratoon crops).
After the harvest of the main crop, it continues to grow vegetatively for a sufficient period of time, and about 60 days after the harvest, it heads and shifts to reproductive growth. The plant height, leaf blade, and leaf color are almost same as that of the main crop, and the plant shape is similar to the main crop.
The number of tillers of one stubble is slightly larger than that of the main crop, and depending on the stubble, it reaches doubled. **The panicle length and the number of spicklets of one panicle is almost the same as that of the main crop**.
Depending on the growing environment, it sometimes may be around 50-70% of that of the main crop, but it can exceed 100%, and **the average yield of SALIBU ratoon crop is often expected around 90-110% of the main crop.**
Repeatedly growing basal shoots after harvesting them (**continuous cultivation for several generations**).
In the tropics, 3-4 crops are possible annually, and the yield of SALIBU ratoon crop will be almost same as that of the main crop, so **the annual income will be 1.5-2 times more than that of the double cropping of the conventional transplant farming method**.
puddling, and rice planting, and these costs (material costs, labor costs) can be reduced.
puddling and transplanting, and the cultivation period is shortened, so the required agricultural
Income opportunities increase to 3-4 times a year. Furthermore, if the transplanting time of the main crop is staggered by one month and cultivated in three plots, **the income opportunity will increase to about 12 times a year**.
As a result of the above, **the annual input labor allocation can be leveled** and the planting scale can be expanded.

		Common knowledge shared in conventional ratooning research
Disadvantages of ratoon cropping against the double cropping of conventional transplant farming method	Increased water management efforts	Nothing in particular (same as conventional transplant farming method).
	Increased harvesting efforts	Nothing in particular (same as the conventional transplant farming method, but the harvest is by manual).
	Stubble leveling work	Nothing in particular (it grows as it is even if there are missing hills).
	Weed control	Nothing in particular (same as conventional transplant farming method).
Challenges for future dissemination	Securing farmers' income	Since the income of the double cropping of the conventional transplant farming method is more than the combination of the main crop and the ratoon crop, **the introduction of ratoon cropping is limited to the areas where the single cropping is common or the areas where risk diversification is required**.
	Securing irrigation water	Nothing in particular (same as conventional transplant farming method).
	Labor saving in harvesting	Nothing in particular (same as conventional transplant farming method).
	Mitigation of damage from birds and rats	Since the harvest time is dispersed in each field, it is necessary
	Others	Selection of highly adaptable varieties with resistance to pests,

New idea of SALIBU rice ratoon cropping systems and difference from conventional ratooning
Increased labor due to the above-mentioned water management from 2 weeks before harvest to 2 weeks after harvest.
One week after harvesting by manual, **the labor for the second cutting stems with a mower is needed, however, combine harvester can be introduced** instead of the combination of manual and mower.
Between 3 and 4 weeks after harvest, **transplant part of the bunch of culms with roots from rich-tillering hills to poor-tillering hills** for leveling the size of the hills is recommended.
Weeds tend to grow during the period when the fields are not flooded, which **increases the time and efforts required to control weeds**.
Nothing in particular (There is no economic problem because it leads to a large increase in income).
Requires stable irrigation water throughout the year (although the amount may be small).
Further labor saving can be achieved if the combine harvester can be introduced (According to ongoing cultivation tests, **the yield of a single cut with a combine harvester is comparable to the yield of a double cut with manual and a mower**).
to take measures to reduce damage from birds and rats.
and development of harvesting technology by combine harvester.

Chapter 2: Encounter with SALIBU rice ratoon cropping systems and the launch of a research project

A fateful encounter with the SALIBU ratoon cropping systems and Mr. Erdiman

In January 2014, chance brought the first author of this book to visit rice paddy fields under the SALIBU rice ratoon cropping systems and meet Mr. Erdiman, the inventor of this technology. The visit to the *Tanah Datar* sub-district in West Sumatra province was a part of the author's field survey on WUAs (Water Users' Associations) and their performances because the author was an expert on irrigation engineering and water resources management.

The first author decided to conduct a field survey of WUAs in cooperation with the Agricultural Infrastructure Facilities Division of the Ministry of Agriculture, Indonesia, realized through the support of Dr. Harjito and Mr. Rusman Heliawan. Dr. Harjito is an Indonesian representative whom the first author met at the international conference held in Kampala, Uganda, in November 2011, organized by the Coalition for African Rice Development. Similarly, Mr. Rusman Heliawan, Deputy Minister of Agriculture, Indonesia, became acquainted with the first author at the international workshop co-sponsored by the Government of Indonesia, Organization for Economic Cooperation and Development, and Asian Development Bank, held in Bogor in December 2011.

The author had Dr. Resfa Fitri, one of the department staff members, arrange the survey and guide to the site, and Dr. Harjito was willing to participate in the survey. In 2011, we conducted a field survey of central Java and Lombok Island, and in 2012 we re-investigated these regions. In 2013, we commissioned a survey of western and eastern Java and Bali Island, and a field survey of Sulawesi Island. As *Bukittinggi*, West Sumatra was the hometown of Dr. Resfa Fitri, the first author was strongly encouraged to visit this region, and in January 2014, the author set foot on Sumatra Island for the first time in his life. She told the author that there was something she wanted to show and someone she wanted to introduce.

The author visited a village near *Bukittinggi* and conducted interviews with village people and Mr. Erdiman, and the researcher willingly gave the author an explanation of the essence of the technology. The author came to have a great interest in the core of his attention to rice plants and the mechanisms of increasing the yield of ratoon crop grain. Mr. Erdiman seemed to understand what the rice plants were asking for as if he could communicate with the plants. The wonder was that farmers, mainly women, actually enjoyed the SALIBU rice ratoon cropping systems and made ratoon rice cultivation a success story using this technology. The author felt then the great potential of the impact of this technology on the future societies of our planet but, simultaneously, supposed that other scientists, such as agronomists, need to introduce this technology to the world.

The first business trip report

The first author submitted the following business trip report to JIRCAS — the original is in Japanese.

"In the normal farming method, the yield from the regenerated new stem, i.e., ratoon, after harvesting the main crop that has grown on the original stem is greatly affected by various conditions such as temperature and fertilizer and is in general considerably lower than the yield of the main crop. In Japan, though the temperature is too low to survive in winter in many cases, it is possible to obtain a maximum yield of approximately 50% of the yield in the main crop in the case of harvesting earlier very early maturing varieties and topped with appropriate fertilizer. For feed rice, there was a case of the Taiwanese native cultivar *Taporuri*, the optimum variety for ratoon cropping, showing the second dry matter yield of 9 t/ha in the ratoon crop, with the first dry matter yield of 10 t/ha in the main crop. In this case, an extremely high yield of 19 t/ha in total was obtained by transplanting in the paddy fields of western Japan, with a considerable amount of basal fertilizer applied in mid-April. In addition, it was done by harvesting and topdressing during the earing season from late July to early August for the first time and the second during the yellow ripening season from late October to early November (http: // www. cropscience.jp/award/pdf/award_14_02.pdf). It is generally difficult in Japan to produce high-quality rice for food by ratooning that can be distributed in the market. As an example of the tropical region, the author witnessed a harvest from rice ratoon crops in the *Muea* district, where irrigated rice is cultivated in the suburbs of Nairobi, Kenya. The yield of the ratoon crop is approximately 20–30% of that of the main crop. In this case, after harvesting the main crop, only irrigation was applied without topdressing, and the ratoon was grown with a minimum of labor and harvested as the main food."

"In contrast, in the SALIBU rice ratoon cropping systems, seedlings were planted at intervals of 26–28 cm in length and width for the main crop, and grains were harvested by hand one week earlier than usual without drainage. Herbicide is sprayed on moist paddy soil, applying irrigation water if dry. Roughly 7–10 d after harvesting from the main crop, when paddy soil is slightly dry, a power mower is used to cut stems into short pieces at 3–5 cm above the ground surface, and cut stems are plowed into the soil. The paddy soil is kept moist and irrigated with a small amount of water. In this state, 20–25 d after harvesting the main crop, a hoe is placed beside the stubbles where the original stem remains, and the plant is pulled out using the left hand, firmly holding the plant roots. The stubbles with roots are divided into roughly 2–3 pieces and one piece is replanted using the left hand at its original place in the soil. While maintaining the flooding depth of 2–3 cm, add ammonia urea fertilizer 75 kg/ha and compound fertilizer (*Phonska*) 50 kg/ha at this time, and add the same amount of fertilizer 40 d after harvesting the main crop."

"With the SALIBU rice ratoon cropping systems, the number of days required for harvesting is nearly 20% lesser than with conventional farming method, and 100 d after harvesting from the main crop ratoon crop can be harvested, and yield is also increased by approximately 10–20% compared to yield from the main crop. The main reason is that the stems are cut at a position lower than the node where normally the shoots of ratoon appear, that is, 3–5 cm above the ground surface, so that the shoots do not come out from the stems but the base. Furthermore, it is considered that the shoots of ratoon can absorb water and nutrients from both the roots of the original stem and the new roots because new roots are connected directly to the shoots. After continuing research at his own expense for nearly five years, in the beginning, he obtained research funds in 2012 and conducted trial cultivation of more than ten varieties thus far to confirm that the system can be applied to any variety. The crops of these varieties have been harvested six times in 22 months."

The author, an irrigation engineer, came to have a great interest in considerable savings in irrigation water for rice farming but is not an expert in agronomics or plant physiology, and therefore believed that for such experts to carry out research activity for the unique farming system was reasonable. However, none of the researchers of JIRCAS noticed this report, and time passed.

Launching the research project on the SALIBU rice ratoon cropping systems

JIRCAS was to start the fourth medium- to long-term research plan from FY2016–FY2020. As the author has been involved in rice cultivation research in Africa for a while, he first set up a research project to be conducted in Ghana, West Africa, and formulated an implementation plan. The project would execute a social experiment to establish and operate a highly cohesive farmers-based organization (FBO), including a new financing scheme for FBO, to strengthen the African rice technology dissemination system. At this time, the author was wondering about the fate of the SALIBU farming method. It had been almost two years since the author wrote the business trip report, and therefore supposed that an expert might have started studies on the subject.

For the time being, the author searched for articles in English on SALIBU farming methods, but none of them returned hits. There was one paper from Indonesia on the subject, but Mr. Erdiman was not named. The author supposed that because he was a rural researcher, the Indonesian agricultural research society was silently killing this groundbreaking rice ratooning cultivation method developed by him, who has no doctoral degree nor capacity to read or write English. The author was studying the System of Rice Intensification, a single young seedling cultivation method for paddy rice, developed initially by missionaries in Madagascar, Africa, then discovered by

American researchers and introduced to the world. Since the cultivation method was introduced to Japan by a group of researchers in agricultural engineering who focused on reducing the amount of irrigation water used, the method has been regarded as heresy among agronomists and plant physiologists, and, therefore, has not been taken up properly in research.

However, the SALIBU rice ratoon cropping system is a farming method that supports current small and poor rice farmers, increasing rice production without expanding agricultural land area or requiring the development of new water resources, but saving these resources. It is an epoch-making cultivation method that can save the planet in the future when pressure on population and resource demand increases. Therefore, it is necessary to overcome unsolved problems through research and development to establish this method.

The author wanted to introduce the SALIBU rice ratoon cropping system to the world with the name of developer Mr. Erdiman as a technology leading to another Green Revolution. Thus, the author wanted to publish an English paper co-authored with Mr. Erdiman. He collected data in his way but also from the point of view of an outsider, i.e., the author, who considered that the data was insufficient for a research paper. Therefore, the author would have liked to conduct cultivation research firmly, collect reliable data, and make a paper by positioning it as a research subject in the fourth medium- to long-term research plan of JIRCAS, in another developing country instead of Indonesia where it seemed to face certain imperceptible obstacles.

Now, the author had to select a country likely to work on such research together. The author had no idea but intuitively chose Myanmar. Then, in July 2016, the author visited Myanmar for the first time in his life and explained the concept of joint research at the Department of Agricultural Research (DAR), Ministry of Agriculture, Livestock and Irrigation, located in *Yezin* in the suburb of the capital *Naypyidaw.* The author received the understanding of the other party and started the collaborative research.

I have traveled to Myanmar 20 times in four years until 2020. For the first year or so, Mr. Erdiman and Dr. Resfa Fitri were invited to Myanmar four times with JIRCAS research funds. Dr. Resfa Fitri was an interpreter between the author and Mr. Erdiman, who did not speak English. It took the form of direct technology transfer from the founder to the third party. Dr. Khin Mar Htay, Chief of the Water Utilization Research Section, DAR, gave us great understanding and cooperation in starting and promoting joint research at DAR. It was crucially important to have positive expectations and support for this research. She retired at the end of 2019, but her subordinate, Mr. Kyaw Myaing, is now the section chief of another research division and continues the collaborative research on introducing combine harvesters into SALIBU rice ratoon cropping systems.

Chapter 3: Beginning of joint research

As described in the chapter "Introduction," technological innovations to increase crop yield per unit area is approaching their limits. Conventional strategies cannot adequately contribute to increases in rice production that have to address increases in demand on an ongoing basis, both now and in the future. Accordingly, a new strategy, namely the introduction of SALIBU rice ratoon cropping systems to small-scale rice farmers, should be considered based on the technology of new ideas leading to another Green Revolution. This farming system can increase the annual yield by approximately 80%, increasing the number of harvests while maintaining the current rice yield per unit area and existing cultivated land area.

Mr. Erdiman's approach in Sumatra

As a rule, we must optimize water supply and fertilizer usage to showcase the optimal capability of high-yield rice varieties, common knowledge since the Green Revolution but difficult for poor small-scale farmers who cannot invest. They are nervous and hesitate to invest a little cash, which constitutes part of their living expenses, on seed, fertilizer, and irrigation, without a 100% of guarantee of increased yield per unit area. They prefer to increase their income by expanding the acreage area by 30% rather than by increasing the yield per unit area by 30% because the latter is riskier for the farmers, whereas researchers tend to focus on refining technological development to increase the yield per unit area.

Mr. Erdiman, a researcher at the local office of the Assessment Institute for Agricultural Technology, *Balai Pengkajian Teknologi Pertanian* in West Sumatra, Indonesia, was not proficient in English reading and writing with little opportunity to review past studies on rice ratooning worldwide, such as English papers and IRRI text on "Rice ratooning" (IRRI, 1988). Accordingly, he did not need to adhere to traditional knowledge supported by researchers, neither affirming nor rejecting the wealth of research accumulated to date.

In 2007, when he visited *Matur* village, his wife's hometown, he received a consultation about the weak points of rice ratooning from local farmers. There are two disadvantages to the farming method. One is the low yield per unit area, and the other is the varibale growth rate of ratoons growing in a single stubble or between hills, which results in uneven maturity and diverse optimal time for panicle harvest. He listened to the feedback from farmers seriously and solely for their sake, continued to observe the rice ratoon growth pattern each day, and cultivated them through repeated trial and error over two years.

Finally, in 2010 the researcher determined that the key to solving such problems was "to make tillers regenerate healthily from the lowest node of the stem of the main crop" (Yamaoka et al., 2017). The stem of a rice plant has several nodes. The shoots of ratoon that grow from the nodes near the surface of the earth grow healthy roots that are directly connected to those in the soil, absorb water and nutrients straight from these fresh roots, and grow like a rice plant cultivated by conventional transplantation. In contrast, the shoots of ratoon that extend from the nodes at the higher position of the stem also grow roots directly connected to them, which become aerial roots and deteriorate and decay over time, so the ratoon crop must absorb water and nutrients by using the old roots and stems of the main crop.

The researcher was not interested in whether the field trials would be well adapted for the manuscript of an academic paper, but instead listened to feedback from farmers and worked hard to tackle the problems they were suffering. Thinking that it is best to improve the cultivation techniques that farmers can easily apply without concerns, he worked on rice cultivation tests in farmers' plots, which ordinal researchers often forgot. He finally devised practical farming systems, achieving a similar yield per unit area as that of conventional transplant cultivation.

Technology transfer from Sumatra to overseas for the first time

Mr. Erdiman, the inventor of the SALIBU rice ratoon cropping systems, visited the Department of Agricultural Research (DAR), Ministry of Agriculture, Livestock, and Irrigation (MOALI), Myanmar four times in November 2016, January and May 2017, and January 2018, on the invitation of Dr. Kazumi Yamaoka with the research fund of JIRCAS. Drs. Resfa Fitri always accompanied Mr. Erdiman as an interpreter between Bahasa Indonesia and English. All parties repeatedly discussed SALIBU rice ratoon cropping systems with Dr. Khin Mar Htay, Chief of the Water Utilization Research Section, DAR. They shared a common understanding of the technology through discussion and findings from field trials. The following are based on shared knowledge:

Key technology

The essential part of the technology is a series of treatments before and after harvest. The main crop needs to be harvested at the time of physiological maturity, namely one week before the time of ordinary harvest, a time when the proportion of greenish spikelets in the panicles is almost twice (20–30%) that of the traditional rice harvest (10–15%). Many of the leaves and stems are still half-greenish at this stage. The cutting height of rice stems at the harvest is 25–40 cm above ground level, and an optimal harvest is performed manually or using a compact combined harvester.

The soil needs to be maintained in high moisture conditions between field capacity and saturation, defined as "optimum moisture condition" hereafter, i.e., adequately moist soil but simultaneously no water appears on the ground surface, and the condition needs to be maintained for four weeks, between two weeks before and after harvest. Fertilizer should be applied one week before harvest to boost initial ratoon growth. One week after harvest, the second cutting of stems is to be performed at 3–5 cm height above ground level. Mr. Erdiman recommends that the second cutting be done using a mower, preferably a backpacking-style engine mower, rather than manually. Manual cutting at 3–5 cm height above ground level is labor-intensive. Therefore, his idea of using the mower machine for the second cutting is particularly noteworthy. Subsequently, shallow irrigation in a 1–3 cm depth of floodwater starts one week after the second cutting.

The reason for performing the harvest at the time of physiological maturity is to maintain the vitality of stubbles and roots up to the second cutting. Another reason is the need to prevent the untimely initiation of young panicle formation near the stem node before harvest, as mentioned in the text under the headings "Differences between the traditional ratoon cropping and SALIBU rice ratoon cropping systems" in Chapter 1: Review of studies on rice ratooning. Rice grains harvested at the physiological maturity stage have no problems, either nutritionally or in terms of quality. For the same reason, the soil needs to be moistened thoroughly for four weeks, two weeks before and after harvesting. However, simultaneously, we must focus on eliminating water from the ground surface because muddy soil reduces the workability of the harvest and the second cutting. Optimum moisture condition is an optimal moisture control benchmark that makes the vitality of roots and workability compatible.

Then why does Mr. Erdiman need the optimum moisture condition maintained, not until the time of the second cutting but until one week after the second cutting? If only the workability of the second cutting is targeted, he must start irrigation immediately after it. As mentioned earlier, it is dangerous for farmers to cut the stems at a height of 3–5 cm above the ground, as unexpected heavy rains under tropical climates may submerge and kill the stubbles and young ratoon. However, this risk is reduced by maintaining optimal moisture conditions, that is, no water appearing on the ground surface, until one week after the second cutting, in addition, after that, by starting shallow irrigation in a depth of 1–3 cm of floodwater, not normal irrigation. This approach to water management, of course, draws attention to farmers to avoid the risk of submerged mortality of ratoon crops.

Other indispensable technology

Normal irrigation in a depth of 5–10 cm of floodwater starts two weeks after the second cutting. Within one week of starting the normal irrigation, the following four tasks are recommended to finish:

1. Separation and addition (Leveling each hill's richness): Transplant part of the bunch of culms with roots from rich-tillering hills to poor-tillering hills for leveling the size of the hills, i.e., the number of tillers on each hill.

2. Insertion: Push down stubble with aerial roots, if they are remarkable, into the soil, because the unprotected aerial roots will die in due course.
3. Weeding: Remove weeds, buds emerging from the seeds dropped from the panicle and culms that headed early because they all should be considered weeds.
4. Fertilizing: Apply the second round of fertilizing.

"Separation and addition (Leveling each hill's richness)" constitute treatment equivalent to that of supplemental transplanting to fill up the missing hills after rice planting via traditional farming practices. Leveling the richness of the stubble, i.e., the number of tillers helps prevent missing hills, uneven heading, and uneven maturity of each panicle, while "Insertion" involves pressing floating stubble down into the soil. There are several nodes on a single rice plant culm capable of sprouting tillers and tillers need to be able to grow up from the node at or closest to the surface of the earth, as such tillers can grow their vital roots directly and absorb moisture and nutrients directly from the fresh roots. If the tillers sprout from the node at a higher position, the root emerging from the node becomes an aerial root and deteriorates over time, meaning the tillers inevitably use existing old stems and roots to absorb moisture and nutrients. Such tillers and ratoons are lacking in nutrition and become thin and weak, resulting in low yield from the ratoon crop. "Weeding" is a particularly important task under optimum moisture conditions, where weeds are more likely to grow than in flooded conditions. Regarding "fertilization," the same approach as for conventional cultivation practice can be used.

Subsequently, cease irrigation four weeks after the second cutting to allow the flooding condition to revert to that of optimum moisture condition and maintain it for two weeks. Six weeks after the second cutting, the third fertilization and second weeding are carried out and irrigation resumed to retain the flooded condition. Moreover, just as for the case of the main crop, harvesting will take place at the stage of physiological maturity, one week before the normal harvest. It is necessary to fertilize for the next generation one or two weeks before the harvest.

Repeating the above procedure for generations, SALIBU rice ratoon cropping systems allow a seven-time harvest within two years for cultivars with early-medium maturity. When the main crop is the cultivar, which needs 115 d from sowing to harvesting, subsequent ratoon crops can be harvested nearly 100 d after the previous harvest, implying that the seventh harvest happens nearly 715 d after the first sowing (see Figure 0-2 in page 14).

Field Survey in West Sumatra Province (May 2017)

Meanwhile, since 2016, JIRCAS (Japan International Research Center for Agricultural Sciences), DAR, MOALI in Myanmar, and IPB-FEM (Faculty of Economy and Management, Bogor Agricultural University) in Indonesia have started a collaborative research group on "Improvement of irrigation water productivity for paddy rice production through SALIBU rice ratoon cropping systems in CDZ, Myanmar" under the JIRCAS's research project on "Development of Agricultural Technologies for Reducing Greenhouse Gas Emissions and Climate-related Risks in Developing Countries."

Since the yield remains almost constant in the main crop and the ratoon crop of each generation, SALIBU rice ratoon cropping systems should be theoretically sustainable for up to several years, but according to farmers in West Sumatra Province, to avoid the soil hardening, many farmers will reset it about one year by re-puddling the paddy fields. When the authors revisited West Sumatra province in May 2017, they author have witnessed that main-crop rice and ratoon-crop rice are being shipped to the local market at the same price. This convinced the author of the trust of local farmers in the systems and consumer support for the products.

The authors of this book together with the Dean and professors in IPB-FEM visited *Tabek, Pariangan,* and *Tigo Bahea, Sungai, Tarab* in *Tanah Datar* sub-district in West Sumatra province and made interview farmers in the villages on 20 and 21 May 2017. The author collected the following information through the interview with the leader of a farmers' group in *Tabek, Pariangan*;

- 460 farmers organize 14 groups in the village on the land basis
- Women organize 7 women farmers' groups
- SALIBU rice ratoon cropping systems are applied by 100% of farmers in the village
- His group consists of 52 farmers, and men/women are about 50:50
- Women are engaged in transplanting, weeding, fertilizing, and postharvest processing
- Men are engaged in land preparation, paddling and leveling, cleaning ditches, harvesting, and cutting off (trimming) for SALIBU ratooning
- Water management is done by each landowner
- Free charge of irrigation and no water shortage all year round
- Ratoon cropping was started in 2006 and SALIBU rice ratoon cropping systems in 2011

The leader felt after introducing SALIBU rice ratoon cropping systems in 2011;

- Water consumption was reduced
- Labors and carefulness for water management were maintained
- Land leveling should be done more carefully than conventional
- Market price of SALIBU rice has been the same as the conventional one
- Yield per acre was slightly increased (6t/ha → 7-8t/ha)
- Total annual costs were reduced

They had already enjoyed almost the same yield in ratoon rice cultivation as the main crop since 2006, however, they were not satisfied because;

- Cutting off was manual, done by hand
- Uneven growth between shoots forced them to harvest twice for the same plant

The first author also discovered through the interview in *Tigo Bahea*, *Sungai*, and *Tarab* that there were different stages of growth of paddy rice among farmers in a village as well as there were different stages of that among plots of one farmer. The former may contribute to the diversification of risk of pests and disease and the latter may contribute to increasing the income opportunity. And group activities such as harvest are maintained in the village. So, each farmer in the village can get cash income around 8 times a year and be engaged in more dispersive group activities. This increase in the opportunity for income and the increase in annual income must strongly encourage farmers to invest more in farming.

PART TWO: Studies on SALIBU rice ratoon cropping systems in three countries

Chapter 4: Change of yield in consecutive nine crops in large open-air pots – Myanmar I

Approach and method

Central Dry Zone (CDZ) in Myanmar covers an area of more than 54,000 km^2, and almost 36% of the population of Myanmar lives in 58 townships, including counties and towns. Dry spells frequently occur during the rainy season of the CDZ, but the degree varies according to place and time. The irrigated paddy fields that stretch around CDZ produce significant rice yield, and irrigation water for these rice productions accounts for the majority of water use in the region. However, the water efficiency of paddy irrigation, already sluggish, is expected to worsen as climate change intensifies. There is an urgent need to develop water-saving agricultural technology for adaptation to climate change in CDZ and its surrounding areas. More rice crops per drop of water, i.e., increased water productivity, is crucial to this region (Yamaoka et al., 2017). Dr. Khin Mar Htay applied SALIBU rice ratoon cropping systems to these regions as a first in Myanmar after Dr. Kazumi Yamaoka introduced the technology at a consultation meeting held in the Department of Agricultural Research (DAR) on June 28, 2016. Since then, continuous cultivation tests over generations have been planned and conducted in large pots under the systems. Experimental trials involving continuous cultivation over generations under SALIBU rice ratoon cropping systems in fifteen large cultivation pots, each with an area of 2.4 x 1.8 m, have been conducted in the Water Utilization Research Section (WURS) in DAR since July 2016.

Fig. 4-1. Continuous cultivation test in 15 large pots under SALIBU rice ratoon cropping systems from January–May 2017

For the experiment, the locally popular rice variety, "*Thee Htat Yin*," was chosen as the main crop variety, sown on July 19, 2016, cultivated using the conventional transplant farming method, and harvested on November 11, 2016. The planting density was 90 hills per pot, i.e., 20.8 hills per square meter. The seedlings for transplantation were 23 d old. The pots were flooded continuously with water. The sample size was chosen randomly for four hills, excluding the outer edge per pot. The weight of 1000 grains and yield was converted to a moisture content equivalent to 14% after direct weighing. We harvested the sixth generation of the ratoon crop on July 28, 2018, demonstrating that locally popular and commonly cultivated rice varieties are harvested seven times a year under the climate of Myanmar with high yields each time in large open-air pots using SALIBU rice ratoon cropping systems. Notably, for the seventh to eighth ratoon crops, we continued with only five cultivation pots, sampled four strains in each cultivation pot to make one sample, measured five crop samples, and calculated the average value.

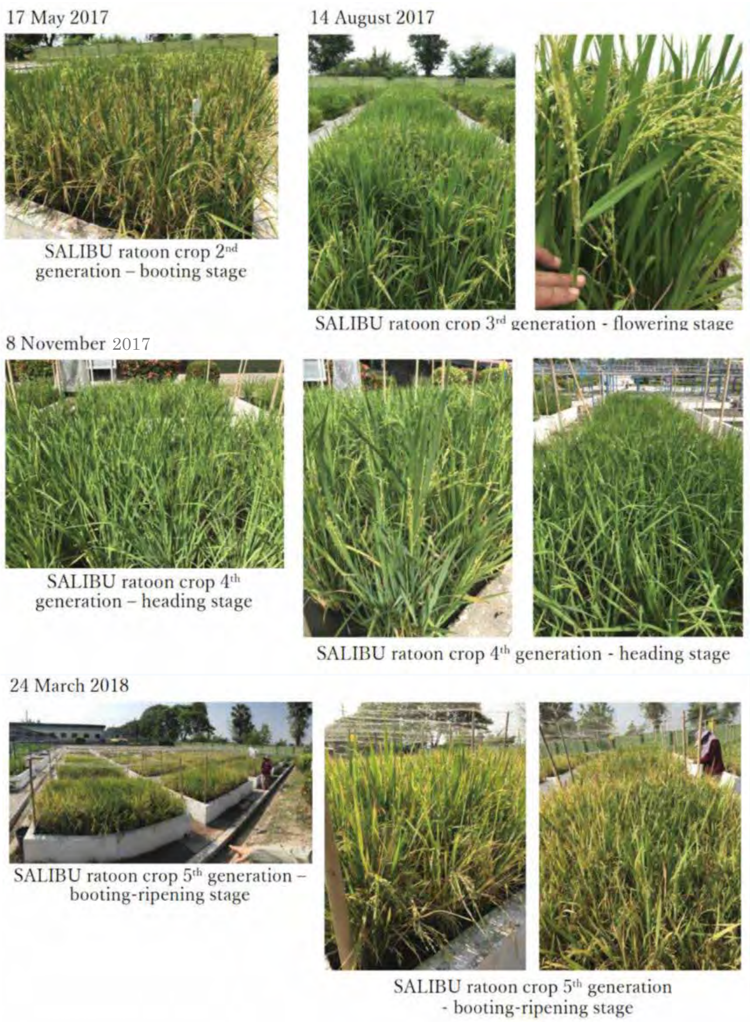


Fig. 4-2. Continuous cultivation test in 15 large pots under SALIBU rice ratoon cropping systems from May 2017 to March 2018

Results and discussion

The cultivation study in the open-air pot of 8ft (244cm) x 6ft (183cm) area proved that a popular local variety in CDZ, namely *Thee Htat Yin* performed yielded 9.1 t/ha of ratoon crop in the first generation, whereas the yield of the main crop was 5.3 t/ha under SALIBU rice ratoon cropping systems. The main crop was harvested on November 11, 2016, and cut off stubbles on November 17, 2016, for SALIBU rice ratoon cropping systems. The harvest of the first generation of the SALIBU ratoon crop was performed on February 22, 2017, 103 d after the main crop harvest. It also showed that ratoon scored a much higher number of tillers, panicle per hill, and biomass weight than the main crop, whereas the number of spikelets per panicle, thousand-grain weight, and the percentage of filled grains were lower compared to those in the main crop. We harvested the second generation of the SALIBU ratoon crop in early June 2017. It was 108 d after the harvest of the first generation of the SALIBU ratoon crop.

Regarding trials of continuous cultivation under SALIBU rice ratoon cropping systems in large pots, **Table 4-1** shows the yield component data of the main crop, the first to the eighth generation of the SALIBU ratoon crops, and the date of harvest and the second cutting. The continuous cultivation test ended with the eighth generation of the SALIBU ratoon crop harvested on January 8, 2019. Nine harvests were obtained from 903 d of continuous cultivation since July 19, 2016, showing that the cultivation period for each generation is almost 100 d.

Table 4-1. Yield component and relevant data over nine generations from the main crop to the eighth ratoon crop

Characteristics	Main crop	Generation of SALIBU ratoon crop							
		1st	2nd	3rd	4th	5th	6th	7th*1	8th*1
Plant Height (cm)	92.7	68.2	96.0	119.9	87.8	76.5	113.3	102.5	70.0
Panicle Length (cm)	23.0	19.9	25.3	25.2	21.9	19.6	23.8	25.5	18.0
Effective Tiller (/hill)	10.0	38.6	16.0	32.6	28.4	49.4	24.3	34.9	20.0
Spikelet / Panicle	126.9	92.4	92.8	127.2	112.4	117.9	112.7	112.6	68.5
Panicle / hill (/hill)	9.8	36.0	16.0	32.6	21.0	49.2	22.7	17.6	18.7
1000 grain Wt (g)	21.7	18.9	19.9	22.3	19.8	17.9	24.1	22.2	19.6
Fill grain (%)	81.9	60.2	68.0	64.4	62.2	56.1	74.1	67.0	63.1
Biomass / hill (g/hill)	22.4	73.7	53.9	123.9	63.4	161.9	102.6	69.6	33.0
HI	0.49	0.51	0.53	0.47	0.46	0.35	0.44	0.40	0.47
Cutting date	Sowing date 19/07/'16	18/11/'16	03/03/'17	14/06/'17	18/09/'17	25/12/'17	09/04/'18	30/07/'18	22/10/'18
Harvesting date	11/11/'16	22/02/'17	10/06/'17	12/09/'17	19/12/'17	03/04/'18	28/07/'18	20/10/'18	08/01/'19
Days to harvest	115	103	108	94	98	105	116	84	80
Yield (t/ha)	5.3	9.1	6.9	11.5	6.9	11.0	9.6	5.7	3.9

Note: n=15, ＊1 :n=5

Figure 4-3 shows the amount of solar radiation observed in DAR during the cultivation period from November 2016 to January 2019. The bar and line graphs show average data values for 5 and 15 d, respectively. The pale orange ellipse indicates when the amount of solar radiation decreased. **Figure 4-4** shows the temperature during the same period (average data values for 5 d). The pale orange ellipse indicates when the temperature is lower.

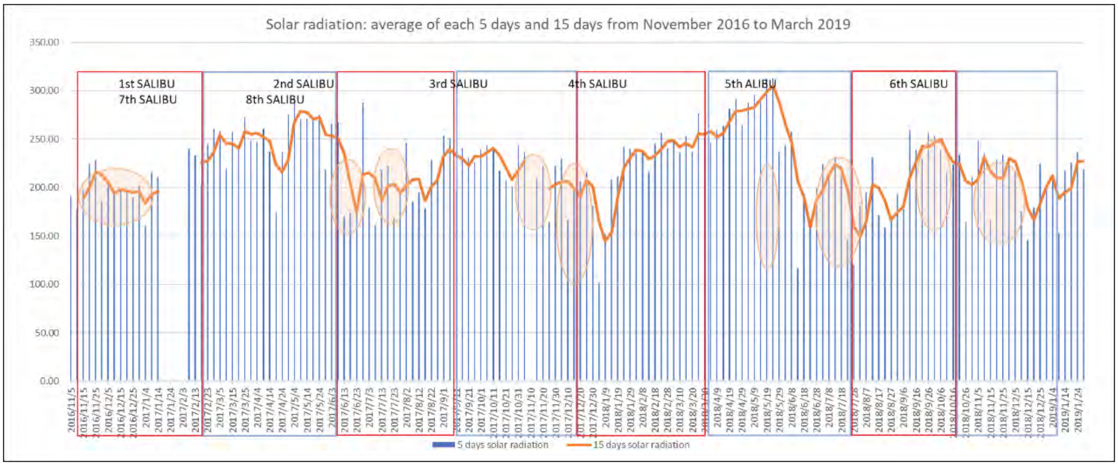


Fig. 4-3. Five days average and 15 d average of solar radiation in DAR from November 2016 to January 2019

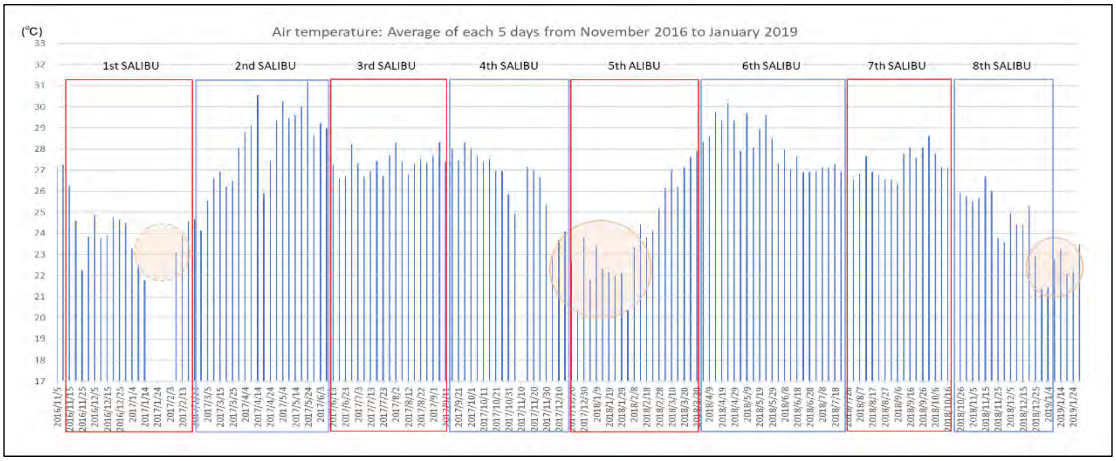


Fig. 4-4. Five days average of temperature in DAR from November 2016 to January 2019

Although the main crop recorded a yield per unit area of 5.3 t/ha, its subsequent SALIBU ratoon crops from the first to the eighth generation yielded 9.1, 6.9, 11.5, 6.9, 11.0, 9.6, 5.7, 3.9 t/ha, respectively. The number of effective tillers and biomass weight are likely to influence the yield in each generation, whereas there is a low correlation between plant height and yield (**Figure 4-5**).

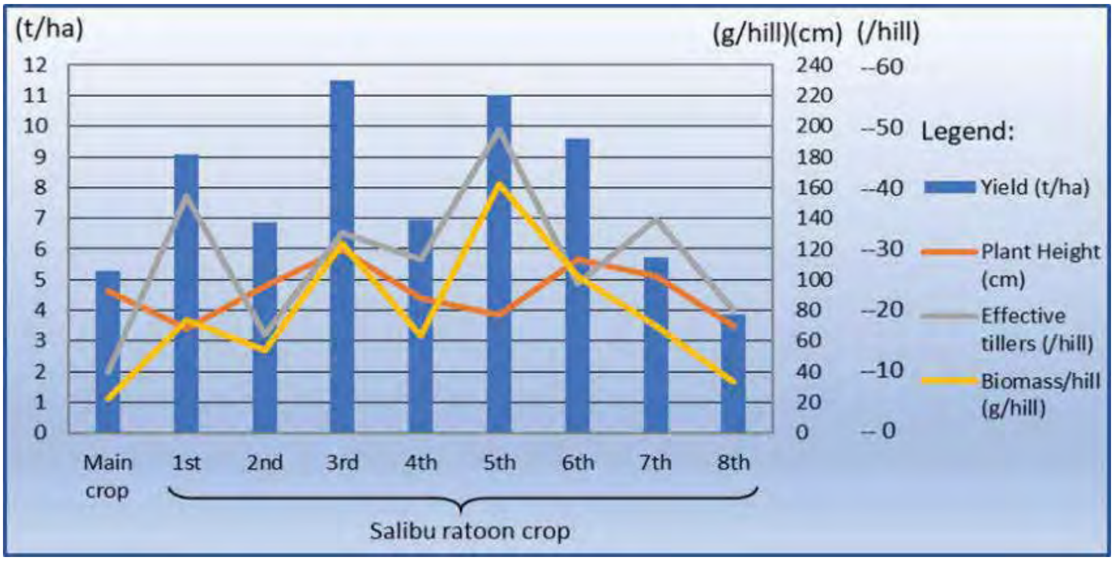


Fig. 4-5. Changes in yield and selected yield component data over nine generations

Conclusion and recommendations

The test was the first continuous cultivation test of SALIBU ratoon cropping systems in Myanmar, using a locally popular variety called Thee Htat Yin in a large pot in an outdoor environment. Starting with the main crop, we continued cultivation up to the sixth generation of ratoon crops in two years, demonstrating that seven harvests are possible in two years. Furthermore, continuous cultivation was performed for up to the eighth generation of the ratoon crop. The ratoon crop yield exceeded the yield of the main crop in all harvests up to the seventh generation.

In addition, a few generations yielded more than twice the main crop yield at maximum, and the increase or decrease in crop yield in each generation is speculated to be due to the increase or decrease in the number of effective tillers. However, outdoor pots are more susceptible to soil and water temperatures than fields, whereas these pots are less sensitive to receive damage from disease, insects, birds, and animals, despite being large. In the future, conducting cultivation tests in a field closer to the actual farming environment will be necessary based on the findings from the big pot test.

Introduction

Rice needs more water for its cultivation than other cereals. The water productivity of cereals can compare to the year-to-year productivity of the same crop in the same region in the same season, but other simple comparisons are meaningless and dangerous. Here, water productivity is defined by the following equation:

$$WP = GY / IW,$$

where WP is water productivity, GY is grain yield, and IW is the amount of irrigation water.

For example, because the value of the water itself, in other words, price per unit water volume, varies from region to region, "grain production per water volume" does not make economic sense when we compare the water productivity of crops cultivated in different areas. Thus, comparing the water productivity of various crops produced in diverse regions, though often observed in research papers, is nonsense. In addition, within the same region, the value of water varies from time to time. Therefore, comparing the water productivity of two crops cultivated at different times within the same region is also not prudent. However, with a thorough understanding of these issues, when we dare compare the water productivity of rice varieties with that of the other two major grain crops, i.e., wheat and maize, the water productivity of rice varieties is almost half that of wheat and maize. In this case, instead of discussing economic efficiency by looking at water as an economic good being able to alternate, it becomes that we recognize water as an indispensable resource that cannot be replaced by other resources and discuss the efficiency of its use.

It makes sense to aim for high water productivity because its substitutes are limited when considering the entire earth, despite the possibility that water can be replaced by other resources such as land and labor under certain circumstances, e.g., abnormally high-priced water. It is urgently necessary to develop an innovative production method with higher water productivity that will increase rice production under conditions of the limit of increase in yield per unit to solve the future food problems corresponding to a massive increase in the world population.

Is there such a favorable and innovative rice cultivation method? Yes, the SALIBU rice ratoon cropping system, an ingenious rice ratooning cultivation invented in West Sumatra, Indonesia, allows for harvesting rice grains up to 3.5–4 times annually. It also allows producing a yield for ratoon crop in the following consecutive generations at the same level as that of the main crop, whereas past studies generally concluded that the grain yield of ratoon crop was within the range of 20–50% of that of the main crop. In other words, these farming systems bring about an effect like increases in acreage by increasing the number of harvests per year while maintaining the yield per unit area each time.

SALIBU rice ratoon cropping systems revolutionarily increase water productivity through consecutive ratooning cultivation because farmers can reduce the amount of irrigation water drastically by shortening cultivation periods and omitting activities such as raising the seedlings, puddling, and transplanting. The water amount used during puddling and transplanting is enormous.

The SALIBU systems can transform monocarpic annual rice plants into perennial types that produce ratoon grains over generations. These do not force farmers to put in additional investment while giving them the advantage of saving resources such as water, labor, and seed. These reduce the cost and adverse environmental effects of frequent mechanized land preparation and allow effective utilization of residual nutrients in paddy fields.

SALIBU rice ratoon cropping systems were invented by Mr. Erdiman, a researcher at the local office of the Assessment Institute for Agricultural Technology, *Balai Pengkajian Teknologi Pertanian* in West Sumatra, Indonesia, in around 2010 and accepted by farmers in West Sumatra. However, reliable cultivation data has not been obtained because it has not been studied actively by researchers in Indonesia.

Therefore, we started collaborative research to acquire and evaluate yield data and yield component data under the application of SALIBU rice ratoon cropping systems at the test field in the Department of Agricultural Research (DAR), Ministry of Agriculture, Livestock and Irrigation in Myanmar. DAR has a well-developed system of cultivation test research under tropical climates and is located on the edge of the Central Dry Zone (CDZ) in Myanmar. As CDZ is predicted to be vulnerable to water shortage owing to future climate change, we focused on the potential of higher water productivity of rice cultivation under the SALIBU rice ratoon cropping systems compared to conventional cultivation, exploring the possibility of obtaining more production with less irrigation water.

Research methods

The collaborative research project undertook field experiments in the test fields of DAR for a more detailed study of the technology and its water productivity. This comparative study is designed to compare water productivity between a) SALIBU ratooning with water management recommended by SALIBU rice ratoon cropping systems, b) SALIBU ratooning with alternate wetting and drying (AWD) water management, and c) non-ratooning conventional transplanting (control). It also compares water productivity between varieties.

For conducting the trials, in June 2017, 36 paddy field test plots of approximately 32 square meters were constructed in the Water Utilization Research Section (WURS) of DAR. In the test area of the paddy field, a comparative test was conducted in four duplications for nine combinations of three rice cultivars (V1–V3) and three water management methods for cultivation (W1–W3).

The trials started on June 24, 2017, with the sowing of rice cultivars, namely *Shwe Thwe Yin*, *Thee Htat Yin*, and *Sin Thu Kha*, transplanted on July 14, 2017, into 36 carefully designed test field plots in WURS, DAR. **Figure 5-1** shows a plane plan of the cultivation fields for water productivity tests, each equipped with pipeline irrigation systems, including tube wells and independent drainage canal systems, to ensure separate irrigation and drainage for each plot.

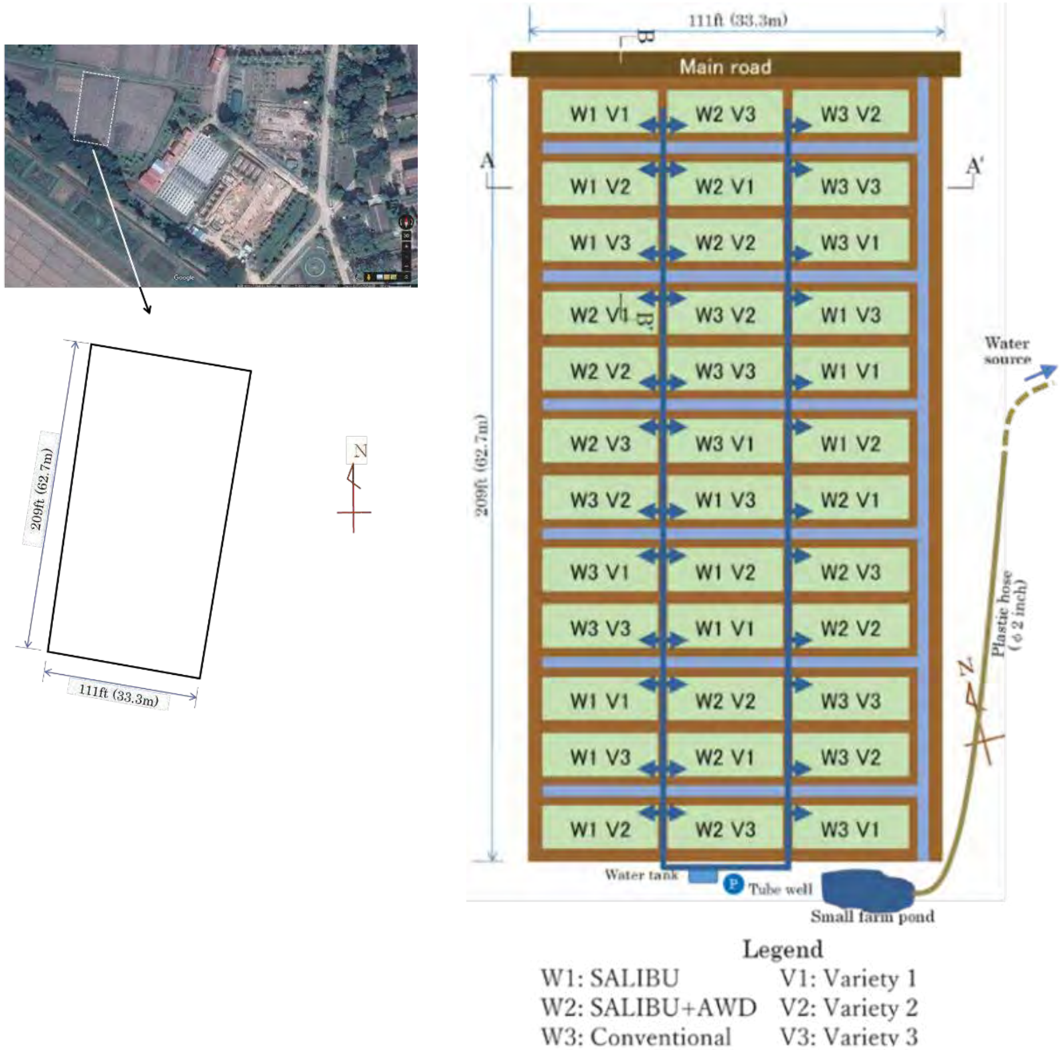


Fig. 5-1. Plane plan of cultivation fields for water productivity tests

Figure 5-2 shows a cross-section of cultivation fields for water productivity tests.

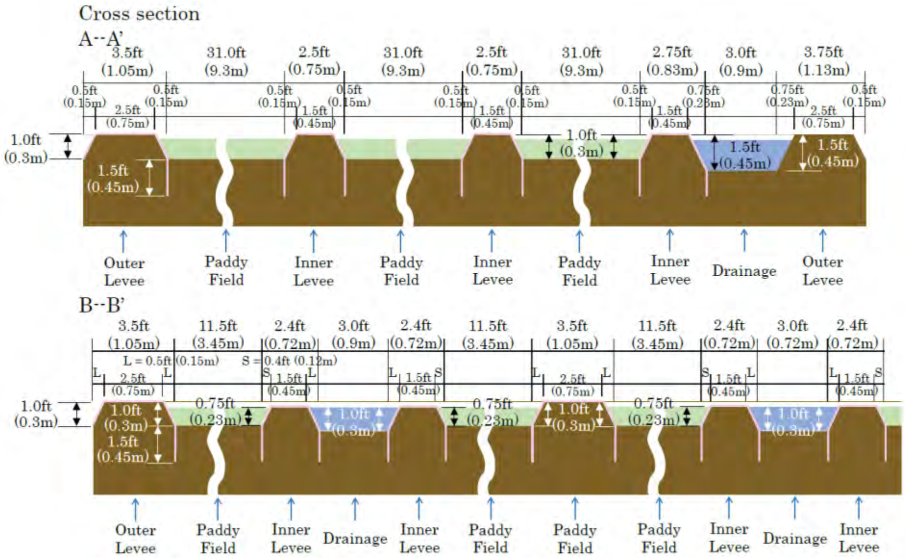


Fig. 5-2. Cross section of cultivation fields for water productivity

The entire band is covered by a water-impermeable plastic sheet, with a part inserted into the soil to suspend the horizontal percolation of water into the same. A detachable portable digital flow meter is equipped rotationally at each discharge port of the pipeline irrigation systems to measure the amount of water irrigated for each plot (see **Figures 5-3** and **5-4**).

Fig. 5-3. Signboard, pipeline, and bund covered by a plastic sheet

Fig. 5-4. Second cutting by engine mower and rat fence

The procedure for cultivating in SALIBU rice ratoon cropping systems is explained in the text under the headings “Key technology” and “Other indispensable technology” in Chapter 3: Beginning of Joint Research. The procedure is illustrated in **Figure 5-5** as a more specific manual for the cultivation of the main crop and ratoon crop.

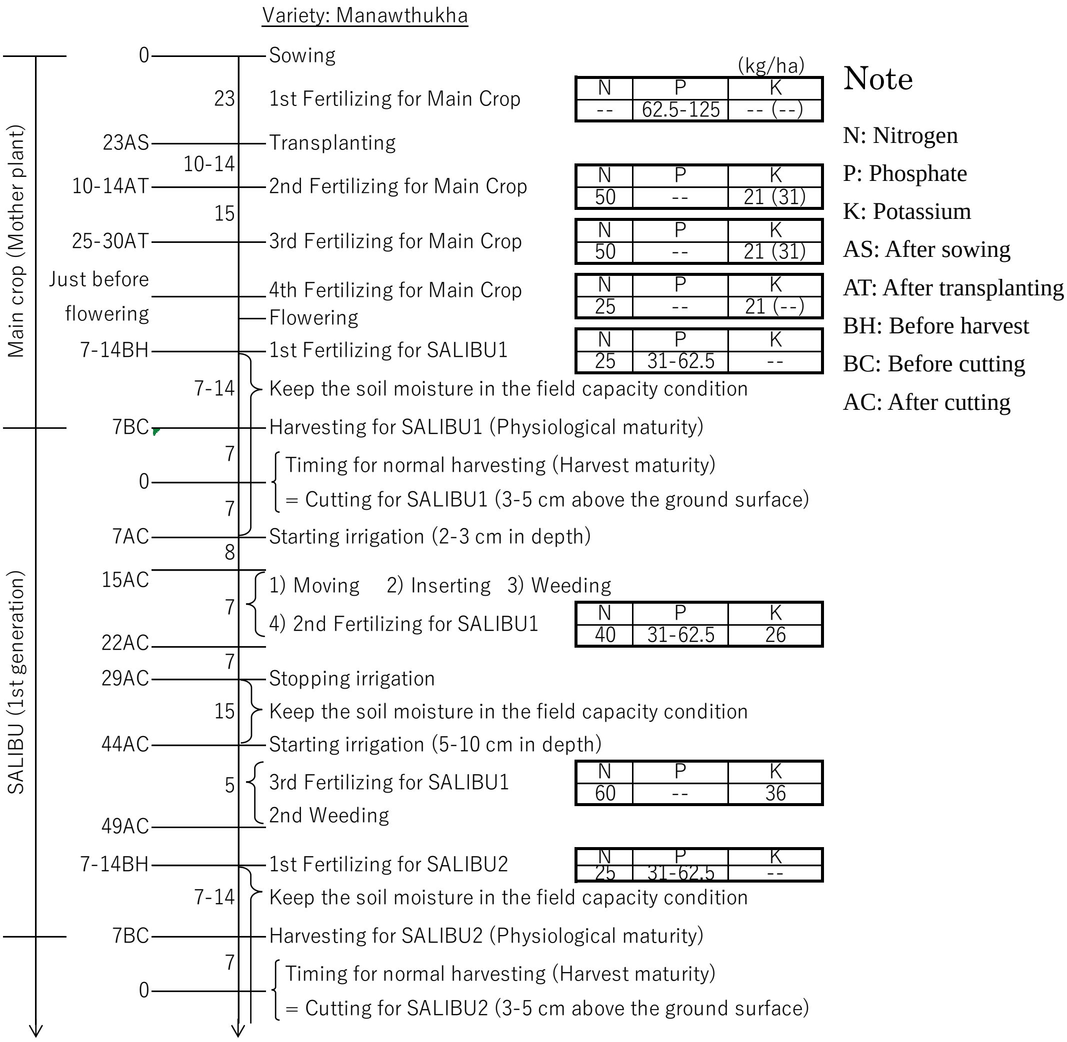


Fig. 5-5. Manual for the cultivation of main and ratoon crop

Results

The main crop was harvested in September and October 2017, and the dates of events such as sowing, second cutting, transplanting, 50% flowering, and harvesting are shown in **Table 5-1**. *Shwe Thwe Yin* (V1) was affected by an accidental event of heavy rains whereby its stubble was submerged for 7–10 h immediately after the second cutting of the main crop. Considering the substantial damage, we removed the stubble and replanted the main crop.

For all three varieties tested, SALIBU cropping was conducted practicing water management as recommended by SALIBU rice ratoon cropping systems (SLB) and under AWD intermittent irrigation water management (SLB + AWD). The first (4.59–5.91 t/ha) and second generation (4.45–6.46 t/ha) yields were equivalent to or better than the yield of the main crop that preceded in the same plots (4.07–5.71 t/ha). The crop yields of *Thee Htat Yin* and *Sin Thu Kha* were also equivalent or superior to crop yields recorded in trials using conventional practices (CP: 3.41–6.27 t/ha) of cultivation conducted in parallel with the first and second-generation trials of SLB and SLB + AWD (**Table 5-2**).

Table 5-1. Dates of events and days to harvest (main crop to third SALIBU ratoon crop)

Treatment	Cultivar	Main crop (Conventional Practice)(2017)				Days to harvest	1st generation of SALIBU ratoon crop (2017-2018)				Days to harvest	2nd generation of SALIBU ratoon crop (2018)				Days to harvest	3rd generation of SALIBU ratoon crop (2018)				Days to harvest
		Sowing	Transplanting	50% Flowering	Harvesting		2nd Cutting	Transplanting	50% Flowering	Harvesting		2nd Cutting	Transplanting	50% Flowering	Harvesting		2nd Cutting	Transplanting	50% Flowering	Harvesting	
W1	V1	6/24	7/14	9/2	9/28	96	10/4 1)	11/16 2)	1/16 2)	2/15 2)	112	2/22 3)	-	3/28 3)	4/27 3)	71	5/4 4)	-	6/23 4)	7/23 4)	87
	V2			9/13	10/11	109	10/18	-	12/12	1/9	90	1/16	-	3/25	4/23	104	4/30	-	7/2	8/3	102
	V3			9/27	10/23	121	10/30	-	12/27	1/29	98	2/5	-	3/26	4/26	87	5/4 5)	2nd cutting 7/26 6)	Virus	Virus	-
W2	V1	6/24	7/14	9/2	9/28	96	10/4 1)	11/16 2)	1/16 2)	2/15 2)	112	2/22 3)	-	3/28 3)	4/27 3)	71	5/4 4)	-	6/23 4)	7/23 4)	87
	V2			9/13	10/11	109	10/18	-	12/12	1/9	90	1/16	-	3/25	4/23	104	4/30	-	7/2	8/3	101
	V3			9/27	10/23	121	10/30	-	12/27	1/29	98	2/5	-	3/26	4/26	87	5/4 5)	2nd cutting 7/26 6)	Virus	Virus	-
Treatment	Cultivar	Main crop (Conventional Practice) (2017)				Days to harvest	Conventional Practice (cultivated in parallel with 1st SALIBU) (2017-2018)				Days to harvest	Conventional Practice (cultivated in parallel with 2nd SALIBU) (2018)				Days to harvest	Conventional Practice (cultivated in parallel with 3rd SALIBU) (2018)				Days to harvest
		Sowing	Transplanting	50% Flowering	Harvesting		Sowing	Transplanting	50% Flowering	Harvesting		Sowing	Transplanting	50% Flowering	Harvesting		Sowing	Transplanting	50% Flowering	Harvesting	
W3	V1	6/24	7/14	9/2	9/28	96	10/26	11/16	1/16	2/15	112	2/23	3/15	4/29	5/31	97	6/6	6/26		9/17	103
	V2			9/13	10/11	109	10/14	10/30	1/16	2/15	124	2/22	3/14	5/10	6/19	117	6/28	7/18		10/11	105
	V3			9/27	10/23	121	10/26	11/16	2/7	3/9	134	3/16	4/5	6/24	7/24	130	7/5	7/26			

Remarks: "Days to harvest" for the plant of CP indicates the days from sowing to harvest while that for
1) Mortality by flood on 8,9 and 12 October 2017
2) Renewal of main crop by conventional practice
3) Cultivated as 1st generation of SALIBU ratoon crop
4) Cultivated as 2nd generation of SALIBU ratoon crop
5) Removing stabbles due to affection of Grassy Virus
6) Cultivating 2nd SALIBU ratoon crop from the stubbles of CP (same period of 3rd SALIBU ratoon crop)

The SLB and SLB + AWD systems showed almost the same level of water productivity as conventional practices using the *Shwe Thwe Yin* cultivar (see the red dotted square in **Table 5-4**). In *Thee Htat Yin* and *Sin Thu Kha*, SLB and SLB + AWD in the first generation of SALIBU rice ratoon cropping systems (1.40-1.92 g/l) scored 2.3 to 2.6 times higher water productivity than conventional practices (0.61-0.73 g/l) (see the purple dotted square in **Table 5-4**). In addition, the same cultivars scored 1.5 to 2.8 times more in water productivity (0.84-1.30 g/l) than in conventional practices (0.47-

0.57 g/l) in the second generation of SALIBU rice ratoon cropping systems (see the indigo blue dotted square in **Table 5-4**).

Table 5-2. Yield per unit area

Yield (t/ha)

Variety regime	Cultivation and water management regime	Generation of rice plant				
		Main crop (Conventional practice)	1st SALIBU ratoon crop	2nd SALIBU ratoon crop	3rd SALIBU ratoon crop	4th SALIBU ratoon crop
V1: Shwe Thwe Yin	SLB	4.52	4.69	4.45		
	SLB+AWD	4.85	4.66	5.78		
	Conventional	5.25	7.17	6.34		
V2: Thee Htat Yin	SLB	4.07	4.59	5.40	4.91	5.04
	SLB+AWD	4.56	4.79	5.40	5.29	4.78
	Conventional	4.78	3.41	5.13	5.37	
V3: Sin Thu Kha	SLB	5.62	5.91	6.46		
	SLB+AWD	5.71	5.90	5.52		
	Conventional	6.26	5.10	6.27		

Table 5-3. Total water use

Total water use (mm)

Variety regime	Cultivation and water management regime	Generation of rice plant				
		Main crop (Conventional practice)	1st SALIBU ratoon crop	2nd SALIBU ratoon crop	3rd SALIBU ratoon crop	4th SALIBU ratoon crop
V1: Shwe Thwe Yin	SLB	520.33	450.83	472.88		
	SLB+AWD	477.06	415.82	484.41		
	Conventional	517.77	633.57	770.00		
V2: Thee Htat Yin	SLB	730.20	328.28	641.47	488.26	310.00
	SLB+AWD	730.20	325.84	583.41	472.02	310.00
	Conventional	730.20	562.66	907.28	619.00	
V3: Sin Thu Kha	SLB	1122.20	336.22	496.13		
	SLB+AWD	1122.20	308.00	502.76		
	Conventional	1122.20	697.90	1337.54		

Table 5-4. Water productivity

Water productivity (g/l)

Variety regime	Cultivation and water management regime	Generation of rice plant				
		Main crop (Conventional practice)	1st SALIBU ratoon crop	2nd SALIBU ratoon crop	3rd SALIBU ratoon crop	4th SALIBU ratoon crop
V1: Shwe Thwe Yin	SLB	0.87	1.04	0.94		
	SLB+AWD	1.02	1.12	1.19		
	Conventional	1.01	1.13	0.82		
V2: Thee Htat Yin	SLB	0.56	1.40	0.84	1.01	1.63
	SLB+AWD	0.62	1.47	0.93	1.12	1.54
	Conventional	0.65	0.61	0.57	0.87	
V3: Sin Thu Kha	SLB	0.50	1.76	1.30		
	SLB+AWD	0.51	1.92	1.10		
	Conventional	0.56	0.73	0.47		

Conclusion and recommendations

Comparative trials of water productivity under different cultivation management and cultivars demonstrated the following.

a) For the variety *Shwe Thwe Yin*, we replanted the main crop because stubbles were submerged and damaged due to heavy rain after harvesting the main crop. Thus, the data of *Shwe Thwe Yin* were referred to as reference values, and the other two varieties, i.e., *Thee Htat Yin* and *Sin Thu Kha*, were considered for comparisons.

b) For *Thee Htat Yin*, the water productivity of the main crop cultivated using the conventional farming method ranged from 0.56–0.65 g/l. The water productivity of paddy rice produced using traditional farming in parallel with the first- and second-generation ratoon crops were 0.61 and 0.57 g/l, respectively. In contrast, the water productivity of the first- and second-generation ratoon crops were 1.40 and 0.84 g/l, respectively, under the water management recommended by SALIBU rice ratoon cropping systems and 1.47 and 0.93 g/l, respectively, under intermittent irrigation water management. The water productivity of the first-generation ratoon crop was 2.3–2.4 times higher than that of paddy rice cultivated using the conventional farming method in parallel with the first-generation ratoon crop. In addition, the water productivity of the second-generation ratoon crop was 1.5–1.6 times higher than that of paddy rice cultivated using the conventional farming method in parallel with the second-generation ratoon crop.

c) For *Sin Thu Kha*, the water productivity of the main crop cultivated using the conventional farming method ranged from 0.50–0.56 g/l. The water productivity of paddy rice produced using traditional farming in parallel with the first- and second-generation ratoon crops were 0.73 and 0.47 g/l, respectively. In contrast, the water productivity of the first- and second-generation ratoon crops were 1.76 and 1.30 g/l, respectively, under the water management recommended by SALIBU rice ratoon cropping systems and 1.92 and 1.10 g/l, respectively, under intermittent irrigation water management. The water productivity of the first-generation ratoon crop was 2.4–2.6 times higher than that of paddy rice cultivated using the conventional farming method in parallel with the first-generation ratoon crop. In addition, the water productivity of the second-generation ratoon crop was 2.3–2.8 times higher than that of paddy rice cultivated using the conventional farming method in parallel with the second-generation ratoon crop.

d) The water productivity of the first- and second-generation ratoon crops under the water management recommended by SALIBU rice ratoon cropping and under intermittent irrigation water management was an average of 2.3 and 2.2 times higher than that of the paddy rice cultivated in parallel using conventional farming, respectively.

e) Compared to conventional farming with seed beds and transplanting, SALIBU ratoon cropping save up to 60% of the irrigation water used per unit yield, implying that replacing traditional double cropping with SALIBU cropping may double the crop yield and income of farmers while reducing irrigation water use by 20% per acre per annum in CDZ.

f) Future research themes include selecting suitable varieties for this farming, mechanisms for obtaining high yields, potential hazards of yield drop under soil conditions caused by continuous cropping, damage by pests, rats, and birds due to differences in growing time from conventional cultivation and rejection by conservative rice farmers.

Additional cultivation tests to compare the different ways of cutting stems at harvest — number of times, timing, and position

After conducting the cultivation trials mentioned above in this Chapter from June 2017 to October 2018 and after conducting the consecutive preliminary tests on 36 plots, we divided each plot into two sections. A total of 36 paddy field test plots, each approximately 32 m^2, constructed in WURS, DAR, were split into 72 subplots. Additional cultivation tests for different ways of cutting stems at harvest — number of times, timing, and position — were conducted in 72 test subplots in paddy fields.

WURS researcher Mr. Kyaw Myaing, who was involved in the cultivation test of 36 plots, had been wondering if he could introduce the one-time cutting of stems at the harvest into SALIBU ratoon cropping systems. SALIBU ratoon cropping systems had been considered appropriate for cutting paddy stems twice, including the first cutting for harvest at a high position around the timing of physiological maturity and the second cutting at 5 cm height above the ground surface a week later. He tried to introduce the one-time cutting of stems at harvesting into SALIBU ratoon cropping systems in vacant test fields around 36 cultivation trial plots in parallel and observed the differences in growth and yield.

Consequently, similar yields were obtained with one-time cutting as with two-time cutting. Therefore, we used 36 test plots for trials to compare the different ways of cutting stems at harvest, including the number of times, timing, and position, sown for the main crop in February 2019 and harvested May 31, 2019, followed by a comparative cultivation test of the first generation of the SALIBU ratoon crop.

Research methods

As shown in **Table 5-5**, 12 combinations were set up, including the cutting length of the stem, number of cuttings, and time intervals between first and second cuttings, with conventional practice (CP), i.e., transplanting, as the control.

Table 5-5. Combinations for trials to compare the different ways of stem cutting

<table>
<tr><th rowspan="2">No</th><th rowspan="2">Symbol</th><th colspan="2">Cutting length of stem (height above the ground surface: cm)</th><th rowspan="2">Intervals of the first and second cuttings (days)</th></tr>
<tr><th>first time (at harvest)</th><th>second time (re-cutting)</th></tr>
<tr><td>1</td><td>CP</td><td colspan="2">No stem cutting but transplanting</td><td>—</td></tr>
<tr><td>2</td><td>SC5</td><td>5</td><td>No re-cut of stem</td><td>—</td></tr>
<tr><td>3</td><td>SC15</td><td>15</td><td>No re-cut of stem</td><td>—</td></tr>
<tr><td>4</td><td>DC15(3)5</td><td>15</td><td>5</td><td>3</td></tr>
<tr><td>5</td><td>DC15(7)5</td><td>15</td><td>5</td><td>7</td></tr>
<tr><td>6</td><td>DC15(11)5</td><td>15</td><td>5</td><td>11</td></tr>
</table>

7	DC40(3)5	40	5	3
8	DC40(7)5	40	5	7
9	DC40(11)5	40	5	11
10	DC40(3)15	40	15	3
11	DC40(7)15	40	15	7
12	DC40(11)15	40	15	11

Remarks — CP: conventional practice, i.e., transplanting; SC: single cutting; DC: double cutting

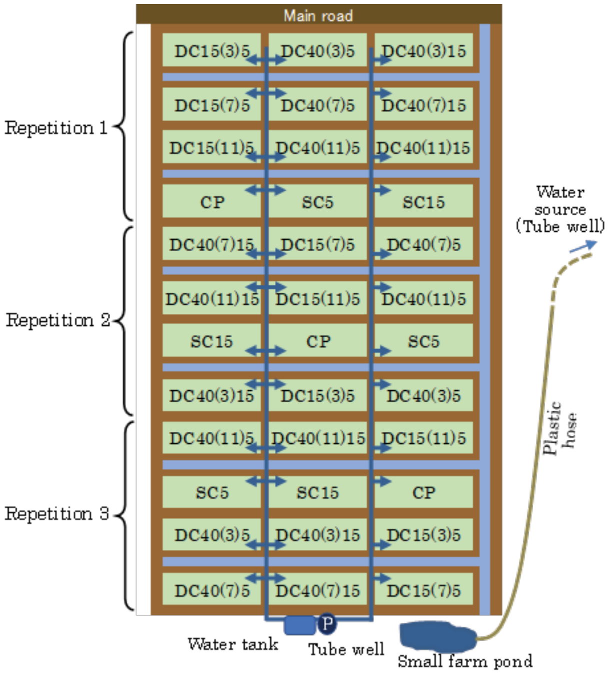


Fig. 5-6. Plane plan of the test fields

The 12 combinations presented in the above table were randomly set in 36 plots with three replications, as shown in **Figure 5-6**. For the CP plot cultivated in parallel with the first generation of the SALIBU ratoon crop, we sowed seeds in the nursery on May 24, raised the seedlings, and then transplanted the seedlings to the plot on June 13. In contrast, the single cutting (SC) and the first cutting in all double cutting (DC) patterns were performed on May 31 as the harvest. For example, in DC15(3)5 cutting method, the second cutting was performed at 5 cm height above ground surface on June 3, 3 d after the first cutting at 15 cm height, and in DC40(11)15 cutting method, the second cutting was performed at 15 cm height above ground surface on June 11, 11 d after the first cutting at 40 cm height. Thee Htat Yin cultivar was used for the trial.

Results are shown in **Figure 5-7**. Note that the error bars in each figure show the standard error (n=3), and the scale for the line graphs of each figure is on the right. Thus, the yield for one-time stem cutting (SC5, SC15) was similar to that for double stem cutting 40(7)5, recommended in SALIBU ratoon cropping systems, and that for the control CP. In addition, in the case of double cutting, yields tended to be lower when the interval between the first and second cuttings was 7 d, compared to 3 and 11 d, regardless of the combination of stem heights to be cut. Furthermore, when the second stem cutting was performed at 15 cm height, the yield was lower than in the other cases.

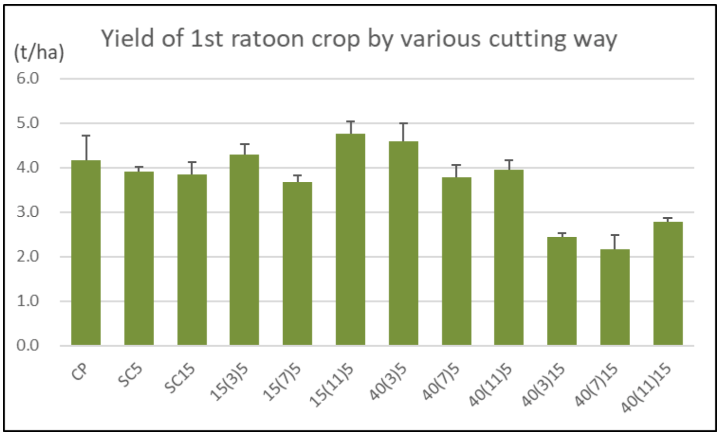


Fig. 5-7. Yield of the first ratoon crop based on various cutting ways (2019)

It is unclear why the interval between the first and second harvests tended to be shorter with a 7 d cutting interval or why 15(11)5 and 40(3)5 had higher yields than others. Thus, we decided to conduct a more precise cultivation test to compare the different ways of cutting stems at harvest in the following year, 2020, and we divided each of the 36 plots into two, preparing 72 subplots. In addition, we decided to conduct a cultivation test to investigate a) the optimal timing for single-cutting systems after physiological maturity (PM) and b) the optimal interval between the first and second cutting for double-cutting systems.

In Myanmar, a few farmers practice paddy rice cultivation using direct seeding instead of conventional transplanting. Direct seeding is a low-cost farming method that saves labor costs, omitting the need for nursery preparation and transplanting, and is practiced by relatively poor farmers, but its yield is generally lower than that of traditional transplant farming.

Therefore, as shown in **Table 5-6**, 24 combinations, including CP as the control and SC and DC of direct seeding, were designed, with 3 repetitions of test plots set up. Thee Htat Yin cultivar was sown in the nursery on January 28, 2020, with the main crop harvested in May of the same year based on trial design. The earliest harvest was for the direct seeding plant without transplanting on May 6, the reaping at physiological maturity was on June 11, and the ordinary harvest was on June 20.

Grain yield was obtained from filled grain weight in randomly chosen 25 hills (g) in each plot and calculated from the crop yield of the harvest area corrected to 14% moisture content. The following formula was used:

$$Grain\ Yield = \frac{\text{Weight of sample }(kg)}{6\ m2} \times \frac{10000\ m2}{1\ ha} \times \frac{1\ ton}{1000\ kg} \times \frac{100\ -\ \text{MC}}{86}$$

where MC is the average moisture content of grains in 25 hills (%).

Table 5-6. Combinations for trials to compare the different ways of stem cutting

Symbol	Day of stem cutting				Cutting height above the ground surface (cm)	
	1^{st} (at harvest)		2^{nd} (re-cutting)			
	Target	Real date	Target	Real date	1^{st} cutting	2^{nd} cutting
CP	CHD	2020/5/20	–	–	30	–
WDS SC5	CHD	2020/5/6	–	–	5	–
WDSDC30(3)5	CHD	2020/5/6	CHD+3days	2020/5/9	30	5
SC5PM0	PM	2020/5/11	–	–	5	–
SC5PM4	PM+4days	2020/5/15	–	–	5	–
SC5PM8	PM+8days	2020/5/19	–	–	5	–
SC5PM12	PM+12days	2020/5/23	–	–	5	–
SC15PM0	PM	2020/5/11	–	–	15	–
SC15PM4	PM+4days	2020/5/15	–	–	15	–
SC15PM8	PM+8days	2020/5/19	–	–	15	–
SC15PM12	PM+12days	2020/5/23	–	–	15	–
SC30PM0	PM	2020/5/11	–	–	30	–
SC30PM4	PM+4days	2020/5/15	–	–	30	–
SC30PM8	PM+8days	2020/5/19	–	–	30	–
SC30PM12	PM+12days	2020/5/23	–	–	30	–
DC15(3)5	PM	2020/5/11	PM+3days	2020/5/14	15	5
DC15(7)5	PM	2020/5/11	PM+7days	2020/5/18	15	5
DC15(11)5	PM	2020/5/11	PM+11days	2020/5/22	15	5
DC30(3)5	PM	2020/5/11	PM+3days	2020/5/14	30	5
DC30(7)5	PM	2020/5/11	PM+7days	2020/5/18	30	5
DC30(11)5	PM	2020/5/11	PM+11days	2020/5/22	30	5
DC30(3)15	PM	2020/5/11	PM+3days	2020/5/14	30	15
DC30(7)15	PM	2020/5/11	PM+7days	2020/5/18	30	15
DC30(11)15	PM	2020/5/11	PM+11days	2020/5/22	30	15

Remarks: CP: conventional practise (transplanting)
WDS: wet direct seeding
SC: single cutting
DC: double cutting
CHD: conventional harvesting day
PM: physiological maturity

Results and discussion

The main crop yield was more than 4.0 t/ha in each plot, 4.7 t/ha on average, and the coefficient of variation was 0.09. The crop yield of each cultivation plot was levelled roughly (see **Figure 5-8**). After harvesting the main crop, a high ratio of missing hills was observed for a few cutting ways. There were no missing hills in the CP system, and the concept of missing hills did not occur in WDS. For SC, when stems were cut at 5 cm height from the ground surface, with harvesting performed at physiological maturity, the missing hill ratio was 48.4%, remarkably high, but in other cases, the ratio was 7% or less. For DC, the missing hill ratio tended to be higher in the case of the second cutting at 5 cm height. Among these similar cutting ways, the missing hill ratio increased as the cut timing went closer to the time of PM for SC and as the interval between the first and second cutting went shorter for DC (see **Figure 5-9**).

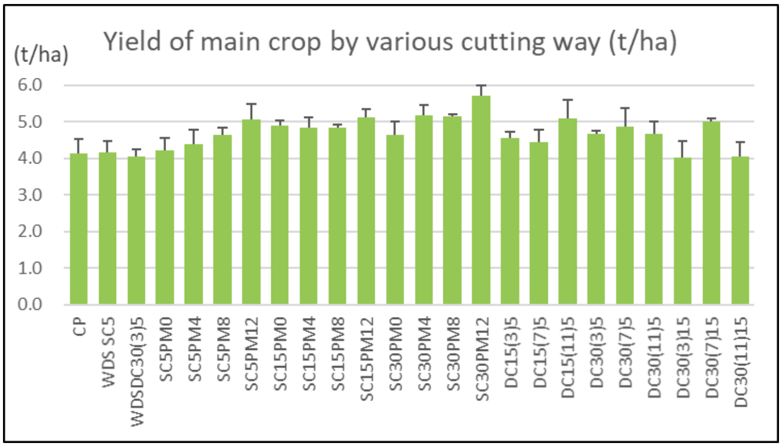


Fig. 5-8. Yield of the main crop based on various cutting ways (2020)

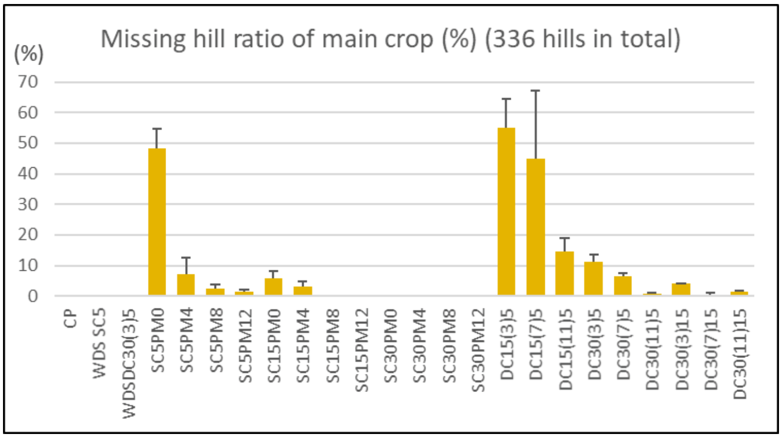


Fig. 5-9. Missing hill ratio of the main crop (2020, 336 hills in total)

Figure 5-10 shows the average yield in the first generation of SALIBU ratoon crop based on various cutting ways in 2020, and the yield index is defined as the yield of each first ratoon crop divided by that of CP of the first ratoon crop in the line graph. The scale for line graphs is on the right. Thus, there was an apparent decrease in yield in the cases of the single-cutting method, with stems cut at 30 cm height above the ground surface (SC30), but other cutting cases scored a yield index between 0.83 and 0.98. The cutting method of SC30, with a yield index between 0.36 and 0.64, is recommended by the International Rice Research Institute (IRRI) as a conventional ratoon cropping method. In contrast, the ratoon cropping developed by Mr. Erdiman in Sumatra is symbolled here as DC30(7)5. In the test, the DC30(7)5 method had a low missing hill ratio in the main crop of 6.3% (standard error, SE = 1.12%), a yield index of 0.96, and an average yield of 3.9 t/ha (SE = 0.14 t/ha), and therefore the ratoon cropping method developed by Mr. Erdiman can be said to achieve a stable high crop yield. The SC15PM4 cutting method resulted in more stable and higher yields than that of DC30(7)5 and was followed by SC5PM4. The missing hill ratio after harvesting the first ratoon crop was generally lower than after harvesting the main crop. It is shown that the missing hill ratio tended to be higher for the SC5 method, with stems cut at 5 cm height, and for the second cutting of the DC method at 5 cm height. In addition, a trend like that for the main crop is evident in the relation between the missing hill ratio and cut timing for SC or the time interval of cuttings for DC. Moreover, both SC and DC of WDS yield 80% or more than the yield of conventional transplant farming.

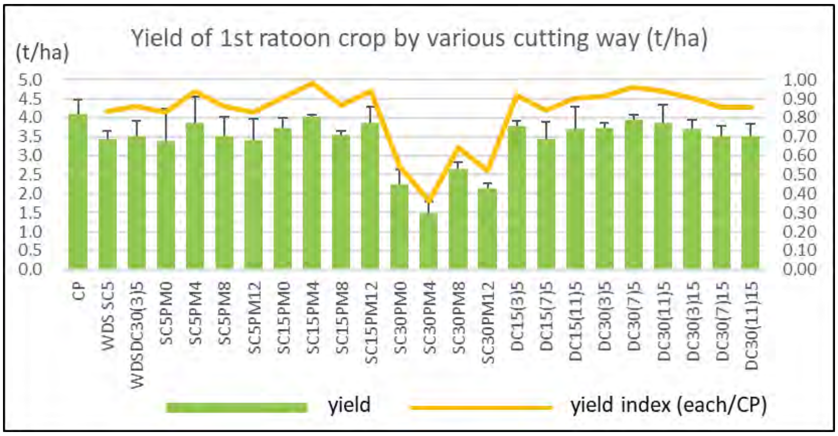


Fig. 5-10. Yield in the first ratoon crop based on various cutting ways (2020)

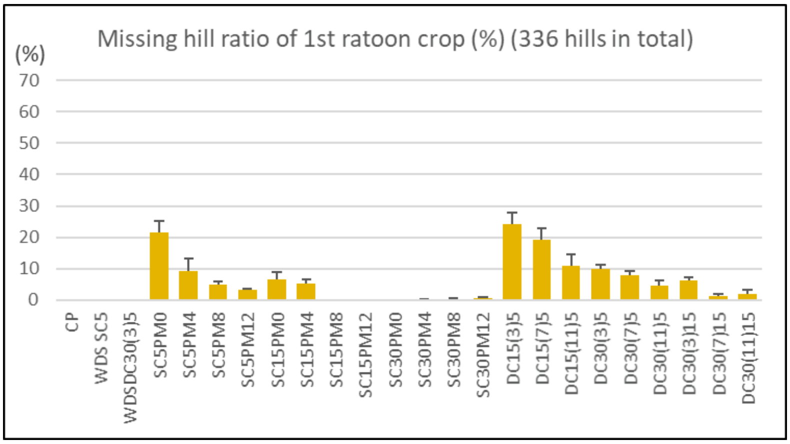


Fig. 5-11. Missing hill ratio of the first ratoon crop (2020, 336 hills in total)

Conclusion and recommendations

a) Single cutting at 30 cm height, SC30, recommended by IRRI, halves the yield, but single cutting at 5 and 15 cm height, i.e., SC5 and SC15, obtain 90% of crop yield of that obtained in CP and are applicable to the SALIBU ratoon cropping systems.

b) DC30(7)5 had a low missing hill ratio of the main crop of 6.3% (SE=1.12%), a yield index of 0.96, and an average yield of 3.9 t/ha (SE=0.14 t/ha), and therefore the ratoon cropping method developed by Mr. Erdiman can be said to achieve a stable high crop yield. In addition, single-cutting method SC15PM4 provides a more stable and higher crop yield than in DC30(7)5 and is followed by SC5PM4.

Chapter 6: Comparative field cultivation test for 33 cultivars- MyanmarⅢ

Introduction

Rice genotypes need to be screened for ratooning ability, adaptation to the soil, climate and topography, pest tolerance, and response to the fertilizer. The optimal time to cut the stems of the main crop for good ratooning is when culms are physiologically matured but still greenish, with the plant physiologically viable for ratoon tillering. Varieties differ considerably in their ratooning ability. Hence, the genetic inheritance of ratooning capacity is exploited. Variations in soil, water, light, and temperature greatly influence ratooning performance. Moreover, the new ratooning method with special cultivation treatment developed in West Sumatra, Indonesia, namely, SALIBU rice ratoon cropping system, allowed the harvest of rice grains 3.5–4 times annually and realized a higher yield of ratoon crop than that of the main crop.

The performance of agronomic characteristics of 33 rice genotype and their ratoon, including the number of tillers per hill, effective tillers per hill, days to flowering, plant height, panicle length, grains per panicle, matured grains ratio, thousand-grain weight, and grain yield were evaluated for the ratooning effects of SALIBU cropping on rice genotypes in Myanmar.

Specific objectives of the joint studies are,

a) To evaluate SALIBU rice ratoon cropping systems' adaptability in various varieties for high-yielding rice crop ratooning
b) To explore factors affecting the high yield of regenerated tiller cultivation under SALIBU rice ratoon cropping systems
c) To determine recommended variety for SALIBU rice ratoon cropping systems in terms of farmers' utility

Materials and Methods

A total of 33 rice entries (*Oryza sativa indica*) were sown on June 30, 2018 and transplanted for experimenting in the test fields of the Rice Research Section, Department of Agricultural Research (DAR), Yezin, Naypyitaw, Myanmar. After the harvest of the main crop of 33 varieties in October and November 2018, ratoon tillers regenerated from the main crop and were cultivated as the first-generation SALIBU ratoon crop, harvested in February–March 2019. The ratoon tillers, originating from the first-generation SALIBU ratoon crop, were grown as the second-generation crop and harvested from the end of April to May 2019. The experiment was conducted in simple trials in a demonstration plot, with a total area of approximately 0.45 ha. The size of each demonstration plot was 12 ft (3.6 m) in frontage width, 95 ft (29.0 m) to 130 ft (39.6 m) in depth, and 104–140 m^2 in area (see **Figure 6-1**.)

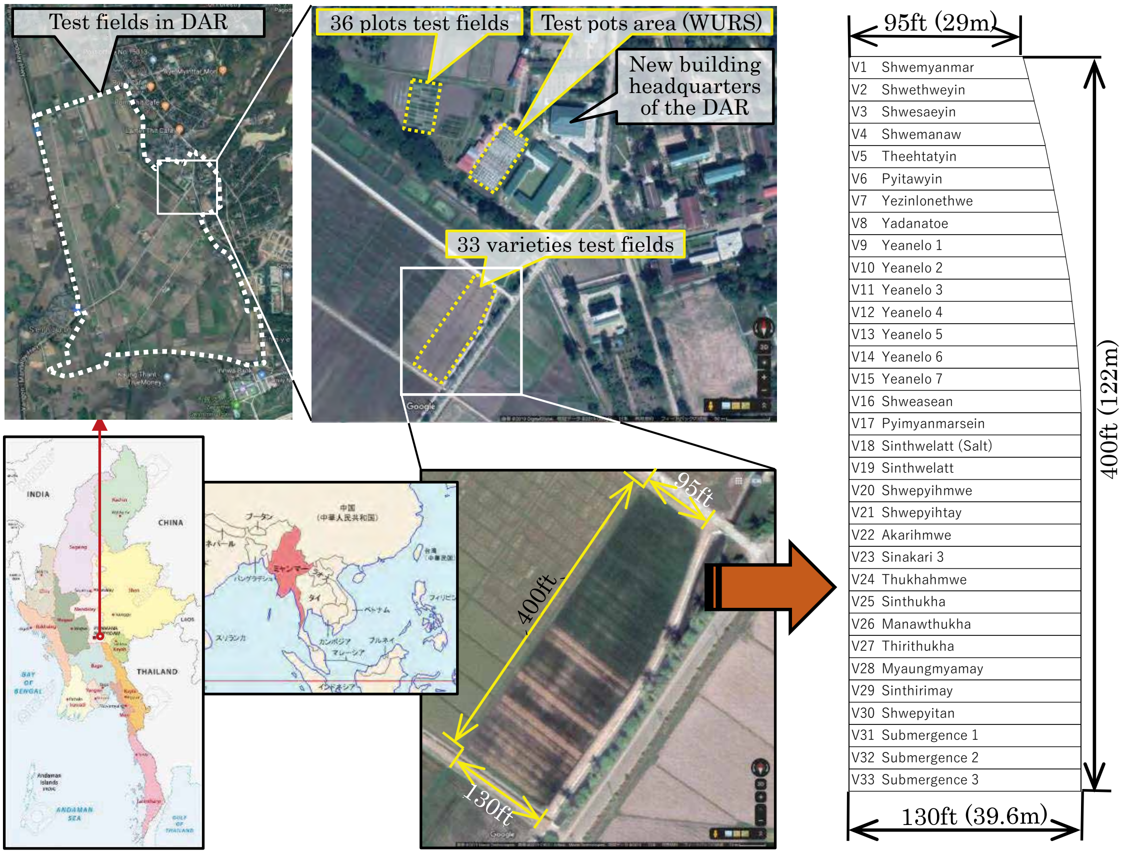


Fig. 6-1. Location and layout of test fields

Of the 33 rice varieties included in the trials, we selected 15, 5, 7, 1, and 5 varieties from the high yielding, quality-rice, drought-tolerant, salt-tolerant, and submergence-tolerant types, respectively. The list of cultivar names, types, parent lines, and places of origin is shown in **Table 6-1**.

Table 6-1. Descriptions of the selected 33 rice genotypes

Entry	Name	Type	Parents	Origin
V1	Shwemyanmar	1	RP 1674 – 690 – 39 (M 63 – 83/IRAT) /N 22	India
V2	Shwethweyin	1	IR 50	Philippine
V3	Shwesaeyin	1	unknown	-
V4	Shwemanaw	1	Tamil Nadu	India
V5	Theehtatyin	1	IR 13240 – 108 – 2 – 2 - 3	Philippine
V6	Pyitawyin	1	IR 77542 -90 -1 – 1- 1- 5 (IR BB 60/ IR 71730 -51 – 2)	IRRI
V7	Yezinlonethwe	2	LTH M4 -14	Myanmar

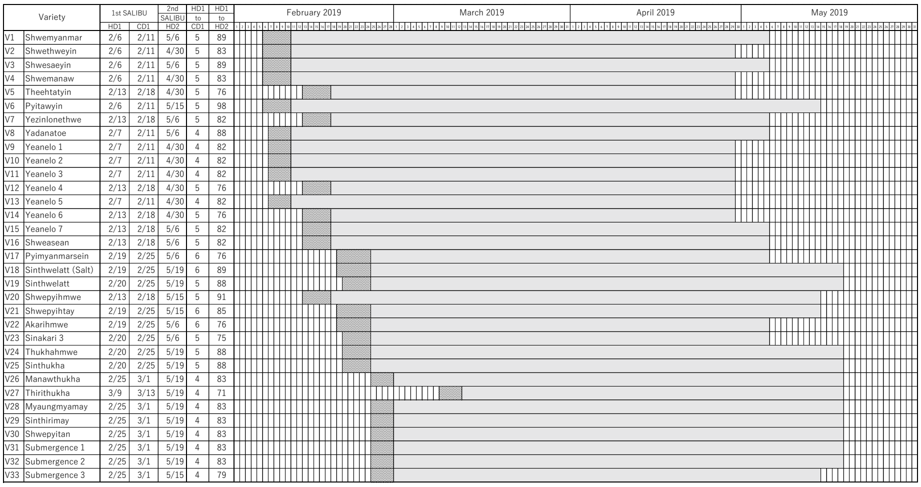
V8	Yadanatoe	1	Thai 1 – 9- 3 E	Thailand
V9	Yeanelo 1	3	IR 55423-01 (UPLRI 5/ IR 12979-24)	Philippine
V10	Yeanelo2	3	UPLRi 7 (C 22 / IR 26//C22/OS4)	Philippine
V11	Yeanelo 3	3	WAB 880 – SG6 (WAB 56 – 50 / CG 14)	WARDA
V12	Yeanelo 4	3	IR 87707 – 446 –B (IR 77298 – 14 -1-2-10/ IR77298 – 5 – 6-11)	Philippine
V13	Yeanelo 5	3	IR 87707 – 44 – 4 –B (IR 77298 – 14- 1 -2-10/IR 64 (NIL)	IRRI
V14	Yeanelo 6	3	IR 87707 – 182 – B – B – B (IR 64 NIL)	Philippine
V 15	Yeanelo 7	3	IR 87705 – 83 – 12 – B (IR 77298 – 14 – 1 -2 – 10/ IR 64	IRRI
V 16	Shweasean	1	unknown	-
V 17	Pyimyanmarsein	1	IR10T107 (IRRI 126/IRRI 135)	Philippine
V 18	Sinthwelatt (Salt)	4	Yn 3220 – MAS – 62 (Sinthwelatt/ Pawkali)	Myanmar
V 19	Sinthwelatt	2	IR 53936-60-3 (IR52912/ IR 29723// IR 28224)	IRRI
V 20	Shwepyihmwe	2	IR 66233 -151 – 1-1 (IET 10364/ IR 59648 – 2181-1-2-1)	Philippine
V 21	Shwepyihtay	1	Yn 2841-B-UL 26 (Tethom/Lonethwehmwe)	Myanmar
V 22	Akarihmwe	2	IR 78525 – 150 -1 (IR 67406 – 6- 49 – 2-3-1-3-3/IR 72865 -95	IRRI
V 23	Sinakari 3	1	RD 23 B	Thailand
V24	Thukhahmwe	2 (1)	Yn 3248 - BC 4 F2-112 (Manawthukha / Nanthahmwe)	Myanmar
V25	Sinthukha	1	IRYn 1068 – 7 -1 (Manawthukha/ IRBB 21)	Myanmar
V26	Manawthukha	1	Mashuri mutant (3628)	India
V27	Thirithukha	1	RMNTK 1- UL-16 (Manawthukha)	Myanmar
V28	Myaungmyamay	5	PRAM BEI KOUR (IR 41581/IR 26460// Lonethwehmwe)	Cambodia
V29	Sinthirimay	5	Tephana – 170-DB	Vietnum

V30	Shwepyitan	1	PSBRC 68	IRRI
V31	Submergence 1	5	Swarna Sub 1 (Swarna// IR49830-7-12 (FR 13 A)	India
V32	Submergence 2	5	BR 11 sub 1 (BR 11* 3 /IR 40931-33-1-3-2)	Philippine
V33	Submergence 3	5	IR 57514 Introgression Line	Thailand

Note: The number of “types” corresponds to each genotype group, such as 1, High yielding variety; 2, quality-rice; 3, drought-tolerant; 4, salt-tolerant; and 5, submergence-tolerant genotypes.

Source: Released New Varieties, Department of Agricultural Research, March 2018.

The day of harvest in the first generation SALIBU ratoon crop of each variety, the day of the second cutting, the day of the second generation harvest, and the duration between these events are shown in **Figure 6-2**. The harvest dates of the second generation SALIBU ratoon crop of 33 varieties started on April 30, 2019, for the earliest maturing variety and finished on May 19 for the latest maturing rice variety, with the growing period, i.e., the number of days from harvesting the first generation to reaping the second generation, ranging from 71–98 d, as shown in **Figure 6-2**. The harvest date of each variety is approximately 23–25 d after the 50% flowering date. Both generations of SALIBU ratoon crops were harvested at physiological maturity, almost one week before the expected ordinary harvest date.

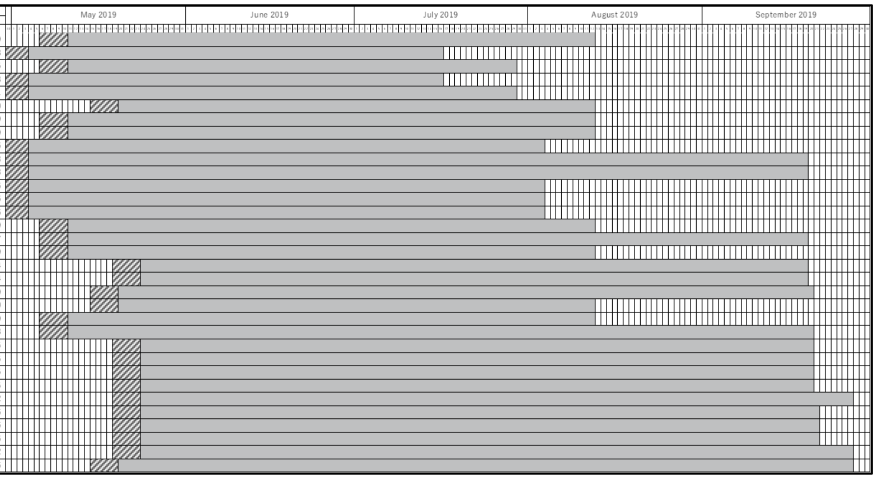


Note: HD1: Day of harvesting the first SALIBU ratoon crop
CD1: Day of the first cutting of the first SALIBU ratoon crop
HD2: Day of harvesting the second SALIBU ratoon crop

Fig. 6-2. Life period of the second SALIBU ratoon crop of each variety

Similarly, the day of harvest in the second generation SALIBU ratoon crop of each variety, the day of the second cutting, the day of the third-generation harvest, and the duration between these events are shown in **Figure 6-3**. The harvest dates of the third generation SALIBU ratoon crops of 33 varieties started on July 17, 2019, while ending on September 28, 2019, for the earliest and latest maturing varieties, respectively, and the growing period, i.e., the number of days from harvesting the second generation to reaping the third generation, being 78–143 d, as shown in **Figure 6-3**.

Variety		2nd SALIBU		3rd SALIBU	HD2 to	HD2 to
		HD2	CD2	HD3	CD2	HD3
V1	Shwemyanmar	5/6	5/11	8/13	5	99
V2	Shwethweyin	4/30	5/4	7/17	4	78
V3	Shwesaeyin	5/6	5/11	7/30	5	85
V4	Shwemanaw	4/30	5/4	7/17	4	78
V5	Theehtatyin	4/30	5/4	7/30	4	91
V6	Pyitawyin	5/15	5/20	8/13	5	90
V7	Yezinlonethwe	5/6	5/11	8/13	5	99
V8	Yadanatoe	5/6	5/11	8/13	5	99
V9	Yeanelo 1	4/30	5/4	8/4	4	96
V10	Yeanelo 2	4/30	5/4	9/20	4	143
V11	Yeanelo 3	4/30	5/4	9/20	4	143
V12	Yeanelo 4	4/30	5/4	8/4	4	96
V13	Yeanelo 5	4/30	5/4	8/4	4	96
V14	Yeanelo 6	4/30	5/4	8/4	4	96
V15	Yeanelo 7	5/6	5/11	8/13	5	99
V16	Shweasean	5/6	5/11	9/20	5	137
V17	Pyimyanmarsein	5/6	5/11	8/13	5	99
V18	Sinthwelatt (Salt)	5/19	5/24	9/20	5	124
V19	Sinthwelatt	5/19	5/24	9/20	5	124
V20	Shwepyihmwe	5/15	5/20	9/21	5	129
V21	Shwepyihtay	5/15	5/20	8/13	5	90
V22	Akarihmwe	5/6	5/11	8/13	5	99
V23	Sinakari 3	5/6	5/11	9/21	5	138
V24	Thukhahmwe	5/19	5/24	9/21	5	125
V25	Sinthukha	5/19	5/24	9/21	5	125
V26	Manawthukha	5/19	5/24	9/21	5	125
V27	Thirithukha	5/19	5/24	9/21	5	125
V28	Myaungmyamay	5/19	5/24	9/28	5	132
V29	Sinthirimay	5/19	5/24	9/22	5	126
V30	Shwepyitan	5/19	5/24	9/22	5	126
V31	Submergence 1	5/19	5/24	9/22	5	126
V32	Submergence 2	5/19	5/24	9/28	5	132
V33	Submergence 3	5/15	5/20	9/28	5	136



Note: HD2: Day of harvesting the second SALIBU ratoon crop
CD2: Day of the second cutting of the second SALIBU ratoon crop
HD3: Day of harvesting the third SALIBU ratoon crop

Fig. 6-3. Life period of the third SALIBU ratoon crop of each variety

Table 6-2 lists the sowing date, harvesting date, and second cutting date of the main crop, the harvesting date and second cutting date of the first to third-generation ratoon crops, respectively, and the number of days for these event days.

Table 6-2. List of sowing date, harvesting date, and second cutting date for main crop and each ratoon crop of 33 varieties and the number of days between events

Variety		Main crop			1st SALIBU		2nd SALIBU		3rd SALIBU		SD to HD0	HD0 to HD1	HD1 to HD2	HD2 to HD3	HD0 to CD0	HD1 to CD1	HD2 to CD2	HD3 to CD3
		SD	HD0	CD0	HD1	CD1	HD2	CD2	HD3	CD3								
V1	Shwemyanmar	6/30	10/23	11/6	2/6	2/11	5/6	5/11	8/13	8/16	115	106	89	99	14	5	5	3
V2	Shwethweyin	6/30	10/13	11/6	2/6	2/11	4/30	5/4	7/17	7/21	105	116	83	78	24	5	4	4
V3	Shwesaeyin	6/30	10/20	11/6	2/6	2/11	5/6	5/11	7/30	8/3	112	109	89	85	17	5	5	4
V4	Shwemanaw	6/30	10/15	11/6	2/6	2/11	4/30	5/4	7/17	7/21	107	114	83	78	22	5	4	4
V5	Theehtatyin	6/30	10/23	11/6	2/13	2/18	4/30	5/4	7/30	8/3	115	113	76	91	14	5	4	4
V6	Pyitawyin	6/30	10/26	11/6	2/6	2/11	5/15	5/20	8/13	8/16	118	103	98	90	11	5	5	3
V7	Yezinlonethwe	6/30	10/25	11/6	2/13	2/18	5/6	5/11	8/13	8/16	117	111	82	99	12	5	5	3
V8	Yadanatoe	6/30	10/27	11/6	2/7	2/11	5/6	5/11	8/13	8/16	119	103	88	99	10	4	5	3
V9	Yeanelo 1	6/30	10/28	11/6	2/7	2/11	4/30	5/4	8/4	8/9	120	102	82	96	9	4	4	5
V10	Yeanelo 2	6/30	10/24	11/6	2/7	2/11	4/30	5/4	9/20	9/25	116	106	82	143	13	4	4	5
V11	Yeanelo 3	6/30	10/30	11/6	2/7	2/11	4/30	5/4	9/20	9/25	122	100	82	143	7	4	4	5
V12	Yeanelo 4	6/30	10/25	11/6	2/13	2/18	4/30	5/4	8/4	8/9	117	111	76	96	12	5	4	5
V13	Yeanelo 5	6/30	10/18	11/6	2/7	2/11	4/30	5/4	8/4	8/9	110	112	82	96	19	4	4	5
V14	Yeanelo 6	6/30	10/21	11/6	2/13	2/18	4/30	5/4	8/4	8/9	113	115	76	96	16	5	4	5
V15	Yeanelo 7	6/30	10/22	11/6	2/13	2/18	5/6	5/11	8/13	8/16	114	114	82	99	15	5	5	3
V16	Shweasean	6/30	10/22	11/6	2/13	2/18	5/6	5/11	9/20	9/25	114	114	82	137	15	5	5	5
V17	Pyimyanmarsein	6/30	10/21	11/6	2/19	2/25	5/6	5/11	8/13	8/16	113	121	76	99	16	6	5	3
V18	Sinthwelatt (Salt)	6/30	11/14	11/20	2/19	2/25	5/19	5/24	9/20	9/25	137	97	89	124	6	6	5	5
V19	Sinthwelatt	6/30	11/9	11/20	2/20	2/25	5/19	5/24	9/20	9/25	132	103	88	124	11	5	5	5
V20	Shwepyihmwe	6/30	10/19	11/14	2/13	2/18	5/15	5/20	9/21	9/26	111	117	91	129	26	5	5	5
V21	Shwepyihtay	6/30	10/25	11/14	2/19	2/25	5/15	5/20	8/13	8/16	117	117	85	90	20	6	5	3
V22	Akarihmwe	6/30	10/27	11/14	2/19	2/25	5/6	5/11	8/13	8/16	119	115	76	99	18	6	5	3
V23	Sinakari 3	6/30	10/30	11/14	2/20	2/25	5/6	5/11	9/21	9/25	122	113	75	138	15	5	5	4
V24	Thukhahmwe	6/30	11/24	11/24	2/20	2/25	5/19	5/24	9/21	9/26	147	88	88	125	0	5	5	5
V25	Sinthukha	6/30	11/5	11/14	2/20	2/25	5/19	5/24	9/21	9/26	128	107	88	125	9	5	5	5
V26	Manawthukha	6/30	11/4	11/14	2/25	3/1	5/19	5/24	9/21	9/26	127	113	83	125	10	4	5	5
V27	Thirithukha	6/30	11/19	11/24	3/9	3/13	5/19	5/24	9/21	9/26	142	110	71	125	5	4	5	5
V28	Myaungmyamay	6/30	11/16	11/24	2/25	3/1	5/19	5/24	9/28	10/1	139	101	83	132	8	4	5	3
V29	Sinthirimay	6/30	11/6	11/24	2/25	3/1	5/19	5/24	9/22	9/27	129	111	83	126	18	4	5	5
V30	Shwepyitan	6/30	11/1	11/16	2/25	3/1	5/19	5/24	9/22	9/27	124	116	83	126	15	4	5	5
V31	Submergence 1	6/30	11/10	11/16	2/25	3/1	5/19	5/24	9/22	9/27	133	107	83	126	6	4	5	5
V32	Submergence 2	6/30	11/5	11/16	2/25	3/1	5/19	5/24	9/28	10/1	128	112	83	132	11	4	5	3
V33	Submergence 3	6/30	11/7	11/16	2/25	3/1	5/15	5/20	9/28	10/1	130	110	79	136	9	4	5	3

In central Myanmar, the climate is classified as monsoon season (June–September), post-monsoon season (October–January), and pre-monsoon season (February–May), and monthly meteorological data is shown in **Table 6-3**.

Table 6-3. Mean monthly meteorological data in the Department of Agricultural Research (DAR) in Myanmar (June 2018 to June 2019)

Months	Solar Radiation (w/m^2)	Air temperature (C)	Rainfall (mm)	Air RH %	Wind Speed (m/s)
JUN 2018	199.4	27.3	8.2	84.1	2.3
JUL 2018	188.7	26.9	8.3	86.8	1.7
AUG 2018	188.5	26.9	5.9	86.2	1.6
SEP 2018	230.4	27.7	3.1	83.6	1.2
OCT 2018	217.0	26.9	3.6	83.0	1.0
NOV 2018	223.7	25.2	0.0	75.9	1.0
DEC 2018	190.0	23.8	0.6	73.7	1.4
JAN 2019	213.0	22.6	0.1	68.2	1.0
FEB 2019	258.0	25.1	0.0	54.5	0.3
MAR 2019	275.0	27.6	0.0	50.1	0.4
APR 2019	297.0	31.0	0.2	51.8	0.4
MAY 2019	312.0	31.2	3.1	66.6	0.5
JUN 2019	235.6	28.6	3.2	79.8	0.7

Source: Section of water utilization research, DAR.

Figure 6-4 shows the amount of solar radiation (average value for 5 d data: bar graph, overlaid with the average value for 15 d data: line graph), and **Figure 6-5** shows air temperature (average value for 5 d data).

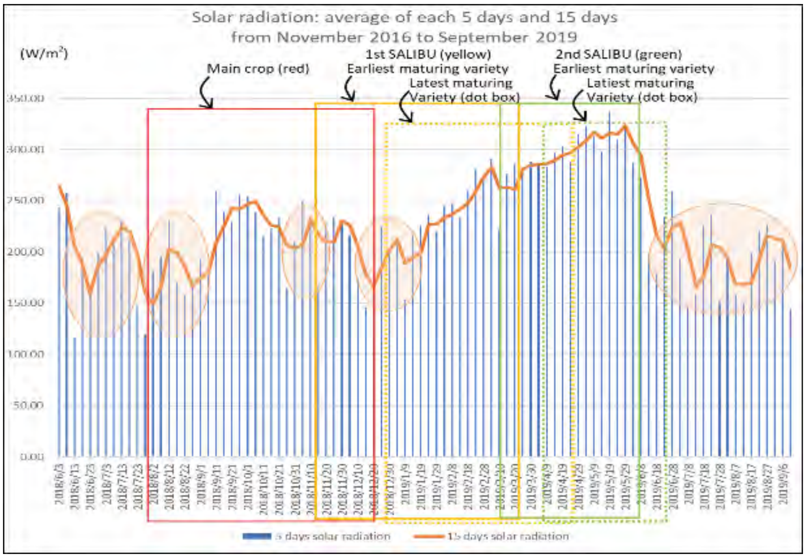


Fig. 6-4. Amount of solar radiation in DAR from June 2018 to September 2019

The intensity of solar radiation decreased from mid-June to the end of August 2018 (80 d), the end of October to the end of November 2018 (30 d), and the beginning of December 2018 to the end of January 2019 (40 d). The life period of the first-generation SALIBU ratoon crops is shown as yellow-lined and yellow-dashed boxes for early-maturing and late-maturing rice varieties, respectively, whereas that of the second-generation SALIBU ratoon crops is shown as green-lined and green-dashed boxes for early-maturing and late-maturing rice varieties, respectively.

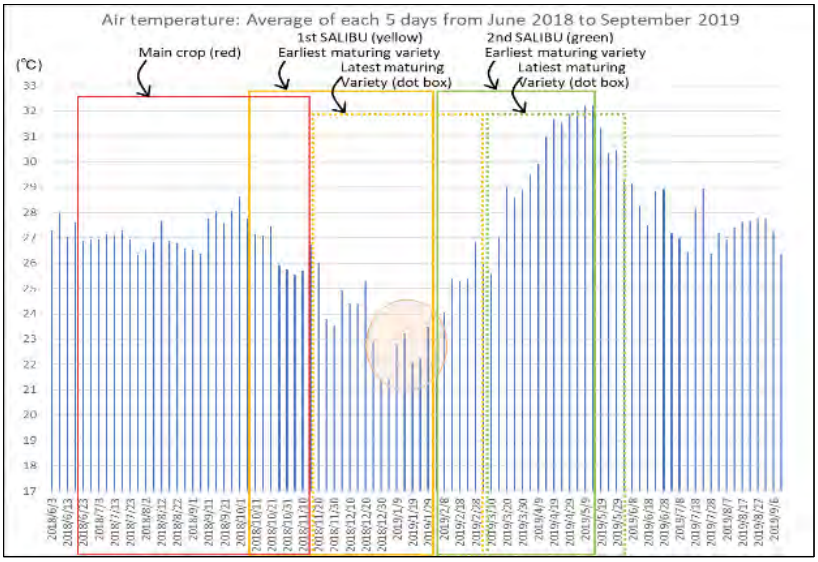


Fig. 6-5. Air temperatures recorded in DAR (June 2018 to September 2019)

Process of SALIBU rice ratoon cropping systems

The main crop is harvested at the physiological maturity stage when its culms are still green. The N and P fertilizers are applied to the main crop 14 d before ordinary harvesting, and the moisture is kept within field capacity two weeks before and after harvesting. The main crop is harvested by cutting at 15 cm above the soil surface, and the stubble is cut a second time at 3–5 cm height 3–4 d after harvesting. Nearly 3–7 d after the second time cutting, tillers come from dormant buds on the stubbles and produce new roots. Therefore, new SALIBU ratoon plants develop. Then, the part of the branch of culm with roots is transplanted from the region bearing more tillering hills to that with fewer tillering hills, a separation process, and stubble with bare aerial roots is inserted into the soil, an insertion process. The field is re-watered when tillers appear at 7–10 cm stem height.

- Fertilizer Management

  Nitrogen fertilizers are to be applied to the main crop 14 d before harvesting. Fertilizer is applied close to stubble rows to ensure rapid nutrient uptake and growth. The N and P fertilizers are necessary because they promote fine root development.

- Water Management

Water management before and after main crop harvest affects ratooning ability. The field needs to be moist but not flooded for two weeks at the end of the main crop ripening for ratooning. Draining paddy field several days after harvest also encourages ratooning. Re-watering is to be done 7–14 d after the second cutting, but the soil needs to be kept moist.

- Pest Management

  At the plot site, the menace of white fly pests and bacterial leaf blight disease was managed using pesticides. Weeds were also present in all plots and were cleaned manually.

- Time of harvest

  The best time to harvest the main crop for raising a good crop is when its culms are still green. The harvest date of each variety is approximately 23–25 d after the 50% flowering date, and the physiological maturity period is almost one week before the expected ordinary harvest date. The main crop was harvested, leaving a stubble height of 15–20 cm above ground level and allowed for ratooning. Four hills were selected for pre and postharvest data collection.

Data Gathering

Four hills were selected randomly from each unit block for pre- and postharvest dates for determining characteristics such as the number of tillers per hill, effective tillers per hill, days to flowering, days to maturity, plant height (cm), panicle length (cm), biomass weight (g), spikelet per panicle, thousand-grain weight (g), harvest index and grain yield.

- Soil analysis

  Before the experiment, we collected a composite soil sample from the experimental area to analyse its texture, pH, electrical conductivity (EC), soil organic matter, and available N, P, and K content. The soil sample was taken with a soil auger from at least 15 places randomly chosen in the experimental site. The analysis results indicated that soil pH was 6.7 and EC was 0.3 dS/m. Available N, P, and K were 52.9, 50.0, and 81.7 ppm, respectively, with 0.6% organic matter and sandy loam soil texture.

- Plant height (cm)

  Plant height was measured from the base of the plant to the tip of the tallest panicle at maturity. Four sample hills from each plot, excluding border hills, were measured randomly in three places.

- Days to flowering

  We recorded days to flowering when 50% of plants in the harvest area had flowered. The flowering date was recorded when 75–80% of each panicle had fully emerged erect. Days to flowering were counted from the sowing date for the mother plant.

- Productive tillers per hill

  The measure included only tillers with well-developed panicles and grains and counted from 12 hills at the physiological maturity stage.

- Length of panicle
  The panicle length was measured from the base of the panicle, i.e., the neck node, to its tip.
- Biomass weight
  Biomass weight was determined by weighing the whole rice plant, including seeds from the sample plant randomly chosen at the physiological maturity stage.
- Total number of spikelets per panicle
  The measure was determined by counting the total number of grains from the panicle in the sample plant selected randomly.
- Weight of 1000 grains (g)
  Thousand-grain weight was obtained by weighing 1000 filled grains, chosen randomly, using an analytical balance corrected to 14% moisture content.
- Grain yield (t/ha)
  Grain yield was obtained from the 2 m x 3 m harvest area in the middle of each plot. The harvested crop was manually threshed, dried, and cleaned before measuring moisture content. Grain yield was computed from the crop yield of the harvest area corrected to 14% moisture content. The following formula was used,

$$Grain\ Yield = \frac{\text{Weight of sample } (kg)}{6\ m2} \times \frac{10000\ m2}{1\ ha} \times \frac{1\ ton}{1000\ kg} \times \frac{100\ -\ \text{MC}}{86}$$

- Harvest index
  The harvest index was the ratio of dry grain yield and total dry weight. It was computed from the sample plants used in determining straw weight.

$$Harvest\ Index = \frac{\text{Dry Grain Yield}}{\text{Total Dry weight}}$$

- Yield index
  The yield index was calculated as the ratio of rice ratoon yield and main crop yield.
  Yield Index = Rice ratoon yield/ Main crop yield

Results and Discussion

Note that the experiment was laid out in simple trials as a demonstration plot, with an approximate total area of 0.45 ha, as mentioned in "Materials and Methods" on p.59. The simple cultivation trials do not allow for any repetition in data gathering, and therefore note that each data may include influence of soil unevenness to a certain extent.

Figure 6-6 compares the yield components and yield of 33 varieties in the main crop, the first and second generation SALIBU ratoon crops, and the order of the data on varieties within each category of rice variety follows the descending order of the yield of the main crop. The yield of the main crop and the first- and second-generation ratoon crops was 2.16–7.05 t/ha (average 4.69 t/ha; coefficient of variability, CV = 0.29), 1.88–5.69 t/ha (average 3.31 t/ha, CV = 0.29), and 2.65–11.45 t/ha (average 5.98 t/ha, CV = 0.35), respectively.

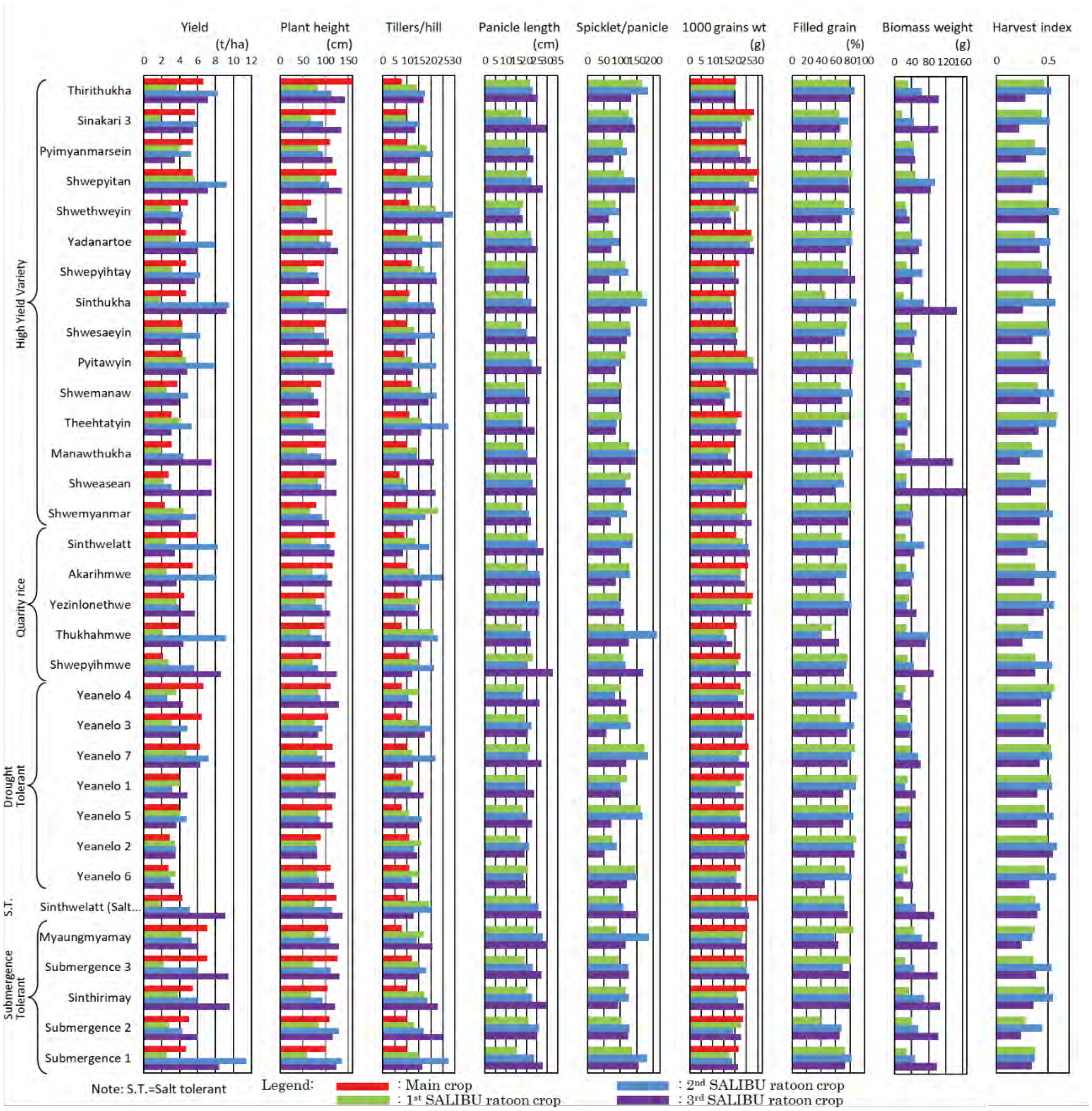


Fig. 6-6. Yield and yield component data of the main crop, the first, second, and third generation SALIBU ratoon crops

There is tremendous variation in yield among varieties in each generation. In contrast, the CVs of the plant height are 0.15, 0.12, 0.16 for the main crop, the first, and the second generation, respectively, and CVs of the thousand-grain weights are all 0.14, while CVs of the number of tillers are 0.13, 0.21 and 0.25, respectively. As the data of the main crop was unavailable, we compared the data of the first-generation SALIBU ratoon crop with that of the second generation. The CV of the panicle length of the first and second generation were 0.09 and 0.12, respectively, and the variation between varieties was slight. In addition, the CV of spikelet per panicle was considerable at 0.21 and 0.25, that of filled grain rate was small at 0.16 and 0.13, that of biomass weight was quite large at 0.24 and 0.37, and that of yield coefficient was small at 0.17 and 0.11, respectively.

Furthermore, to compare the data of each variety of the first and second generation SALIBU ratoon crops with the corresponding data of the main crop, the ratio of the data values of both first and second-generation SALIBU ratoon crops to the corresponding data value of the main crop was calculated, individually. In case of no data of the main crop, the ratio of the value of the second-generation SALIBU ratoon crop to that of the first-generation SALIBU ratoon crop was calculated, as shown in **Figure 6-7**.

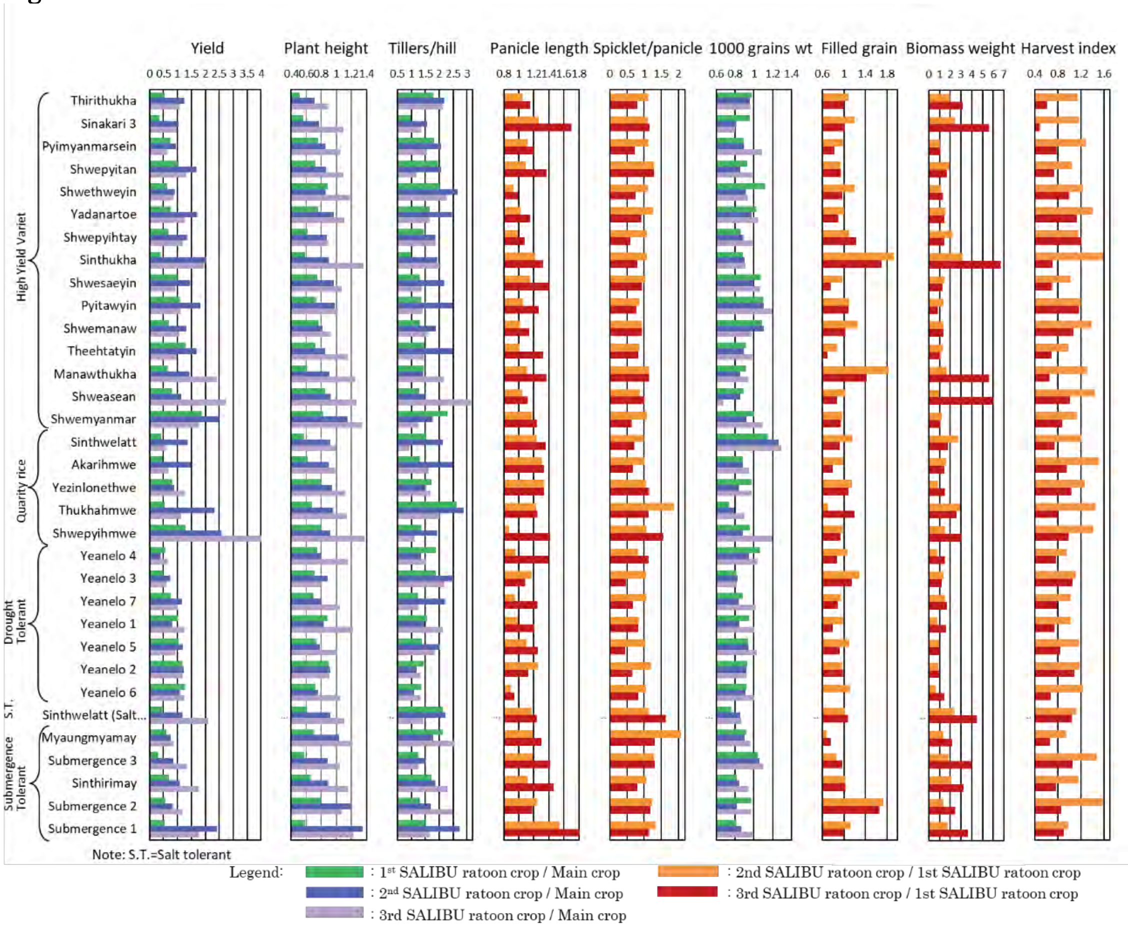


Fig. 6-7. Ratio of yield and yield component data of the main crop to that of the first and second generation SALIBU ratoon crops

Of the 33 varieties, 23 showed a decreased yield in the first-generation SALIBU ratoon crop, whereas 10 showed crop yields greater than in the main crop. Of these ten varieties, eight varieties showed a further increase in yield in the second generation. In addition, in 24 rice varieties, the rice yield of the second generation exceeded that of the main crop. However, there were nine varieties whose rice yields were below that of the main crop, and of these, eight rice varieties presented a rice yield of the first generation below that of the main crop.

In addition, there were nine varieties in which the yield in the second generation was more than 1.5 times that of the main crop, of which five rice varieties had crop yields more than twice that of the main crop. In four of these nine varieties, the crop yield in the first generation was below that of the main crop yield, but in the second generation, the crop yield recovered considerably. There were nine varieties with rice yields of the first and second generation more than that of the main crop and eight varieties with rice yields of the first and second generation less than that of the main crop. In addition, the most general case was 15 varieties with a rice yield of the first generation less than that of the main crop but with a rice yield of the second generation more than that of the main crop. The yield ratio of the first-generation crop to that of the main crop was 0.32:1.88, with an average of 0.77. However, the yield ratio of the second-generation crop to that of the main crop was 0.40:2.60, with an average of 1.36. Moreover, the yield ratio of the second-generation crop to that of the first-generation crop was 0.72:5.06, with an average of 2.00. In addition, the yield of the second-generation exceeded that of the first-generation in 30 varieties.

The plant height of the first-generation SALIBU ratoon crop was shorter than that of the main crop for all varieties. In the second generation, four rice varieties presented a plant height higher than in the main crop. The ratio of the first-generation plant height to the main crop plant height was 0.52:0.90 (average 0.71), and that of the second-generation plant height to the main crop plant height was 0.71:1.35 (average 0.91). In 31 varieties, the number of tillers of the first-generation SALIBU ratoon crop exceeded that of the main crop. Of these, in 23 rice varieties, the number increased in the second generation. In the second generation, the number of tillers exceeded that in the main crop in all rice varieties. The ratio of the first-generation tiller to the main crop tiller was 0.95:2.63 (average 1.59), and that of the second-generation tiller to the main crop tiller was 1.09:2.88 (average 1.97). Twenty-four varieties in the first generation and 28 rice varieties in the second generation presented thousand-grain weights lower than that of the main crop. The ratio of the first-generation thousand-grain weight to the main crop thousand-grain weight was 0.74:1.15 (average 0.94), and that of the second-generation thousand-grain weight to the main crop thousand-grain weight was 0.79:1.27 (average 0.91).

In addition, as data for specific characteristics such as panicle length, the number of spikelets per panicle, filled grain rate, biomass weight, and yield coefficient was not available for the main crop, we compared the corresponding data of the first-generation SALIBU ratoon crop with that of the second generation. The panicle length in 26 varieties was longer in the second generation than in the first generation. The ratio of the second-generation panicle length to that of the first-generation was 0.87:1.55 (average 1.12). There were 26 varieties with more spikelets per panicle in the second generation than in the first generation. The ratio of the number of spikelets per panicle in the second generation to that of the first generation was 0.82:2.08 (average 1.13). This ratio exceeded 1.8 in two varieties. Twenty varieties in the second generation presented a higher filled grain rate than in the first generation, and the ratio of the filled grain rate of the second generation to that of the first generation was 0.68:1.93 (average 1.10). In three varieties, the ratio exceeded 1.7. Twenty-six rice varieties in the second generation presented higher biomass weight than in the first generation, and the variation among these varieties was quite wide. The ratio of the second-generation biomass weight to the first-generation biomass weight was 0.69:3.16 (average 1.61). In fifteen rice varieties, the ratio exceeded 1.5, whereas, in eight, it exceeded 2.0. Twenty-nine rice varieties in the second generation presented a higher yield coefficient than in the first generation, and the ratio of the second generation yield coefficient to the first generation yield coefficient was 0.95:1.59 (average 1.22).

Next, the correlation coefficient between the main crop, first-generation, and second-generation SALIBU ratoon crop was obtained for the yield, plant height, number of tillers, and thousand-grain weight. In addition, the correlation coefficient between the first-generation and the second-generation SALIBU ratoon crop was obtained for panicle length, the number of spikelets per panicle, filled grain rate, biomass weight, and yield coefficient. Furthermore, for the first and second-generation SALIBU ratoon crops, we obtained a correlation between crop yield and the number of tillers and between crop yield, spikelets per panicle, and biomass weight. These results are listed in **Table 6-4**.

Table 6-4. Correlation coefficients between selected variables

Data	Explanatory variable	Response variable	Square value of correlation coefficients	Correlation coefficients	Evaluation
Yield	Main crop	1st Ratoon crop	0.0064	0.08	Almost no
Yield	Main crop	2nd Ratoon crop	0.0645	0.25	Some
Yield	1st Ratoon crop	2nd Ratoon crop	0.0005	0.02	Almost no
Plant height	Main crop	1st Ratoon crop	0.1981	0.45	Considerable
Plant height	Main crop	2nd Ratoon crop	0.3688	0.61	Considerable
Plant height	1st Ratoon crop	2nd Ratoon crop	0.0499	0.22	Some
Tiller/Hill	Main crop	1st Ratoon crop	0.0407	0.20	Some
Tiller/Hill	Main crop	2nd Ratoon crop	0.1776	0.42	Considerable
Tiller/Hill	1st Ratoon crop	2nd Ratoon crop	0.1105	0.33	Some
1000 grain weight	Main crop	1st Ratoon crop	0.5487	0.74	Strong
1000 grain weight	Main crop	2nd Ratoon crop	0.539	0.73	Strong
1000 grain weight	1st Ratoon crop	2nd Ratoon crop	0.7263	0.85	Strong
Panicle length	1st Ratoon crop	2nd Ratoon crop	0.1292	0.36	Some
Spicklet/panicle	1st Ratoon crop	2nd Ratoon crop	0.3947	0.63	Considerable
Filled grain	1st Ratoon crop	2nd Ratoon crop	0.0451	0.21	Some
Biomass weight	1st Ratoon crop	2nd Ratoon crop	0.1226	0.35	Some
Harvest index	1st Ratoon crop		0.3005	0.55	Considerable
1st Ratoon crop	Yield	Tiller/hill	0.0398	0.20	Almost no
1st Ratoon crop	Yield	Biomass	0.6573	0.81	Strong
1st Ratoon crop	Yield	Spicklet/panicle	0.0002	0.01	Almost no
1st Ratoon crop	Spicklet/panicle	Biomass	0.0174	0.13	Almost no
2nd Ratoon crop	Yield	Tiller/hill	0.387	0.62	Considerable
2nd Ratoon crop	Yield	Biomass	0.582	0.76	Strong
2nd Ratoon crop	Yield	Spicklet/panicle	0.2958	0.54	Considerable
2nd Ratoon crop	Spicklet/panicle	Biomass	0.2502	0.50	Considerable

Based on these results, thousand-grain weight showed a “strong correlation” between the main crop and the first and second-generation SALIBU ratoon crops. There was also a “strong correlation” between yield and biomass weight in the first and second-generation SALIBU ratoon crops. In contrast, the yield showed “almost no correlation” or “a little correlation” between the main crop, the first generation, and the second generation SALIBU ratoon crops. In addition, the first-generation SALIBU ratoon crop showed “almost no correlation,” whereas the second generation SALIBU ratoon crop showed a “considerable correlation” correlation between rice yield and the number of tillers, between rice yield and the number of spikelets per panicle, and between the number of spikelets per panicle and biomass weight.

Considerations and trial selection of suitable varieties for SALIBU cropping systems

Overall, the following considerations were made regarding the yield of 33 varieties in the main crop and the first and second-generation SALIBU ratoon crops.

1. No noticeable trend differences were observed related to the yield and yield components of SALIBU ratoon crops among the five categories of varieties, including fifteen high yielding, five quality-rice, seven drought-tolerant, one salt-tolerant, and five submergence-tolerant varieties. Overall, the average yield ratio of the first and second-generation ratoon crops to that of the main crop was 0.77 and 1.36, respectively, much higher than the average yield ratio of 0.2–0.5 of conventional ratoon cropping to that of the main crop. It is confirmed that high-yielding SALIBU ratooning applies to wide varieties. However, as there is a considerable variation in yield between rice varieties, selecting varieties with higher adaptability is necessary.

2. Within none of the main crop and the first and second-generation SALIBU ratoon crop combinations, there were considerable variations in yields between varieties (CV = 0.29–0.35), and the SALIBU ratoon crops in both generations had a strong correlation between yield and biomass weight. The variation in yield is considered to be strongly influenced by the physiological characteristics of each variety.

3. For 15 varieties, the yield in the first generation was less but in the second generation was more than that in the main crop. In addition, in 30 rice varieties, i.e., most of the tested varieties, the yield of the second generation exceeded that of the first generation. The rice yield is strongly influenced by the growth environment, such as low solar radiation and air temperature

4. There was little or no correlation between the yields in the main crop and the first and second-generation SALIBU ratoon crops, likely due to the influence of the previous generation crop, i.e., if the earlier crop was successful, the next is poor, and conversely, if the preceding crop was poor, the next becomes successful. This trend was observed in the nine-generations continuous cultivation test in a large pot in

DAR, suggesting that factors other than the physiological characteristics and growth environment of each variety may significantly influence the yield of ratoon crops.

5. There was no correlation between yield and the number of tillers, spikelets per panicle, and biomass weight under adverse growth conditions such as low solar radiation and low air temperatures during the period when the first generation SALIBU ratoon crops grew. In contrast, there was a relatively high correlation between them under good growth conditions during the second-generation SALIBU ratoon crop cultivation period, suggesting that the mechanism that affects the yield depending on the growth environment may vary depending on the variety.

It is necessary to carefully discuss with the DAR counterparts the aspects for selecting recommended varieties to compile a technical manual for SALIBU rice ratoon cropping systems and to present rice varieties suitable for this cultivation method to farmers. From the viewpoint of securing the yield linked to the farmer's income, considering the complexity of the interaction between "physiological characteristics of varieties" and "growth environment conditions" described in points "4" and "5" above, evaluation with the numerical value of yield is not enough nor reasonable. Rather than simply evaluating rice yield itself, we need to consider the compatibility of two facts "continuous cultivation gives a high yield of a certain level per year" and "stable yield as much as possible is desirable for each generation of continuous cultivation."

Thus, the total yields and their CVs were calculated for the 33 varieties in the first to third generation SALIBU ratoon crops and the main crop.

A) Total yield: Total value of crop yields in the above four generations from June 30, 2018, to July 17, 2019, or September 28, 2019, for 1 year and 1–3 months (382–455 d).
B) CV: Coefficient of variation of yield for the above four generations.

Based on these calculations, an evaluation method to classify each variety into "highly suitable," "suitable," and "others" categories is proposed (see **Figure 6-8**).

A) "Highly suitable varieties" have a total yield > 22 t/ha and CV < 0.22.
B) "Suitable varieties" have a total yield > 18 t/ha and CV < 0.30, except A.

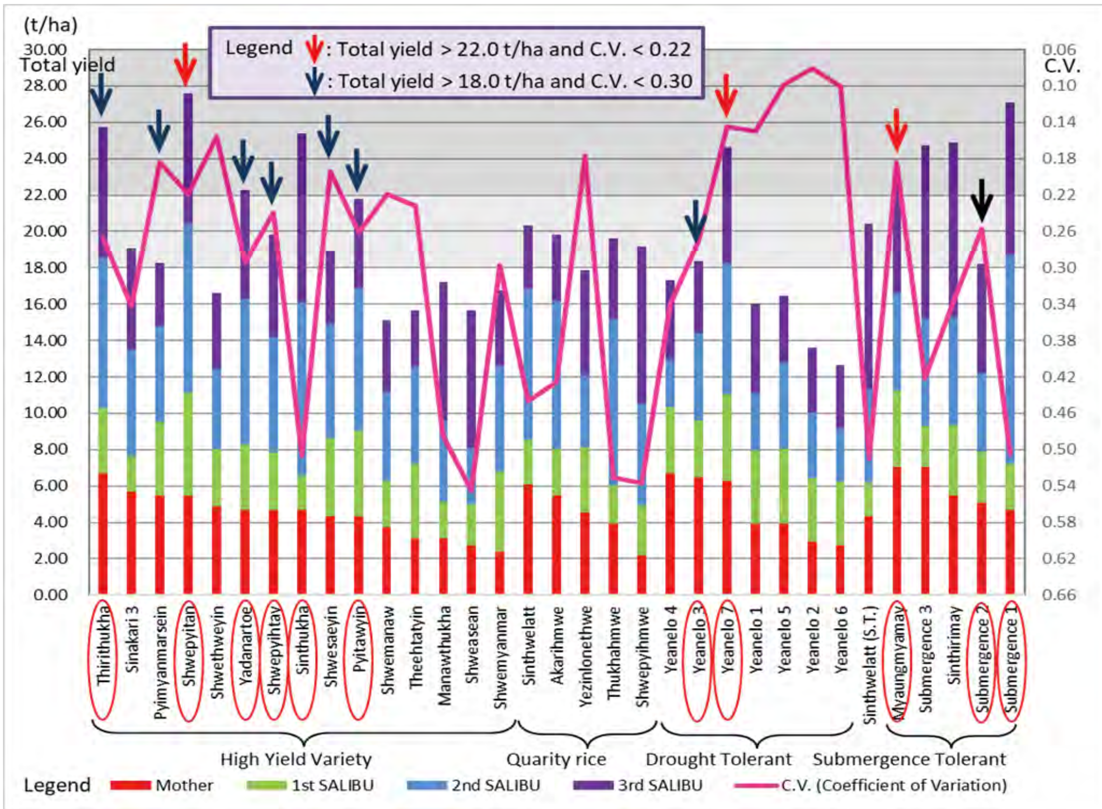


Fig. 6-8. Total yield and coefficient of variation in the yields of 4 consecutive generations

A) The category "highly suitable variety" consists of three varieties, i.e., *Shwepyitan*, *Yeanelo 7*, and *Myaungmyamay*.
B) The category "suitable variety" consists of eight varieties, i.e., *Thirithukha*, *Pyimyanmarsein*, *Yadanartoe*, *Shwepyihtay*, *Shwesaeyin*, *Pyitawyin*, *Yeanelo 3*, and Submergence 2.

Based on the above information, we made the following modifications.

1) Submergence 1 of the submergence-resistant cultivar category had the second highest average yield of 6.78 t/ha among the 33 cultivars, but its CV was 0.50, with a high yield fluctuation due to low crop yield in its first-generation SALIBU ratoon crop. Its total rice yield of second to third generation SALIBU ratoon crop was the highest among 33 varieties. The high performance of this ratoon crop was hard to overlook, and we added it to the "suitable varieties" category.
2) The high-yielding cultivar *Sinthukha* had the fourth highest average yield of 6.35 t/ha among the 33 varieties, but its CV was 0.51, with a high yield fluctuation due to the low yield of its first-generation SALIBU ratoon crop. Its total rice yield of second to third generation SALIBU ratoon crop was the second highest among the

33 varieties. The high performance of this ratoon crop was hard to neglect, and we added it to the "suitable varieties" category.

3) The high-yielding varieties *Pyimyanmarsein* and *Shwesaeyin* had low yield fluctuations of 0.18 and 0.19, but the total yields were 18.25 t/ha and 18.92 t/ha, respectively, higher than the criterion of 18 t/ha but lower than the average of the high-yielding varieties of 19.7 t/ha. As other rice varieties were recommended from the high-yielding varieties category, both these varieties were excluded from the list of "suitable varieties."

Ultimately, we selected 11 varieties, i.e., Thirithukha, Shwepyitan, Yadanartoe, Shwepyihtay, Sinthukha, Pyitawyin, Yeanelo 3, Yeanelo 7, Myaungmyamay, Submergence 1 and Submergence 2 as recommended varieties for farming under the SALIBU rice ratoon cropping systems. These cultivar names are circled in red in **Figure 6–8**.

Conclusion

In this Chapter, we evaluated 33 rice varieties among the popular varieties in Myanmar with as wide a range of characteristics as possible under conditions resembling those in the paddy fields used by farmers subjecting them to continuous cultivation for one year and three months from the main crop to the third generation of SALIBU ratoon crops. The purpose was to demonstrate the applicability of the original SALIBU rice ratoon cropping system developed by Mr. Erdiman, which requires manual harvesting at a high height of stems and the second cutting of these stems at a low height one week later to a wide range of cultivars. The demonstration also aimed to raise the interest of researchers, extension workers, and farmers.

In addition, in continuous cultivation throughout the year, the differences in cultivation period between early-maturing and late-maturing varieties accumulated, and the growing season of each variety shifted. As a result, it is not possible to test each cultivar under the same climatic conditions, and there is little point in making strict comparisons of yields and yield components for each harvest. Therefore, we organized the data without performing the repetitious plots considering the soil nonuniformity of the field. We selected 11 cultivars for which introducing SALIBU rice ratoon cropping systems can be recommended according to the calculation of the total yield of four times of harvests from the main crop to the third generation of SALIBU ratoon crop in succession and the coefficient of variation in yield.

The following are the findings obtained in this study:

a) Overall, the average yield ratios of the first and second-generation SALIBU ratoon crops to that of the main crop were 0.77 and 1.36, respectively, much higher than the average yield ratios of 0.2 to 0.5 of conventional ratoon cropping to that of the main crop.

b) Within none of the main crop and the first to third generation SALIBU ratoon crop combinations, there were considerable variations in yields between varieties (CV = 0.29–0.35), and SALIBU ratoon crops in the first and second generations had a strong correlation between yield and biomass weight.

c) Yield and yield component characteristics were highly variable in the main crop and the first and second-generation SALIBU ratoon crops because of highly variable genotypes, such as high-yielding, quality-rice, salt-tolerant, drought-tolerant, and submergence-tolerant genotypes. Moreover, ratooning ability depends on the varietal gene, based on other studies, so we must consider which variety is most suitable for SALIBU rice ratoon cropping systems.

d) Compared with the main crop, the first and second-generation SALIBU ratoon crop yield and yield component characteristics changed from season to season because of different environmental effects. In rice, some genes were affected by the environment because of changing the physiology process in the reproductive stage especially. There was genetic and environmental interaction (G x E) effect so some of the morphology characters were changed from generation to generation.

e) There was little or no correlation between yields in the main crop and the first and second-generation SALIBU ratoon crops for each variety.

f) There was no correlation between yield and the number of tillers, spikelets per panicle, and biomass weight under adverse environments such as low solar radiation and air temperatures but a relatively high correlation between these characteristics under a suitable setting.

g) One of the critical factors was field management in terms of fertilizers, water, weeds, harvesting, the timing of the second cutting, and the separation and filling up of the missing hills. Sometimes our trial facing with flooding conditions because of the adverse effect of weather. Although this technology could save all the agricultural input, we should consider the right way of agricultural practices.

h) Finally, the varieties *Shwepyitan*, *Yeanelo* 7, and *Myaungmyamay* were nominated as highly suitable varieties, and *Thirithukha*, *Pyimyanmarsein*, *Yadanartoe*, *Shwepyihtay*, *Shwesaeyin*, *Pyitawyin*, *Yeanelo* 3 and *Sinthirimay* were nominated as suitable varieties for high-yielding rice cultivation under SALIBU rice ratoon cropping systems. However, as these trials lacked replicates, there may be suitable varieties among the other 22.

Rice ratooning is not a new concept for the rice breeder but evaluating high-yielding main crop varieties for ratooning has a tremendous prospect for tropical agriculture. However, a higher yield with sound field management practice, predominantly vegetative and reproductive performance, is desired. We can conclude that rice ratooning offers an opportunity to increase annual yield per unit of the area because

SALIBU ratoon crops were almost 2–3 weeks shorter than the main crop. In addition, the advantage of SALIBU rice ratoon cropping systems is higher crop productivity, reduced production cost, and lower irrigation water requirements. Finally, more detailed ratoon cropping research on all aspects is needed, simultaneously with the search for resistant genetic material.

Future Plan

Further studies are needed for introducing agricultural machinery such as combine harvester in SALIBU rice ratoon cropping systems in the Rice Research Section test fields at DAR, Yezin, Naypyitaw. The combine harvester has rapidly become popular among rice farmers in Myanmar. Many Myanmar farmers have traditionally hired workers from their neighbors to harvest and thresh by hand. However, the level of labor costs is rising year by year in rural areas of Myanmar, and to reduce the amount of payment required for harvesting and threshing work, the introduction of combine harvesters that can perform these works at once is becoming a fashion.

Acknowledgments

We sincerely acknowledge the JIRCAS project (Development of Agriculture Risk Management for Climate Change Adaptation in Myanmar) for funding and other logistics. We gratefully thank the Director General, Department of Agricultural Research (DAR), Yezin, Naypyitaw, Myanmar, for his untiring efforts in monitoring and evaluating the project. The authors are thankful to young scientists from the Water Utilization Research Section in DAR, who participated actively in the conduct of the project.

Chapter 7: Introducing combine harvester into the field trial for 11 rice varieties and a cultivation test in a farmer's field – Myanmar Ⅳ

Introducing a combine harvester into the field trial for 11 rice varieties

Until now, rice has commonly been harvested manually in Myanmar. In addition, it has been common practice to thresh rice in rice fields using a threshing machine, spreading paddy on roads and squares paved with asphalt or concrete, exposing them to sunshine and high temperatures, and drying them. Like transplanting, harvest is done by village people paid daily wages to them, but labor costs in rural areas increase with each passing year. In contrast, large combine harvesters are imported mainly from China, and the business of renting them to farmers is rapidly spreading. Due to rising labor wages, manual harvesting is being replaced by combine harvesting in rural areas.

Considering the results of the cultivation test in Chapter 5, compared to the original method of SALIBU ratoon cropping systems with stems cut two times, a comparable yield can be obtained with the harvesting technique at one time at 5 cm height above ground level. Therefore, in this chapter, in cultivation tests to compare different harvesting methods, harvesting was performed at approximately 5 cm above ground level using manual harvesting methods and a combine harvester. In harvesting with a combine, there was no clarity about the damage received by plants due to the pressure of caterpillars running over stubbles. The total weight of a large combine harvester with 5–6 cutting rows was close to 4 tons, and therefore instead of using this initially, a comparative cultivation test was conducted using a small combine harvester with 2–3 cutting rows with a total weight less than 1 ton.

Unlike the previous Chapter 6, which aimed to compare yield and yield components between cultivars, the objective was to compare the differences in harvesting methods of the same cultivar. Therefore, as the growing period is the same between the two harvesting techniques and the comparison is made under the same weather conditions, to measure and compare the differences in yield and yield components as strictly as possible, three repetition plots for one cultivar were set up in the test fields where cultivation tests of 33 varieties had been conducted.

The cultivation test was conducted in February 2020 for about three years. During this, on February 1, 2021, a disgusting coup d'état by the military broke out, throwing Myanmar into political and economic turmoil. Although daily life was greatly affected, fortunately, the safety of the staff was protected at DAR, and there was no damage due to riots. However, after the coup d'état broke out, traveling from Japan to Myanmar became impossible, and we communicated only through e-mails and remitted funds for collaborative research. Considering the cancellation of many joint research projects between Japan and Myanmar it was almost a miracle that we managed to continue our collaborative research in such a challenging situation for three years.

Materials and methods

Using the 11 varieties selected as recommended varieties for farming under the SALIBU rice ratoon cropping systems in Chapter 6, we continued to investigate the impact of introducing combine harvesters for SALIBU on yield in the same experimental fields. As shown in Figure 7-1, 33 plots were divided into three zones, 11 cultivars were planted in each zone, and three replicate data were obtained.

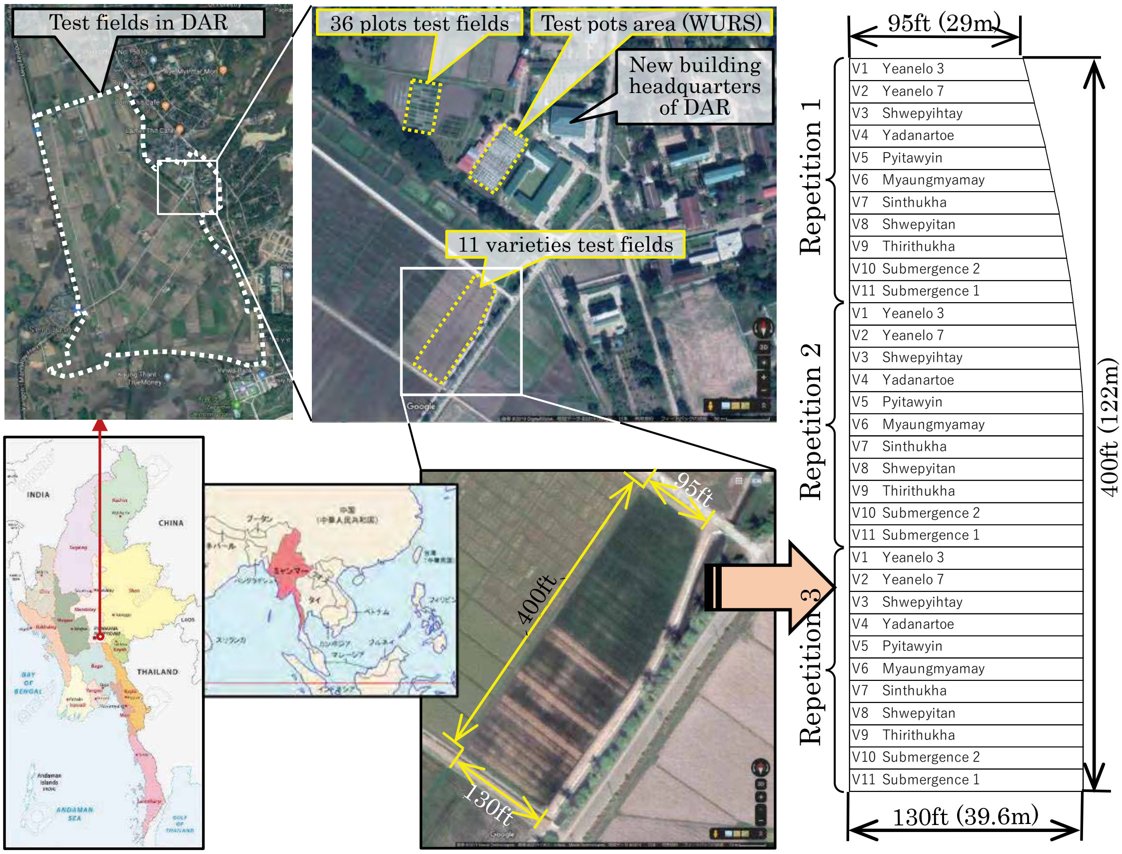


Fig. 7-1. Location and layout of test fields

Each of the 33 plots was divided into two harvesting areas, with one of the areas harvested using a combine harvester and the other manually (see **Figure 7-2**). And grain yield was obtained from filled grain weight in randomly chosen 25 hills (g) in both the areas in each plot and calculated from the crop yield of the harvest area corrected to 14% moisture content. The following formula was used:

$$Grain\ Yield = \frac{\text{Weight of sample }(kg)}{6\ m2} \times \frac{10000\ m2}{1\ ha} \times \frac{1\ ton}{1000\ kg} \times \frac{100\ -\ \text{MC}}{86}$$

where MC is the average moisture content of grains in 25 hills (%).

Fig. 7-2. Test fields (left in 2020, right in 2021 with rat fence)

In the cultivation test performed in 2020 (left photo), a few rats caused damage, and therefore in the cultivation test conducted in 2021 (right photo), we installed a vinyl fence to keep out rats. The damage caused by rats was partial and seemed not to impact the yield data primarily. In the spring of 2020, we ordered a small new combine harvester from Japan, as shown in **Figure 7-3**, and used it from June 2020, when the harvest of the main crops began. The cutting height used for combine harvester and manual cutting was approximately 5 cm in all tests.

Fig. 7-3. Combine harvester

Results and discussion

In 2020, the main crop was sown in nurseries on February 6 and harvested one by one based on varieties from June 3 to July 9. We harvested the first generation of SALIBU ratoon crops one by one based on varieties from September 5 to October 20. In the second generation of the SALIBU ratoon crop, eight out of eleven cultivars did not grow due to disease and insect damage, and only three cultivars, Yanelo7, Yadanatoe, and Pyitawyin, were harvested in December.

To finish harvesting the second generation of SALIBU ratoon crop by November, we decided to accelerate preparations for the start of cultivation trials in 2021. Therefore, in 2021, the sowing of the main crop in nurseries was performed in late January, and seedlings were transplanted in mid-February and harvested sequentially based on varieties from May 17 to June 25. The first generation of the SALIBU ratoon crop was harvested sequentially based on rice varieties from August 14 to October 2. In the second generation of the SALIBU ratoon crop, seven out of eleven cultivars did not grow due to disease and pest damage, and only four cultivars, Yanelo7, Yadanatoe, Pyitawyin, and Sinthukha, were harvested from November 17–25.

In 2022, the sowing of the main crop in nurseries was performed on January 22, 2022, with seedlings transplanted on February 11, 2022. As the crop suffered from pest damage caused by brown plant hoppers (BPH) and rice grassy stunt virus transmitted by them for two consecutive years in 2020 and 2021, in 2022, we applied highly effective pesticides in advance and conducted a cultivation test. The main crop was harvested sequentially based on varieties from May 16 to June 16, and the first generation of the SALIBU ratoon crop was harvested sequentially based on rice varieties from August 15 to October 19.

The average yield of the main crop of 11 varieties in 2020 (see **Figure 7-4**) harvested using a combine harvester ranged from the lowest for Thirithukha (4.2 t/ha; standard error, SE = 0.16 t/ha) to the highest for Submergence 1 (7.4 t/ha; SE = 0.09 t/ha), and that harvested manually ranged from the lowest for Submergence 2 (3.9 t/ha; SE = 0.51 t/ha) to the highest for Submergence 1 (7.0 t/ha; SE = 0.80 t/ha). Note that the error bars in each figure show SE (n = 3), and the coordinate axes for the line graphs of each figure are on the right.

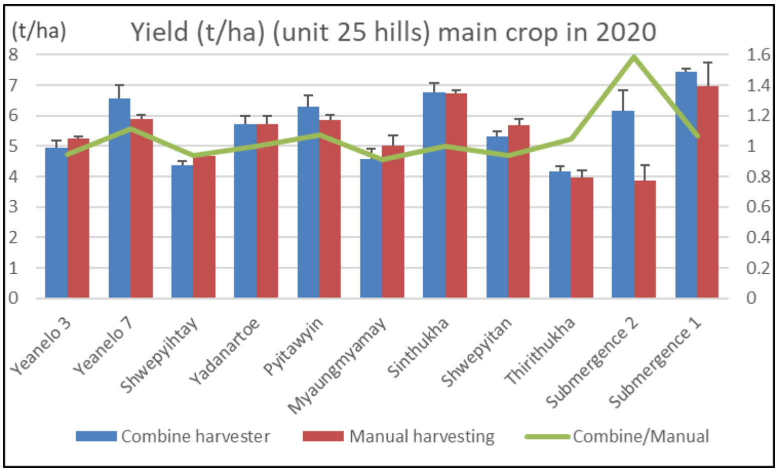


Fig. 7-4. Average yield of the main crop of 11 varieties in 2020

The difference between the yield of crops harvested using a combine harvester and by manual cutting was small (Combine/Manual, C/M = 0.91–1.11) except for Submergence

2 (C/M = 1.58). There is no general trend of higher yields by harvesting method. After harvesting the main crop, most stubbles of the first ratoon crop generated healthy shoots, but a few missing hills were seen. Both plots of Yeanelo 3, Shwepyihtay, and Sinthukha and the combine harvesting plot of Submergence 2 exceeded 5% in the proportion of missing hills, whereas others were below 5%.

The average yield of the first generation of SALIBU ratoon crop of 11 varieties in 2020 (See **Figure 7-5**) harvested using a combine harvester ranged from the lowest for Submergence 2 (2.1 t/ha; SE = 0.27 t/ha) to the highest for Yadanartoe (4.9 t/ha; SE = 0.26 t/ha), and that harvested manually ranged from the lowest for Myaungmyamay (2.1 t/ha; SE = 0.44 t/ha) to the highest for Pyitawyin (4.3 t/ha; SE = 0.08 t/ha). The average yield in 11 cultivars between the main crop and first ratoon crop reduced by 39% from 5.7–3.6 t/ha in combine-harvested plots and by 40% from 5.4–3.2 t/ha in manually harvested plots.

The difference between the yield of crops harvested using a combine harvester and by manual cutting in the first generation of SALIBU ratoon crops (C/M = 0.82–1.71) was greater than that in the main crops. The average yield of crops harvested using a combine harvester was 14% higher than that harvested manually.

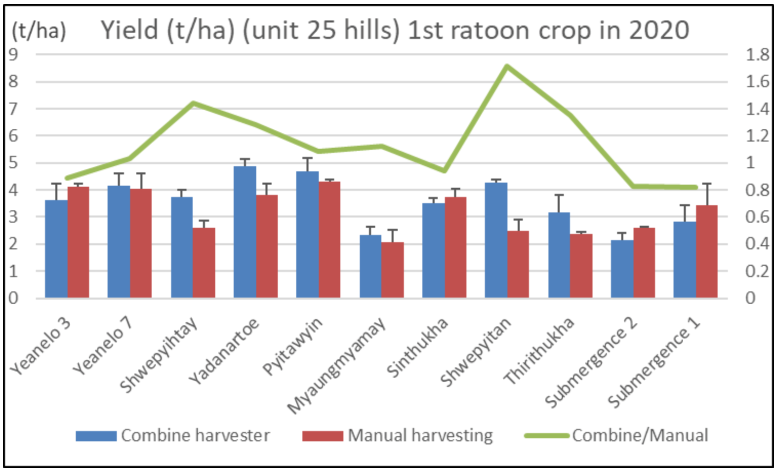


Fig. 7-5. Average yield of the first ratoon crop of 11 varieties in 2020

In the first generation of the SALIBU ratoon crop in 2020 many cultivars were affected by pest damage caused by BPH. The average proportion of missing hills of Yanelo 7, Yadanatoe and Pyitawyin was 26.7, 26.5, and 13.67% in combine-harvested plots and 43.8, 38.8, and 21.8% in manually harvested field plots, respectively, whereas other cultivars scored higher than 60%, mostly 80–100%. Thus, in the second generation of the SALIBU ratoon crop, eight cultivars became un-harvestable due to pest damage, and only three cultivars, Yanelo 7, Yadanatoe, and Pyitawyin, were able to be harvested. The yield of crops harvested using a combine harvester was slightly lower than that harvested manually (C/M = 0.85–0.99) (see **Figure 7-6**).

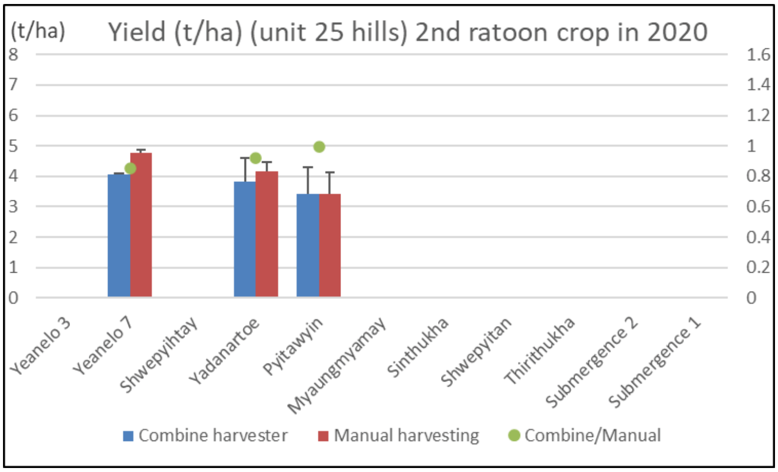


Fig. 7-6. Average yield of the second ratoon crop of 11 varieties in 2020

In 2021, we installed a vinyl fence to avoid the damage caused by rats based on the experience of 2020. The average yield of the main crop of 11 varieties in 2021 (see **Figure 7-7**) harvested using a combine harvester ranged from the lowest for Yanelo 7 (5.0 t/ha; SE = 0.39 t/ha) to the highest for Submergence 1 (6.8 t/ha; SE = 0.31 t/ha), and that harvested manually ranged from the lowest for Yanelo 7 (4.4 t/ha; SE = 0.31 t/ha) to the highest for Submergence 1 (7.1 t/ha; SE = 0.50 t/ha).

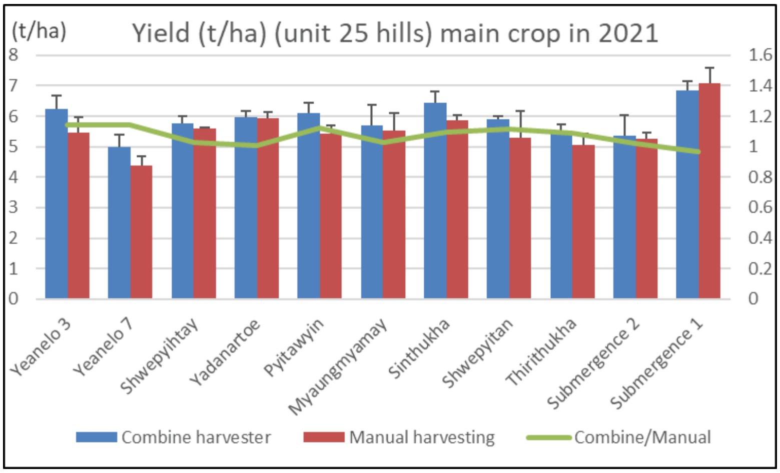


Fig. 7-7. Average yield of the main crop of 11 varieties in 2021

The difference between the yield of crops harvested using a combine harvester and by manual cutting was small (C/M = 0.96–1.14) for all cultivars. The average yield of crops in 11 cultivars harvested using a combine harvester was 5.9 t/ha, slightly higher than that harvested manually with 5.5 t/ha. After harvesting the main crop, most stubbles of the first ratoon crop generated healthy shoots, but some missing hills were seen. Both plots of Yeanelo 3, Shwepyihtay, Sinthukha, and Submergence 2 exceeded 11% in the proportion of missing hills, whereas others were below 11%.

The average yield of the first generation of SALIBU ratoon crop of 11 varieties in 2021 (See **Figure 7-8**) harvested using a combine harvester ranged from the lowest for Thirithukha (2.5 t/ha; SE = 0.27 t/ha) to the highest for Yadanartoe (4.4 t/ha; SE = 0.08 t/ha), and that harvested manually ranged from the lowest for Myaungmyamay (1.7 t/ha; SE = 0.41 t/ha) to the highest for Pyitawyin (4.4 t/ha; SE = 0.21 t/ha). The average yield in 11 cultivars between the main crop and the first ratoon crop reduced by 40 and 45% from 5.9–3.5 and 5.5–3.1 t/ha in combine-harvested and manually harvested plots, respectively.

The difference between the yield of crops harvested using a combine harvester and by manual cutting in the first generation of SALIBU ratoon crops (C/M = 0.93–1.65) was slightly higher than that in the main crops. The yield of crops harvested using a combine harvester is generally higher than that harvested manually. The average yield of crops harvested using a combine harvester in 11 cultivars was 15% higher than that harvested manually.

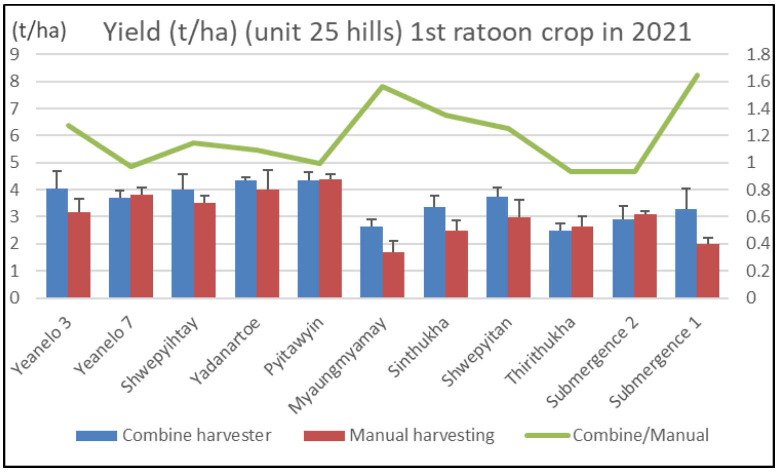


Fig. 7-8. Average yield of the first ratoon crop of 11 varieties in 2021

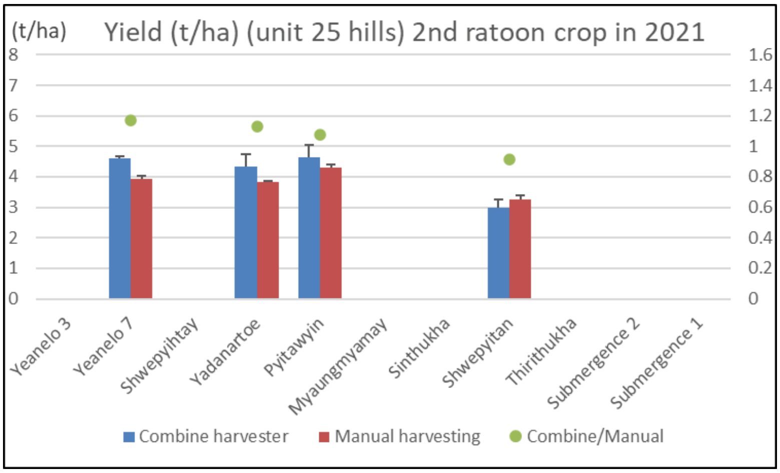


Fig. 7-9. Average yield of the second ratoon crop of 11 varieties in 2021

In the first generation of the SALIBU ratoon crop in 2021, many cultivars were again affected due to pest damage caused by BPH. The average proportion of missing hills is generally higher than 60%, mostly nearly 100%. Only four cultivars, Yanelo 7, Yadanatoe, Pyitawyin, and Shwepyitan, showed an average proportion of missing hills below 60% in combine harvested plots at 58.1, 29.9, 9.6, and 36.0%, respectively, although in manually harvested field plots, the corresponding values for these cultivars were 83.9, 40.6, 44.6 and 64.7%, respectively. Thus, in the second generation of the SALIBU ratoon crop, many cultivars became un-harvestable due to pest damage as in 2020, and the abovementioned cultivars, Yanelo 7, Yadanatoe, Pyitawyin and Shwepyitan, were able to be harvested. The yield of crops harvested using a combine harvester was slightly higher than that harvested manually (see **Figure 7-9**).

In 2022, we prepared and applied effective chemicals to avoid the damage caused by BPH based on the experience of 2020 and 2021. The average yield of the main crop of 11 varieties in 2022 (See **Figure 7-10**) harvested using a combine harvester ranged from the lowest for Shwepyihtay (4.9 t/ha; SE = 0.50 t/ha) to the highest for Yadanartoe (6.1 t/ha; SE = 0.75 t/ha), and that harvested manually ranged from the lowest for Shwepyihtay (4.6 t/ha; SE = 0.53 t/ha) to the highest for Yadanartoe (6.1 t/ha; SE = 0.16 t/ha).

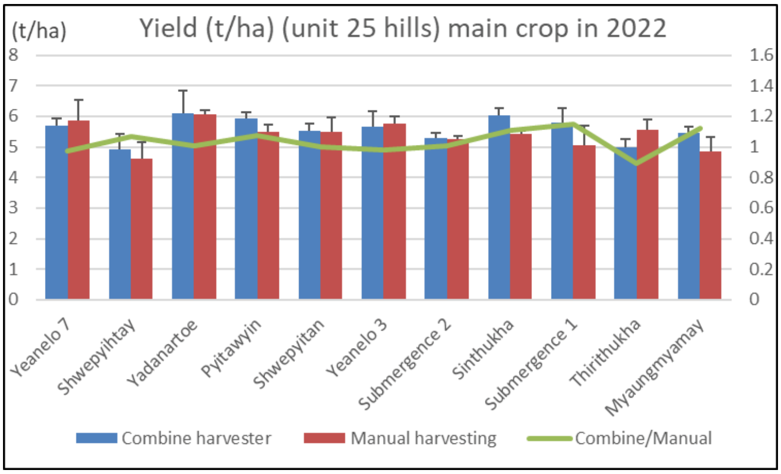


Fig. 7-10. Average yield of the first ratoon crop of 11 varieties in 2022

The difference between the yield of crops harvested using a combine harvester and by manual cutting was small (C/M = 0.89–1.15) for all cultivars. The average yield of crops harvested using a combine harvester in 11 cultivars was 5.6 t/ha, slightly higher than that harvested manually with 5.4 t/ha. After harvesting the main crop, a high ratio of missing hills was observed in the stubbles of the first ratoon crop in a few cultivars. Both combine-harvested and manually harvested plots of Shwepyihtay and Sinthukha and the manually harvested plot of Yanelo3 exceeded 60% in the proportion of missing hills, whereas others were mostly below 30%. There was no tendency for the missing hills ratio to be higher in combine-harvested plots, and for many cultivars, the missing hills ratio was lower in combine-harvested field plots than in manually harvested plots. (See **Figure 7-11**)

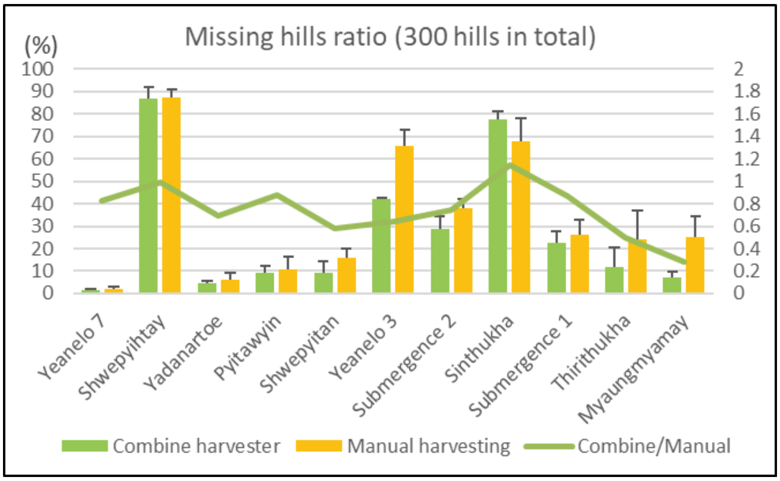


Fig. 7-11. Ratio of missing hills of the main crop in 2022

The average yield of the first generation of SALIBU ratoon crop of 11 varieties in 2022 (see **Figure 7-12**) harvested using a combine harvester ranged from the lowest for Yanelo 3 (4.4 t/ha; SE = 0.06 t/ha) to the highest for Shwepyitan (5.5 t/ha; SE = 0.26 t/ha), and that harvested manually ranged from the lowest for Sinthukha (4.3 t/ha; SE = 0.30 t/ha) to the highest for Shwepyitan (5.6 t/ha; SE = 0.24 t/ha). The difference between the yield of crops harvested using a combine harvester and by manual cutting in the first generation of SALIBU ratoon crops is small (C/M = 0.93–1.18) for all cultivars. The average yield of crops harvested using a combine harvester was 4.9 t/ha, slightly higher than that harvested manually with 4.7 t/ha.

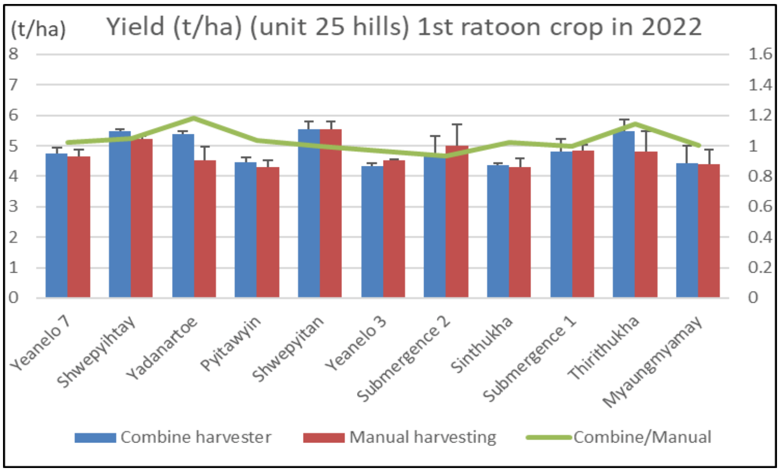


Fig. 7-12. Ratio of missing hills of the main crop in 2022

In the first generation of the SALIBU ratoon crop, none of the cultivars were affected by pest damage owing to the appropriate effect of the applied chemicals to avoid the damage caused by BPH. Therefore, the yield of the first ratoon crop of each cultivar scored stable at a high level, vastly improved from the crop yields in 2020 and 2021. The average crop yield in a total of 11 cultivars between the main crop and the first ratoon crop was reduced by 13% from 5.6–4.9 t/ha in combine-harvested plots and by 12% from 5.4–4.7 t/ha in manually harvested field plots.

All cultivars scored the yield of the first ratoon crop more than 70% of that of the main crop. Shwepyihtay scored 11–14% higher yield in the first ratoon crop than in the main crop for both harvesting methods, but its high performance could have depended on its management to fill the missing hills because of its high missing hills ratio (87–88%). In contrast, Shwepyitan had a low missing hills ratio of 9.1% in combine-harvested plots and 15.8% in manually harvested field plots, and the yield of the first ratoon crop was 100% compared to the main crop yield, showing excellent results (see **Figure 7-13**).

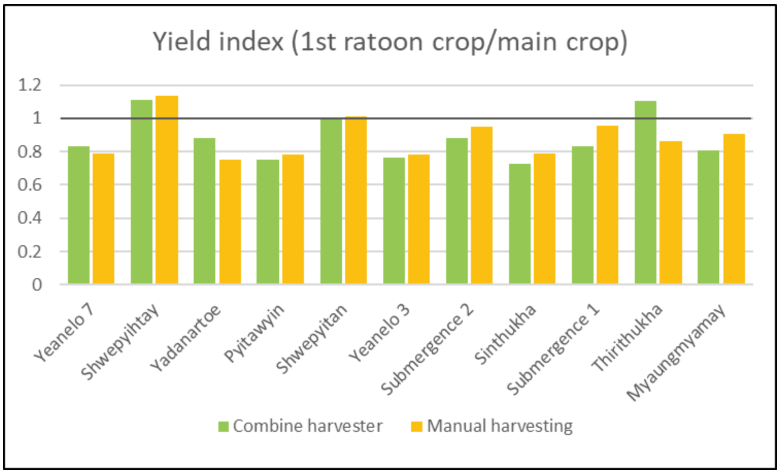


Fig. 7-13. Yield index of the first ratoon crop against the main crop in 2022

Conclusion and recommendations

The following are the findings obtained in this study:

a) In the case of combine harvesting, we expected that the plants would be damaged by the pressure of caterpillars running over stubbles. However, there was a tendency that the missing hills ratio did not depend on the harvesting method, and the yield of the first ratoon crop in the case of combine harvesting was equal to or more than that of manual harvesting, dispelling such concerns.

b) In this cultivation test, to secure the bearing capacity of the soil against the weight of the combine harvester, water was drained one week before harvesting, although it is considered that the decrease in yield due to this was negligible.

c) Harvesting with a small and light combine harvester with 2–3 cutting rows caused no damage to stubbles compared to manual harvesting and can be concluded to be introduced practically well into SALIBU ratoon cropping systems.

d) Whether there is a high incidence of pests such as BPH depends on field and weather conditions, but it is desirable to adopt adequate measures when the occurrence is recognized. In the worst case, there is a risk that the second generation of SALIBU ratoon crop will harvest none.

Supplementary cultivation test in a farmer's field

The main crop was sown in May 2019 in a farm field of Taze township located about 120 km north-northwest of Mandalay, the second largest city in Myanmar, harvested on September 4, 2019, and then continuously cultivated for ratoon crops under the SALIBU rice ratoon cropping systems. The outline of the cultivation verification test is as follows.

- Camp name: *Myoma* Extension Camp
- Extension staff: U Myat Kyaw
- Plot size: 0.8 ac
- Variety name: *Sin Thu Kha*
- Life period: 135 d
- Nursery preparation date: May 2, 2019
- Sowing date: May 22, 2019
- Spacing: 6 x 8 inches
- Growing technique: Line sowing with manual transplanting (one line omitted after every six lines sown)
- Fertilizer application
    - For mother plant
        - Basal Fertilizer application: Compound (15:15:15) – 50 kg
        - Tillering stage (25 – 30 DAT): Urea – 50 kg
        - Fertilizer applied amount: T-super – 25 kg and urea – 25 kg (at 114 DAS)
- Harvest date of mother plant: September 4, 2019 (134 DAS)
- Yield: 88 basket / 0.8 acre (5.7 t/ha)
- Fertilizer application
    - For first SALIBU
        - At 7 DAS: Compound (15:15:15) – 50 kg
        - At 25 – 30 DAS: Urea – 25 kg
        - Two weeks before harvest: Urea – 25 kg
- Irrigation frequency: Total two times – September 18, 2019, and October 29, 2019 (only one-third duration is needed than in a regular irrigation system)
- Expected harvest date of the first generation of SALIBU – November 30, 2019 (87 d after harvesting the main crop)

The main crop was harvested with a mower on September 4, 2019, at a cutting height of 15 cm from the soil surface, and 5 d after harvesting, on September 9, 2019, the second cutting of stems was performed using the mower. However, as the mower caused a few cracks, damaging the tip of the remaining crop stump, the farmer changed to using a reaper instead of the mower.

Ripening stage of mother plant for SALIBU technique (6.8.2019)

Harvesting the mother plants (4.9.2019)

Measuring 3 to 5 cm from the soil surface for second time cutting (9.9.2019)

Second cutting with mower (9.9.2019) before replacing with reaper

Cutting height of 3 to 5 cm from the soil surface (9.9.2019)

Shallow irrigation in the field (18.9.2019)

Growth condition of Wet season of 1st SALIBU plants on 19.9.2019 (15 days after harvest)

Growth condition of Wet season of 1st SALIBU plants on 19.9.2019 (15 days after

25 kg of Compound fertilizer (15:15:15) application on 19.9.2019.

Gap filling (20.9.2019)

Manual weeding (20.9.2019)

Insecticide (AI: Cartap hydrochloride) spraying to prevent from stem borer and brown plant hopper infestation. (29.9.2019)

Kasugamycin spraying for prevention of Bacterial Leaf Blight. (7.10.2019)

Panicle emergence stage of wet season of 1st SALIBU:

Manual weeding and gap filling, i.e., moving a part of tillers with roots from the rich stubbles to poor stubbles for leveling, were done on September 20, 2019. Although rodent problems occurred in other transplanted plots near the area, there were no rodent problems in this plot for the first generation of the SALIBU ratoon crop. It is supposed that rodents could not bite the rigid parts of the stubble of the main crop at 3–5 cm above the soil surface.

Field Day at paddy SALIBU technique trial plot in Taze township at the time of the first SALIBU ripening stage on November 22, 2019.

On November 22, 2019, the *Taze* township office, Department of Agriculture (DOA), MOALI, conducted the Field Day at the paddy SALIBU technique plot. This activity was conducted at the request of a Parliament Member of *Taze* township, and he paid for any necessary cost of this field day. On the field day, 70 farmers attended and observed farming conditions at the SALIBU plot. Therefore, this SALIBU technique has become popular not only among the farmers of the Taze township area but also at the regional level, and DOA *Sagaing* Regional Director also conducted a field day on this SALIBU plot, held on November 30, 2019. Over 100 farmers have visited this SALIBU plot, and the owner farmer was invited as a trainer to explain the entire process of the SALIBU technique to farmers from other villages outside the project area. The owner farmer believes that the yield from the first SALIBU plant will get more than the yield harvested from the main crop.

Chapter 8: Profitability of SALIBU rice ratoon cropping systems - Indonesia

Introduction

Background

Indonesia is a populous country with the fourth-biggest population in the world, exceeding 262 million people in 2017. Accordingly, the government should provide sufficient food to feed all these people. Based on data from the Agency of National Statistics, the rice consumption rate in Indonesia is 114 kg/year/capita, a slight increase from the 2008 figure of 110 kg/year/capita. The population growth rate in Indonesia is 0.86%, more than 2 million per annum. The trend toward increased rice consumption in Indonesia underlines the need to boost rice production as one of the leading national staples.

The Government of Indonesia has released many policies to intensify rice production, starting with "*Padi Sentra*" in 1958, INSUS in 1979, SUPRA INSUS in 1987, and right up to PTT in 2010. Although some have been successful, others have failed to achieve the target. The successful INSUS program saw self-sufficiency in rice attained in 1984. However, the success story did not last, as Indonesia later experienced a food deficit and needed to import rice from overseas due to technology becoming obsolete and unstable production (Wahyuni and Indraningsih 2003).

To meet the demand for food from the growing population of Indonesia, the government, through the PPBN program, set a target of rice self-sufficiency by increasing paddy production by 2.21% per annum (MOA 2015). This target would be achieved through 1) extensification by developing new rice fields, i.e., sawah, 2) increasing rice productivity using the PTT model, and 3) increasing the harvesting index (HI) by increasing land productivity (Abdulrachman et al. 2017).

Increasing land productivity implies the need for an agricultural intensification program, which frequently impacts adversely on farming resources such as soil and water. Intensive soil tillage depletes the soil nutrients beneficial for plant growth. Simultaneously, the degradation of the topsoil causes upstream erosion, which, in turn, leads to flooding and drought during rainy and dry seasons, respectively. Over-using irrigation water will render it scarce, particularly during the dry season.

Conversely, an extensification program would be problematic. The trend toward land conversion has significantly reduced the area of arable land, especially in Java, where land with fertile and good soil has been converted for other purposes, e.g., in industrial and residential areas. Based on data from the Ministry of Agriculture, the rate of land conversion is approximately 96,512 ha/year (Mulyani et al., 2016). At this rate, sawah, highly converted at 4% per year, will be unavailable, i.e., zero, in 2045, while approximately 200,000 ha of moderately converted sawah (2 to 4%) will remain in 2045, compared to 1.7 million ha in 2014 (Mulyani et al. 2016).

SALIBU technology could solve these problems. This paper argues that SALIBU rice technology, devised and developed in Indonesia, allows rice production to be boosted using agricultural resources, such as irrigation water, seed, and labor, much more efficiently.

Introduction of SALIBU technology

SALIBU technology is a rice farming innovation wherein the rice plant regrows after the stem is cut-off. Buds grow from lower nodes and spawn new root growth, implying nutrients for new plants are received from old, i.e., the mother plant and newly developed roots. This mechanism has helped boost the growth and productivity of new paddy plants and seen them even outperform the old (mother) plant.

SALIBU technology was invented by Mr. Erdiman, a researcher who worked at the local office of the Assessment Institute for Agricultural Technology, *Balai Pengkajian Teknologi Pertanian* in West Sumatra, Indonesia, and is one of the co-authors of this paper. This technology originated from ratoon technology, wherein people cut off stems of paddies when harvesting, and new crop regrows from the cut stem of paddy. In a sub-district of *Matur* in *Agam* Regency, West Sumatra, farmers practice ratoon technology as usual and let new crops grow. Despite no record of results, this has been practiced by farmers for a long time, and a few have produced paddy in bulk, which encouraged Mr. Erdiman to refine this ratoon technology further and make it profitable. He thus made his test field for research: applying treatment such as re-cutting stem at 3–5 cm height above ground level after harvesting the main rice crop at physiological maturity and letting straw remain in the field to enrich the organic content of the soil. He also deposited only a shallow level of water to maintain soil humidity. Surprisingly, this informal research elicited significant results for paddy productivity and the efficient use of resources such as seed, water, and labor, which prompted Mr. Erdiman to conduct several larger-scale formal research projects under the local office of the Assessment Institute for Agricultural Technology in West Sumatra Province.

The excellence of SALIBU technology stems from its ability to shorten the duration of paddy farming compared to the conventional system. This kind of technology eliminates the need for many activities common to traditional farming systems, such as land preparation, sowing, and transplanting, in turn, promoting the efficient use of irrigation water, seeds, and labor, an environmentally friendly approach, and low production costs (Erdiman et al. 2013, Abdulrachman et al. 2017 and Pasaribu et al. 2018). Due to the short period involved, paddy cultivation using SALIBU technology can promote harvests more than twice a year, which boosts HI by approximately 0.5 and 1.0 in highland and lowland areas, respectively, and increases rice production by up to 4–6 tons of husked paddy per harvest/ha/year (Erdiman et al. 2013).

Following the successful implementation of SALIBU rice technology at the farmers' level, the following three successive steps of SALIBU rice technology are recommended (Erdiman et al., 2013).

- Planting the mother plant (planting season 1) following the conventional farming system, with harvesting performed at the timing of physiological maturity, a week earlier than conventionally used to be done. The soil condition needs to be humid when harvesting. When the soil is overly dry, it needs to be irrigated with a 2–3 cm depth of water.
- Starting SALIBU rice farming (planting season 2) nearly 7 d after harvesting by cutting off the stem at 3–5 cm height from the soil surface. During this period, the land needs to be free from weeds with the water at overly low levels: within "field capacity" conditions.
- Maintenance of plant/buds 20–25 d after harvesting. During this period, several treatments need to be applied, such as separation and insertion, i.e., moving a few tillers with roots from thick stubbles to thin stubbles, press-in, i.e., pressing floating stubbles into the soil, fertilization, weeding and burying the straw of the rest of stem after cutting.

After performing these three steps, paddy farming follows the conventional system until the point of harvesting, when the SALIBU technology treatments restart.

The above successful recommendation is translated from Erdiman (2013) into guidance known as the SALIBU Technology Package, as presented in Table 8-1.

Table 8-1. SALIBU Technology Package

Parameter	**Activities**
Harvesting of the mother plant	Conducted 7–10 d earlier than for a conventional system, and the soil needs to be humid during harvest.
Land preparations	Weed-killing spray, i.e., contact herbicide to be applied. When the land is too dry, it needs to be irrigated with a 2–3 cm depth of water and left for 2–3 d after stopping irrigation.
Cutting off the stem	Needs to be conducted 7–10 d after harvesting (dah).
Land tillage	None
Sowing and nursing seedlings	None
Transplanting	None
Separation and insertion	At 20–25 dah
Press-in	At 20–25 dah
Fertilization	Based on local recommendations. With N at 25–

	50%, the first fertilization should be at 23 dah, with the next at 35–40 dah.
Weeding	Earlier and burying the straw at 20–25 and 35–40 dah.
Maintenance	IPM standard
Age when harvesting	At physiological maturity, 20% younger than a conventional system.
Potency of production	10-20% higher than in a conventional farming system.

Source: Erdiman (2013)

SALIBU technology and using agricultural resources efficiently

The excellence of SALIBU technology, particularly in terms of the scope to use agricultural resources efficiently, can be attributed to three dominant factors, namely water utilization, fertilization, organic matter, and agricultural labor.

Water use efficiency

Irrigation water is one of the key factors dictating the successful growth of a plant. Water is needed, particularly during land preparation, for puddling the soil, and during the vegetative growth of a plant, when buds develop into new tillers and thus become new plants. In conventional rice farming systems, a high volume of irrigation water input is needed, but irrigation water usage is particularly efficient with SALIBU rice technology, as it eliminates the need to puddle soil as part of land preparation. During the ratooning process, paddy soil needs to be moist and not flooded for weeks before harvesting, then drained with shallow irrigation water after harvesting (Oad et al., 2002). SALIBU rice needs the soil in field capacity condition (Erdiman, 2013). Accordingly, water condition needs to be managed during the critical stages of paddy growth, e.g., before and after harvesting (Yamaoka et al., 2017), including before the crucial time of cutting off the stem in the SALIBU system.

SALIBU technology only requires water after shoots appear in the node and roots are growing and after the first fertilization (Oad et al., 2002). The land needs to be flooded to a water depth of approximately 5 cm above ground level at this time, as implemented for conventional rice farming. Based on the field experience of Mr. Erdiman in managing SALIBU rice farmers in West Sumatra, the water use efficiency of SALIBU technology was 2.5 times higher than conventional rice technology (Erdiman, 2013).

Fertilizer efficiency and environmental friendliness

According to Abdulrachman et al. (2017), 75% of rice productivity is determined based on rice variety, water availability, and nutrients from soil or fertilization. The government has regulated the use of N, P, and K (NPK) fertilizers for conventional rice farming in each sub-district, named R1, whereas the local specific dosage of NPK fertilizers, as used at the plot level, is determined as R2.

Based on verification conducted by Abdulrachman et al. (2017), to optimize the number of tillers, SALIBU rice needs only 75% of the R1 dosage. In this case, SALIBU rice can produce 13.1–17.2 productive tillers per stool, equivalent to rice at R2 dosage, which generates 12.1–16.0 tillers per stool. The number of productive tillers increases by 45 to 52% from the control plant (without NPK fertilizers), which means the usage efficiency of fertilizers in SALIBU rice technology exceeds 25%.

The efficient use of fertilizer in SALIBU rice technology can also be implemented using a straw to enrich soil organic matter. After harvesting and cutting off the paddy stem, straw is not burned or discarded but instead left in the rice field to function as organic fertilizer. In conventional planting systems, straw is usually either burned or thrown away. When burned, the soil will be poisoned or disturbed, whereas when the straw is thrown away, it means discarding soil nutrients. Burying straw inside paddy soil allows nutrients lost after harvesting to be returned via the straw or parts of stems after cutting off. The activity of returning straw to paddy soil, i.e., recycling waste, also reflects the environmentally friendly nature of SALIBU technology. Erdiman et al. (2013) estimated that 20–30% of organic fertilizers are returned to the soil by burying the rice straw.

Labor efficiency

One of the problems faced by the Indonesian government is the lack of human resources to work in the agricultural sector, since most young people lack any interest in farming in rural areas. They prefer to migrate to urban areas to work in industry or the private or informal sectors, even for low salaries. The drain of young people as a demographic trend in rural areas adversely affects rural development (Oad et al., 2002), reducing the available labor for rice farming, while the government needs to meet rice production targets to ensure sustainable food security.

SALIBU rice technology has become a means of combatting the lack of available human resources in paddy farming, and as it eliminates the need for the three activities of land preparation, sowing, and transplanting, labor also gets reduced. In addition, most farmers, particularly in West Sumatra, use family labor rather than hired help for rice production, and hence, production costs are minimized. In this case, SALIBU rice technology needs laborers only during the stem-cutting process, fertilization, weeding, separation and insertion, burying straw or weeds, and harvesting.

Field experiments involving SALIBU technology in Indonesia

Several field research projects on SALIBU rice technology have been conducted in Indonesia, with the first experiment conducted by Erdiman, Nieldalina and Misran (2013). Data were collected from 2010–2013 to determine the number of productive tillers, grains per panicle, and productivity. The treatment included: the time of stem cutting, stem-cutting height, and dosage of fertilizers. The results of one experiment conducted in *Tabek* Village in the *Tanah Datar* District are presented in **Table 8-2**.

Table 8-2. Result of experiment in Tabek Village, Tanah Datar District, West Sumatra

No.	Treatment	Number of Productive Tillers	Number of Grains per Panicle	Productivity (t/ha)
A	Stem-cutting height			
	3–5 cm	22	132	7.7
	8–10 cm	18	116	6.8
B	Time of stem cutting			
	3 d after harvest	16	120	5.4
	7 d after harvest	19	134	7.6
	15 d after harvest	17	124	5.9
C	Fertilization			
	100 Urea + 100 Ponska	17	124	6.6
	150 Urea + 150 Ponska	22	137	8.3

Source: Erdiman et al. (2013)

This research showed that cutting the stem at 3–5 cm height above ground level elicited optimum results in boosting the number of productive tillers, total grains per panicle, and productivity, compared to other treatments. In terms of stem cutting time, 7 d after harvesting is optimal for cutting the stem, whereas in terms of the dosage and combination of fertilizer, "150 Urea + 150 *Ponska*" proved an optimal dosage and a combination eliciting 22 productive tillers, 137 grains per panicle and 8.3 t/ha of rice productivity.

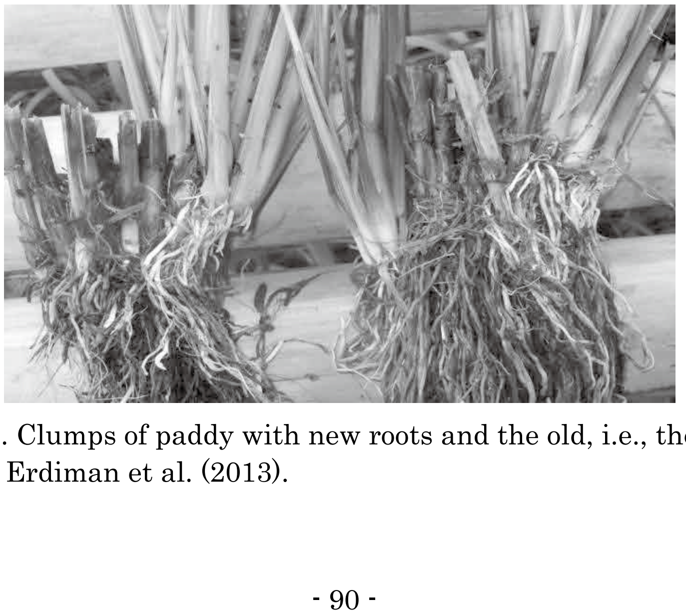


Fig. 8-1. Clumps of paddy with new roots and the old, i.e., the mother plant
Source: Erdiman et al. (2013).

This initial research has become the basis for the future development of SALIBU rice technology in Indonesia and worldwide. The optimal stem-cutting height of 3–5 cm is attributable to the fact that the lowest node close to the soil surface produces roots, which easily extract nutrients from the soil as well as old, i.e., the mother plant and thus can thrive as they are receiving nutrients from two sources (see **Figure 8-1**), which boosts the number of tillers and grains per panicle (Abdulrachman, 2017).

For the timing of cutting the stem, Abdulrachman et al. (2015) note that cutting off the stem 7–8 d after harvesting could produce more productive tillers compared to cutting 3 d after harvesting because the later the cutting, in terms of the number of days after harvesting, the more hormones are produced. Other than carbohydrates and organic matter, phytohormones such as gibberellin, kinetin, and auxin are influential in producing new tillers (Pasaribu et al., 2018). Furthermore, cutting off stem 7 d after harvesting promotes the optimal vegetative growth of the plant in terms of roots and tillers (Pasaribu et al., 2018; Abdulrachman et al., 2017).

The second research was conducted by Erdiman et al. in 2014 and focused on the implementation of SALIBU rice technology within three agroecosystems, namely highland (900 m above sea level), moderate (600 m above sea level) and lowland (60 m above sea level). This research aimed to determine the growth of paddy with SALIBU technology within these three agroecosystems. The results of the experiment are presented in **Table 8-3**.

Table 8-3. Comparison of plant height and number of tillers between the SALIBU rice system and conventional rice system in three agroecosystems

No.	Agroecosystem	Parameter	*SALIBU* technology	Conventional system
1	Highland (>900 asl)	Plant height (45 dah)	75	*70*
		Number of tillers (45 dah)	33	*24*
2	Moderate (600–700 asl)	Plant height (45 dah)	73	*70*
		Number of tillers (45 dah)	32	*25*
3	Lowland (60 asl)	Plant height (45 dah)	70	*75*
		Number of tillers (45 dah)	31	*16*

Note: asl, above sea level; dah, days after harvesting.
Source: Erdiman et al. (2014).

This research shows that the plant height and number of rice tillers with SALIBU technology exceed that of rice grown with a conventional system. Another significant finding is that the number of tillers and plant height are almost similar among all three agroecosystems, with results in lowland areas slightly lower, which reflects the scope for SALIBU rice technology to adapt to the three agroecosystems and allow farmers in each of the three areas to use it for rice farming. For lowland areas, results are often substandard, considering the lower quality of drainage and soil aeration compared to highlands and moderate ecosystems (Erdiman et al., 2014). Accordingly, farmers in lowland areas need to manage soil problems carefully, and there may be a need to combine this technology with intermittent irrigation systems such as alternate wetting and drying.

This experiment also underlines the potential to replicate SALIBU technology in other parts of Indonesia, and information received from various sources suggests that many provinces have done this successfully. Examples include *Buleleng* District in Bali Province, with rice productivity for the first generation of SALIBU rice of 7 t/ha (Tribun News, 2018). In *Ngawi* District, East Java Province, the productivity of SALIBU rice was 4–6 t/ha, with HI increasing by 0.51 per year (Antara News, 2016). Farmers in *Kerinci* District, Jambi Province, have been using SALIBU technology since February 2016 and have enjoyed an increase in rice productivity of up to 5.8 t/ha, with cost efficiency boosted by 41% and the cultivation age of rice shortened by up to 85 d compared to 120 d for conventional rice (BPTP Jambi, 2016). In *Bulukumba* District, South Sulawesi Province, farmers started using SALIBU technology in 2016 and achieved a yield of 6–7 tons per plot in only 70 d (Bulukumba Terkini, 2017). At the international level, SALIBU technology has been replicated in Myanmar. An initial study under pot cultivation reported that a yield of 9.1 t/ha was achieved using SALIBU technology, whereas the crop yield was only 5.3 t/ha using conventional farming (Yamaoka et al., 2017).

Profitability of SALIBU technology

No formal socioeconomic research into SALIBU technology in Indonesia has been performed yet. However, a few economic aspects of the technology are evaluated from the success story and previous studies of SALIBU rice technology in Tanah Datar District, West Sumatra (Erdiman et al., 2014). As described above, a few technical indicators of SALIBU are reviewed in this section to evaluate these aspects.

There are three arguments justifying that SALIBU technology is technically more efficient than conventional technology. First, SALIBU technology uses more efficient resources than traditional farming, particularly seeds and labor. Second, SALIBU rice productivity is superior to transplanting technology and higher than the productivity of the main crop. Third, as SALIBU rice technology is harvested many times, it increases cropping intensity per annum, ultimately boosting land productivity.

As explained above, the core of SALIBU technology involves stimulating the growth of shoots from the side of the cut rootstock instead of using seeds. After the first harvest of the main crops, rice in the next production period is grown without seeds or tillage, which reduces the cost of paddy seeds and, more importantly, saves on the labor required for land preparation. Another possible technical benefit of SALIBU technology is that it uses less water due to the minimum or zero tillage technique.

SALIBU technology consistently elicits higher rice grain yields than conventional technology (Kusnadi, 2017). Experiences in several districts of West Sumatra Province revealed a SALIBU yield for rice grain 10.3% higher than in traditional technology (**Table 8-4**). Depending on rice seed varieties and agroecosystem environment, SALIBU technology outperforms conventional technology by 5–20%. SALIBU technology has been practiced by rice farmers in five sub-districts, namely *Halaban*, *Lima Kaum, Matur, Priangan*, and *Sepuluh Koto Singkarak*, using 12 different rice varieties (Kusnadi, 2017). This experience suggests that rice cultivation technology in West Sumatra produces more grain in different rice varieties and different environments compared to conventional technology. More importantly, the technology has been adopted at the farm level. These findings showed the potential to apply SALIBU technology to other provinces outside West Sumatra. To support the dissemination of this technology, the Agricultural Research and Development Agency of the Ministry of Agriculture issued a manual on SALIBU technology (Abdulrachman et al., 2015). Many technical parameters need to be considered, namely genetic factors, i.e., varieties, environment, and cultivation techniques to use this technology outside West Sumatra (Abdulrachman et al., 2017).

Table 8-4. SALIBU rice productivity (t/ha) at Agam, Tanah Datar, Limapuluh Kota, and Solok districts, West Sumatra Province, 2010–2013

No	Sub-district	Variety	Year	Yield (t/ha)	Increase (%) *
1	Halaban	Madang Pulau	2011	5.3	5
2	Lima Kaum	Anak Daro	2011	6.4	10
3	Lima Kaum	Batang Piaman	2012	7.2	15
4	Matur	Lumuik	2010	7.2	15
5	Priangan	Cisokan	2012	6.9	15
6	Priangan	Cisokan	2013	7.1	15
7	Priangan	Batang Piaman	2012	8.3	15
8	Priangan	Batang Piaman	2013	7.9	10
9	Priangan	Batang Piaman	2013	8.6	15
10	Priangan	Batang Piaman	2013	7.3	10
11	Priangan	Batang Piaman	2013	7.1	5
12	Priangan	Cisokan	2013	8.3	15
13	Priangan	Hibrida Hipa-3	2013	7.4	2
14	Priangan	Hibrida Hipa-5	2013	7.8	3
15	Priangan	Inpari-12	2013	5.6	2

16	Priangan	Inpari-21	2013	6.4	3
17	Priangan	Logawa	2013	7.8	10
18	Sepuluh Koto Singkarak	Cisokan	2013	6.4	20
Average				7.2	10.3

* Percentage increase compared to transplant technique in the same area.
Source: Erdiman et al. (2014).

The third possible source of the economic benefit of SALIBU technology is that the rice plants can be harvested more than once. Therefore, SALIBU technology can significantly increase soil productivity (t/ha) caused by increased cropping intensity annually. Experiences in West Sumatra showed that SALIBU rice was harvested up to five times continuously within 22 months and produced 40.5 tons of rice grain (**Figure 8-2**). This technique created cropping intensities of more than 250% annually and yielded 22.1 t/ha/year of rice grain. These findings may increase rice productivity in Indonesia. Generally, rice cropping intensity in Indonesia is approximately 200%, implying that rice is planted twice a year and rice-grain yield is almost 13 t/ha/year.

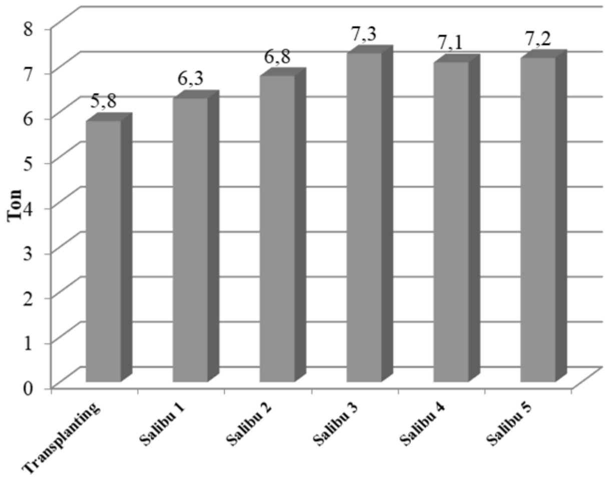


Fig. 8-2. Rice yield (t/ha) of the main crop and five consecutive harvests of ratoon crops under SALIBU technology
Source: Erdiman (2014).

As described above, a few profitability indicators of SALIBU technology can be derived using productivity indicators. In financial terms, SALIBU technology is more profitable than conventional technology (Table 5). The first advantage comes from higher total product value, as a logical consequence of producing more rice at the same price compared to conventional technology. The second advantage is that SALIBU uses less input and, hence, incurs fewer production costs due to savings on labor and seeds. SALIBU technology reduces labor usage considerably by eliminating the need for land preparation and planting, which constitutes the lion's share of farm labor in conventional technology. Both soil preparation and planting in traditional rice cultivation needs abundant farm labor and must be completed promptly to pursue planting schedules. Both activities usually use hired labor to a considerable extent for family farms. In addition to farm labor reduction, conversely, a little additional farm labor is required for thinning, unusual for conventional technology. Thinning in SALIBU technology is needed when the shoots grow excessively and are concentrated in a single area. Nevertheless, SALIBU technology can achieve labor and total cultivation cost savings of approximately 26.7 and 25.8%, respectively. As a final result, the SALIBU technology gross margin is 20.20% higher than conventional technology.

Further analysis showed that the SALIBU technology return on labor per day outperformed conventional technology (by 33.3%). Return on labor input is a reasonable benchmark to measure labor income and can be compared to the prevailing wage in the agricultural sector. The return on labor per day with both technologies exceeds the wage rate we used in the analysis (IDR 35,000/day). Another financial indicator is the R/C ratio. From **Table 8-5**, it is concluded that SALIBU technology, in cost terms, outperforms conventional technology by 31.6%.

Table 8-5. Profitability of SALIBU and transplanting rice technology at Solok and Tanah Datar Districts, West Sumatra Province, 2014

Items	SALIBU technology (IDR/ha)	Conventional system (IDR/ha)
Labor		
Land preparation	-	2,300,000
Seedling	-	300,000
Planting	-	1,300,000
Cutting stems for SALIBU	600,000	-
Thinning	600,000	-
Weeding and fertilizing	1,000,000	1,000,000
Harvesting	6,800,000	6,500,000
Total labor cost	9,000,000	11,400,000
Seeds	-	300,000
Fertilizers	900,000	750,000
Total cost of production	9,900,000	12,450,000
Total value product	34,000,000	32,500,000
Gross margin	24,100,000	20,050,000
Return on labor (IDR/day)	128,722	96,557
Revenue cost ratio (R/C)	3.43	2.61

Source: Erdiman (2014)

Conclusion and recommendations

SALIBU technology, which originated from the modification of ratoon technology, is a rice farming invention and technology which has been successfully implemented at the farming level in West Sumatra Province and elsewhere in Indonesia. The excellence of the technology comes from its ability to shorten the duration of farming processes by eliminating many activities such as land tillage, i.e., puddling, sowing, and transplanting, which in turn, helps use agricultural resources such as land, water, seeds, and labor more efficiently and protects the environment by returning straw to the soil as organic matter. This excellence subsequently boosted the profitability of SALIBU technology, as shown through three profitability indicators, among others, i.e., increasing product value due to higher productivity, using fewer inputs, which cut production costs, and return on labor per day, which exceeds that of conventional systems. Fundamental research conducted by Erdiman et al. (2013) and Erdiman et al. (2014) showed that the optimum results in terms of productive tillers, number of grains per panicle, and rice productivity came when the stem-cutting height was 3–5 cm above ground level 7–8 d after harvesting, whereas the optimal fertilizer dosage was 150 kg of urea and *Ponska*, respectively. Another result revealed no considerable difference in rice productivity among the three agroecosystem zones using this technology.

SALIBU technology remains in its preliminary stages and needs to be developed by conducting studies and further research, especially in international contexts. This technology has the potential to be replicated in tropical countries, allowing food production to feed the entire population and achieve sustainable food security. On a national level, profound and far-reaching government intervention is required to ensure that SALIBU technology spreads throughout all provinces in Indonesia.

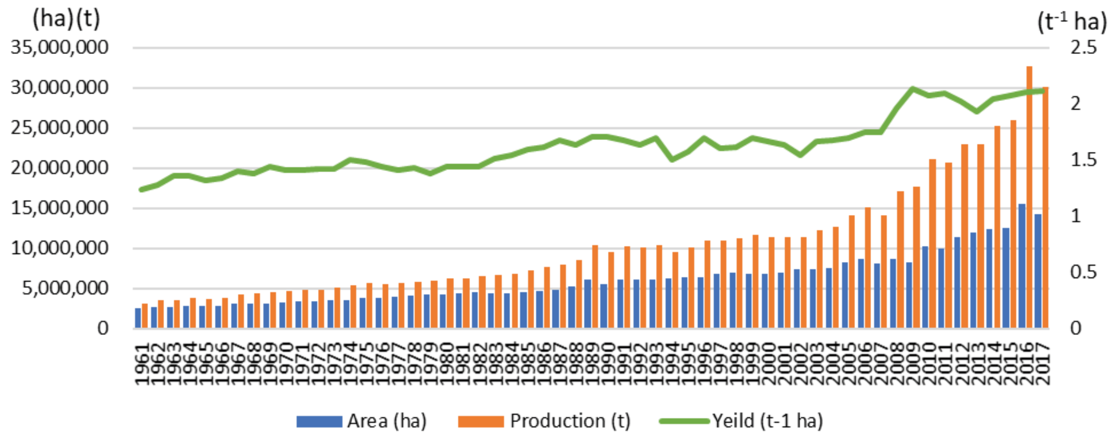
Chapter 9: Comparison of water productivity by field cultivation test – Ghana Ⅰ

Introduction

Recent increases in rice consumption in Africa are noteworthy. Especially the demand for rice from sub-Saharan African countries is steadily increasing. Consequently, the consumption of rice in these countries is estimated to grow from 19.8 million tons in 2010 to 34 million tons in 2020 (Africa Rice Center, 2011), which will result in importing 14 million tons of milled rice in 2020 and consuming a large amount of foreign currency crucial for the economy of these countries. Boosting the domestic production of rice is a prioritized economic issue of these countries.

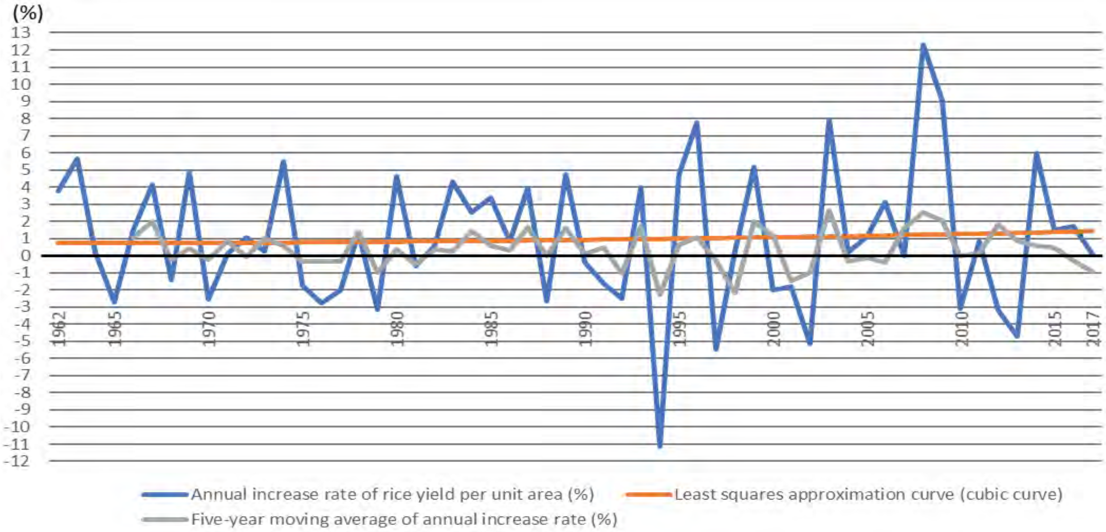
In the 56 years from 1961–2017, the world rice crop area has expanded 1.45 times. Meanwhile, production has increased 3.57 times, and the yield per unit area has increased 2.46 times (FAOSTAT, 2019). In sub-Saharan Africa, which consists of Eastern, Central, Southern, and Western Africa, simultaneously, the rice crop area has expanded 5.61 times. Meanwhile, production has increased 9.58 times, and the yield per unit area has increased 1.71 times (FAOSTAT, 2019) (**Figure 9-1**).

On a global basis, the annual increase rate of rice yield per unit area from 1962-2017 clearly shows a downward trend in the approximate curve. That is, those that exceeded 2% in the 1960s and 1970s cut less than 2% in the 1980s, less than 1.5% in the 2000s, further less than 1% in the 2010s, and are expected to reach zero in 2030 (Yamaoka et.al., 2019). However, in sub-Saharan Africa, it has gradually increased by approximately 1.0% since the 1960s and has maintained this level until now. The annual increase rate of rice yield per unit area in the region seems to be stable at 1% (**Figure 9-2**).



Source: FAOSTAT (2019) http://www.fao.org/faostat/en/#data/QC

Fig. 9-1. Harvested area, production and Yield per unit area of rice (1961-2017: Sub-Saharan Africa)



Source: FAOSTAT (2019) http://www.fao.org/faostat/en/#data/QC

Fig. 9-2. Annual increase rate of rice yield per unit area, its five-year moving average and trend curve (1962-2017: Sub-Saharan Africa)

In Asia, the realization of the formula “Green Revolution = irrigation development × introduction of high-yield varieties × fertilizer input” has achieved an increase in yield per unit area exceeding 2% annually since the 1960s. However, in sub-Saharan Africa, where agricultural development has been delayed, the investment in irrigation development required to realize this formula is weak, the increase in yield per unit area is limited, and the growth in rice production is mainly due to the increase in acreage. The ratio of irrigated paddy rice in the expansion of rice production area is low, and the area expansion of rainfed paddy is the main contributor.

In sub-Saharan Africa, unfortunately, it is not possible soon to expect a considerable increase in the area of irrigated paddy fields with marked investment. There are several reasons for this. First, there is the problem of finding ways to increase production in irrigated paddy fields that have already been developed after high-yield varieties have been introduced. The second problem is to find ways to increase rice production in rain-fed paddy fields, with the largest area and the highest expansion in cultivated area. In either case, a scenario to increase production by introducing more high-yield varieties does not hold.

It is fundamental to continue to using varieties widely cultivated by farmers in irrigated and rain-fed areas. Furthermore, it is challenging to increase irrigation water volume through new irrigation development, so it is necessary to find a way to increase rice production without increasing irrigation water volume.

Methods

Following the preceding paragraph, the question is whether there is such a favorable and innovative rice cultivation method. The answer is Yes. SALIBU rice ratoon cropping systems is an innovative rice ratooning cultivation originating from West Sumatra, Indonesia. It allows for harvesting rice grain up to 3.5-4 times annually. It also allows the farmer to produce a yield for the ratoon crop in the following consecutive farming seasons at the same level as that of the main crop. Past studies have generally concluded that the grain yield of the ratoon crop was within the range of 20-50% of that of the main crop (Krishnamurthy, 1988).

SALIBU rice ratoon cropping systems should revolutionarily increase water productivity through consecutive ratooning cultivation because farmers can reduce the amount of irrigation water drastically by shortening cultivation periods and omitting seedling raising, puddling, and transplanting. The water amount used during puddling and transplanting is huge.

The system can transform monocarpic annual rice plants into a tropical perennial type that produces ratoon grains over generations. It does not require farmers to put in additional investment but gives them the advantage of saving resources such as water, labor, and seed. Furthermore, they reduce the cost and adverse environmental effects of frequent mechanized land preparation and allow effective utilization of residual nutrients.

A joint study was, therefore, conducted by Dr. Kazumi Yamaoka of Japan International Research Center for Agricultural Sciences (JIRCAS) and Dr. Joseph Ofori of Soil and Irrigation Research Center, University of Ghana (SIREC – UG) to evaluate the potential of the SALIBU rice ratoon cropping systems for increased rice yield and water productivity in coastal savannah agro-ecological zone of Ghana.

The specific objectives of the joint study are as follows.

i. To determine suitable variety for the perennial rice ratoon farming system
ii. To determine the yield of rice in the main crop and five generations of ratoon crop
iii. To compare water productivity in the SALIBU system with the conventional non-ratooning but transplanting rice system

The study was conducted at the Soil and Irrigation Research Center (SIREC) of the University of Ghana, which is about 8 km away from Kpong, during the minor rainy season. The area lies around latitudes 06° 09' N and longitude 00° 04' E in the Eastern region of Ghana. It is part of the Accra plains and has annual rainfall between 800 and 1100mm. The major rainy season lasts from April to mid-July while the minor rainy season lasts from early September to mid-November.

The soils in the study area are mainly the vertisols of the Accra plains. These are characterized by montmorillonite clay minerals with a clay content of 35–40%. The soils characteristically swell and become sticky when wet. When dried, they become hardened and crack extensively which makes them difficult to cultivate with simple farm implements.

A split plot design with cropping systems (1. Perennial rice cropping system (SALIBU rice ratoon cropping systems) and, 2. Conventional non-ratooning rice system characterized by complete submergence) as the main plot and rice variety (V1. Aromatic short, V2. Shewpyithtay, V3. Yadanartoe, V4. Shwethweyin (replaced later with Jasmine 85), V5. Theehtatyin, V6. Sinthukha, V7. Amankwatia, V8. AGRA and V9. Ex Baika) in subplots, was used. As shown in **Figure 9-3**, the layout of the 54 sections of a 1 m square container is set so that the comparison of two cultivation methods and nine varieties is randomly arranged in three rows and three repetitions. The main plots were separated from each other by bunds at a distance of 3 m whiles metallic barriers of size 1 m^2 were then buried 30 cm deep in each subplot to minimize lateral movement of water and nutrients. The subplots were separated from each other at a distance of 0.7 m each other.

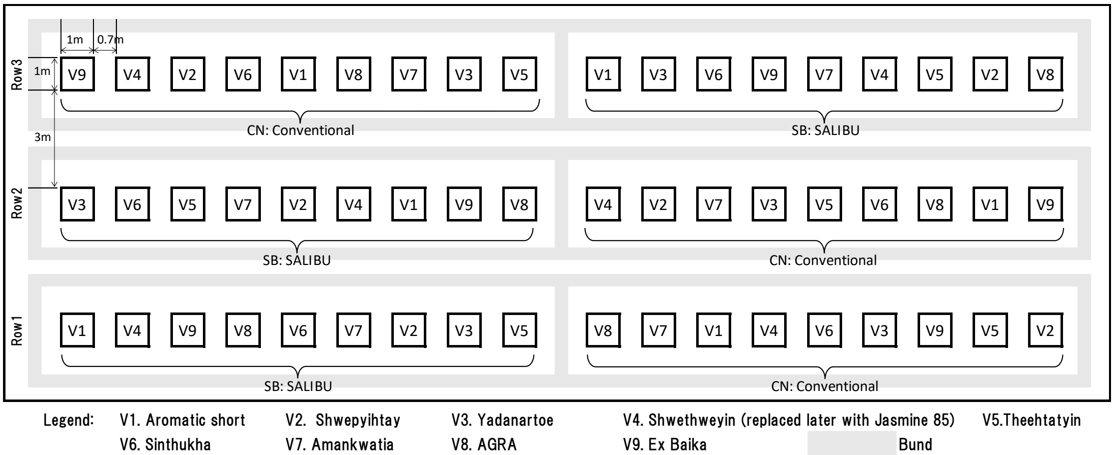


Fig. 9-3. Placement of main plots and sub plots

Seedlings were raised on a seedbed and transplanted when they were 15 d old on October 20, 2017 at a spacing of 20 cm X 20 cm at 1 seedling per hill. Basal fertilizer of NPK (15-15-15) at the rate of 45kg/ha was split applied at transplanting and active tillering stages, 20 days after transplanting (DAT). The rest of N (45 kg/ha) was also split – applied at maximum tillering and early booting stages.

Two water management methods were imposed. In the main rice crop under the SALIBU rice ratoon cropping systems, an alternate wet and dry (AWD) method was adopted during the vegetative stage, but the field was submerged at the reproductive stage. According to Dr. Ofori, the same test field had been conducting research on water-saving irrigation water volume by AWD until a year ago, and at that time, it was found that the soil reached field capacity condition when the groundwater level was about 25 cm below ground surface. He would like to utilize this knowledge so that the groundwater level was observed by inserting a PVC pipe with a diameter of about 50 mm and 45 cm in length into the soil perpendicular to the ground surface in the container. In addition, to measure the amount of supplemental irrigation water for each container, water was discharged under natural pressure through a hose from the tank, and a bucket was used to calibrate the amount of water discharged per second according to the time required to supply water to each container. With regards to conventional rice farming practices, the plots were submerged throughout the growing period until 10 days to harvest.

Cultivation management of the generations of rice ratoon crops after the harvest of the first main crop is summarized in **Figure 9-4**.

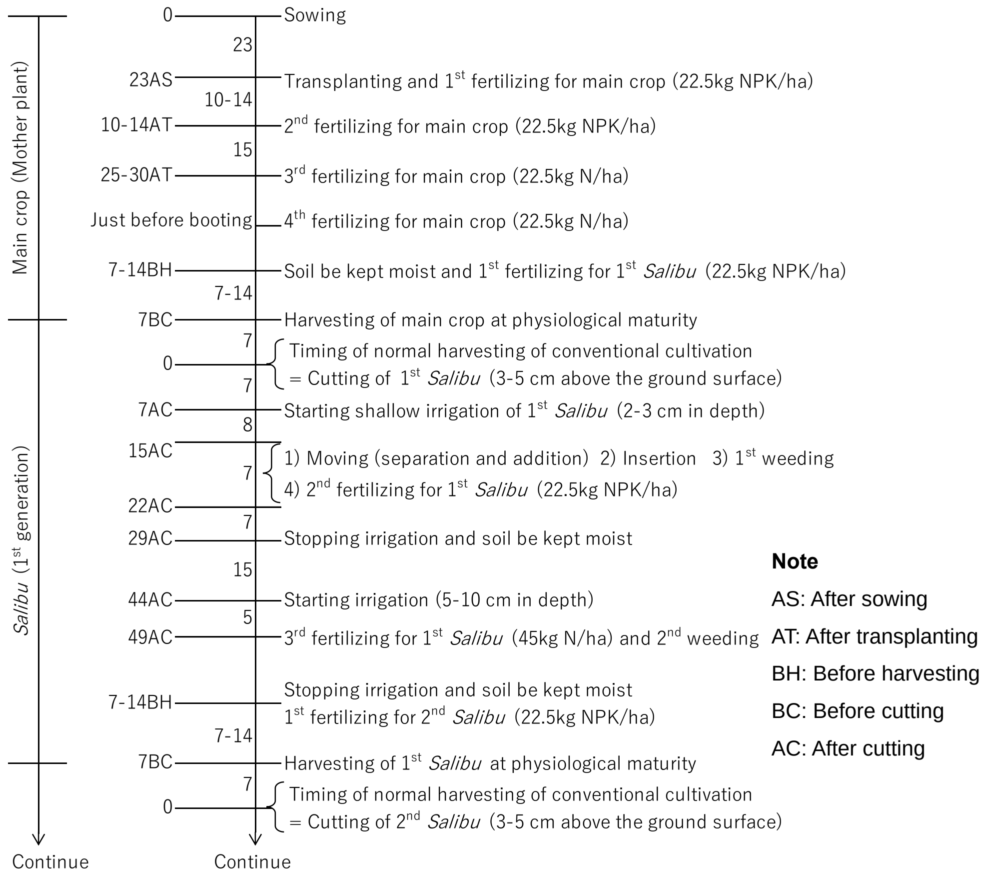


Fig. 9-4. Summary of Perennial (SALIBU) Rice Methodology for Ghana

Figure 9-5 shows a panorama of the entire test field, and **Figure 9-6** shows the installation of plastic tanks for precise irrigation to each plot. Irrigation to each plot is carried out by hose irrigation with natural pressure of water that is pumped up from the irrigation canal right next to the plastic tank and stored in the tank. Photos were taken on 29 November 2017.

Fig. 9-5. Full view of the test fields

Fig. 9–6. Plastic tank and bund installed in the test fields

Figure 9–7 is a close-up photograph of the first SLIBU ratoon crop on March 14, 2018, rearranged based on cultivar. The main crop of all nine cultivars had been harvested and re-cut at 3–5 cm above the ground surface one week after the harvest.

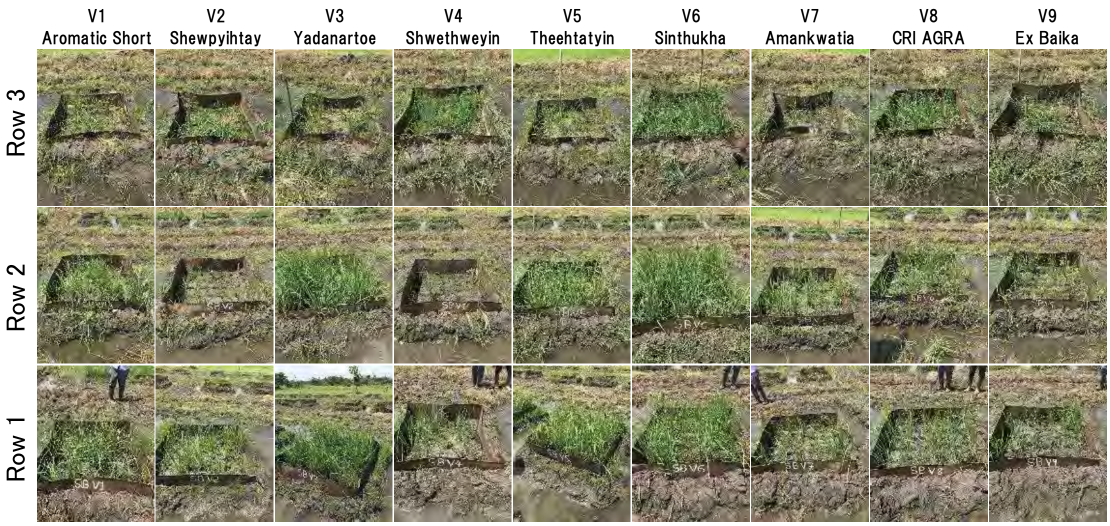


Fig. 9–7. The first SLIBU ratoon crops rearranged based on cultivar

In Asian rice varieties, when comparing the growth of V4 Shwethweyin and V5 Theehtatyin, which were harvested about a month earlier than the other cultivars, the latter grew vigorously with more tillers than the former. In addition, among the three cultivars that were harvested about one month later than these, V3 Yadanartoe and V6 Sinthukha grew extremely vigorously, surpassing even V5 Theehtatyin. On the other hand, V2 Shewpyithtay had few tillers and slow growth like V4 Shwethweyin. Four cultivars of African rice were harvested almost at the same time, and among them, V1 Aromatic short showed strong tillering and growth, and its future growth situation was considered promising. Although it was not used in this test, Jasmin85, a local cultivar popular in Ghana, is said to have relatively good ratoon ability so it was decided to stop testing V4 Shwethweyin and plant Jasmin85 in an empty container to test.

Data collection

Days to 50% flowering were recorded when half of the total plants within a plot had flowered, while days to maturity were also recorded when the panicle had turned yellowish (physiological maturity). Plant height and the number of tillers per hill were all measured/counted from five hills within each plot and recorded.

Yield parameters: grains per panicle, 1000 grain weight, filled and unfilled grains, and panicle length were measured and recorded from ten panicles randomly selected from each plot.

Water was applied through a hose pipe and the amount of water consumed per plot was measured using containers with a known volume. The amount of water used was obtained from periodic measurements. The depth of irrigation water (mm) applied was computed by dividing the volume of water applied by the area of the subplot. In addition, the amount of precipitation during the period (rainfall events and amounts) were recorded.

Water productivity was calculated using the following equation.

$$WP = \frac{GY}{TWA}$$

Where, WP = water productivity (kg m^{-3}), GY = grain yield (kg/ha) and TWA = total water applied (irrigation water and rainwater used) expressed in m^3 ha^{-1}.

Data collected were subjected to analysis of variance using GenStat statistical software package (12th edition). Where significant differences were observed among the treatment means, the least significant difference (LSD) at a 5% probability level was used to separate the means.

Results and discussion

Performance of Rice in the Main Rice Conventional and Main Crop (Mother Plants) of SALIBU

Days to 50% flowering was significantly (p<0.05) influenced by, variety, farming systems their interactions. Varieties *Shwetheweyin* and *Theehtatyin* performed flowered earliest while *Sinthuka* and *Yadanartoe* were observed to be long-duration varieties. All the other varieties were found to be medium duration. Plant height was significantly (p<0.05) different among the varieties. AGRA, *Amankwatia*, Aromatic short, *Sinthuka*, and *Yadanartoe* were all taller varieties, while *Shwethweyin* and *Theehtatyin* were the shortest among the varieties. Tillers per hill was significantly (p<0.05) influenced by variety and interaction of varieties and farming system. *Shwepyihtay*, *Theehtatyin* and *Yadanartoe* had tillered better than the other varieties **(Table 9-1)**.

Table 9-1. Some growth attributes of rice under the first conventional rice crop (CN) and main crop (mother plants) for SALIBU ratoon crop (SB)

Variety	Days to 50% Flowering		Number of Tillers/hill		Plant Height (cm)	
	SB (mother)	CN	SB (mother)	CN	SB (mother)	CN
AGRA	94	93	13	12	112	115
AMANKWATIA	94	96	11	13	115	109.3
AROMATIC SHORT	85	93	13	15	108.7	108
Ex BAIKA	90	92	15	12	89.7	91.3
SHWEPYIHTAY	98	98	22	18	91	89.3
SHWETHWEYIN	61	61	19	15	70	71.7
SINTHUKHA	103	103	14	12	103	104
THEEHTATYIN	63	63	15	19	82	88
YADANARTOE	96	108	14	16	114.7	95
Mean	89	87	15	15	98.4	96.9
Lsd (5%) Mgmt(M)	2*		1		4.2	
Lsd (5%) Variety(V)	4*		3**		8.9**	
Lsd (5%) M × V	6*		4**		12.5	

* = significant at 5% significant level ** = significant at 1% significant level

Panicle lengths were influenced significantly (p<0.05) by variety. *Amakwatia* and *Yadarnatoe* had the longest panicle length, followed by AGRA and Aromatic short. The number of grains per panicle was significantly (p<0.05) affected by the farming system and variety. While *Amankwatia* had the highest grains per panicle, the lowest was recorded by *Shwethweyin*. The percentage of filled grain was affected by the farming system and variety and not their interaction. Thousand-grain weight was significantly (p<0.05) influenced by variety only. AGRA rice had the highest value of 28.3 g. Grain yield for the first main crop and SALIBU mother plant were affected significantly (p< 0.05) by the type of variety and interaction between the farming system and variety.

AGRA rice had the highest yield but was not significantly different from *Amankwatia*. This was followed by *Shwepyihtay*, and *Yadarnatoe* (**Table 9-2**).

Table 9-2. Yield parameters of first conventional rice crop (CN) and main crop (mother plants) for SALIBU ratoon crop (SB)

Variety	Panicle length (cm)		Grains per panicle		Filled Grains (%)		Test weight (g)		Grain Yield (t ha^{-1})	
	SB (mother)	CN	SB (mother)	CN	SB (mother)	CN	SB (mother)	CN	SB (mother)	CN
AGRA	26.5	25.8	149.7	145.3	91.71	94.87	26.7	28.3	9.2	10.1
AMANKWATIA	27.8	28.1	168.3	163.1	95.34	97.10	22.0	24.0	9.7	9.9
AROMATIC SHORT	25.5	25.9	123.5	144.0	93.82	92.44	24.7	25.7	8.1	9.1
Ex BAIKA	24.2	24.4	141.1	129.0	95.40	96.68	26.0	25.7	8.5	6.8
SHWEPYIHTAY	24.4	23.5	129.3	129.2	91.61	94.73	24.3	21.7	9.0	7.8
SHWETHWEYIN	22.4	21.3	114.5	70.8	92.95	92.78	24.0	22.7	5.5	5.0
SINTHUKHA	22.7	22.7	175.1	128.1	95.55	96.76	24.7	25.3	5.9	7.1
THEEHTATYIN	22.1	22.8	133.2	104.3	94.70	95.39	24.0	22.0	7.5	7.6
YADANARTOE	26.4	26.8	114.6	126.1	92.18	94.17	24.7	25.7	8.0	8.0
Mean	**24.9**	**24.6**	**138.8**	**123.3**	**93.70**	**94.99**	**24.6**	**24.8**	**7.9**	**7.9**
Lsd (5%) Mgmt(M)	0.6		9.44**		1.20**		1.35		0.26	
Lsd (5%) Variety(V)	1.3**		20.02**		2.54**		2.87**		0.56**	
Lsd (5%) M × V	1.8		28.32		3.59		4.06		0.79**	

** = significant at a 5% significant level

The main (mother plant) rice crop for SALIBU was put under an alternative wet and dry water management system, the water productivity was significantly higher than was observed under the conventional system (**Table 9-3**).

Table 9-3. Comparing water productivity of the first conventional rice crop (CN) and main crop (mother plants) for the SALIBU ratoon crop (SB)

Variety	Water Productivity (kg m^{-3})		
	SB (mother)	CN	Mean
AGRA	0.77	0.594	0.682
AMANKWATIA	0.814	0.539	0.677
AROMATIC SHORT	0.711	0.52	0.616
Ex BAIKA	0.746	0.4	0.573
SHWEPYIHTAY	0.709	0.43	0.569
SHWETHWEYIN	0.713	0.316	0.514
SINTHUKHA	0.465	0.394	0.429
THEEHTATYIN	0.878	0.487	0.683
YADANARTOE	0.662	0.436	0.549
Mean	**0.72**	**0.46**	
Lsd (5%) Mgmt(M)		0.041**	
Lsd (5%) Variety(V)		0.087**	
Lsd (5%) M × V		0.122**	

** = significant at a 5% significant level

Rice yield and water productivity

1) Annual yield and water Productivity in SALIBU and Conventional Systems

The average annual yield and water productivity for each rice variety were computed for both SALIBU and conventional systems, with the average yield recorded in the SALIBU system per year being higher by 1–9 t/ha than the conventional rice cultivation system. *Shwepyihtay*, *Theehtatyin*, *Amankwatia*, and *Ex Baika* showed the highest differences in their performance in SALIBU and conventional systems. Water productivity per year was more than twice as much in the SALIBU system as conventional rice system. *Theehtatyin* recorded the highest annual water productivity of 2.0 kg/m^3 followed by *Shwepyihtay* and *Amankwatia* (1.8kg/m^3) and thus shows how water could be saved in rice cultivation under the SALIBU system without sacrificing rice yield (**Table 9-4**).

Table 9-4. Annual yield and water productivity of rice under SALIBU rice ratoon cropping systems and conventional rice farming systems (CN)

Variety	Annual yield (t/ha)		Annual Water Productivity (kg m^{-3})	
	Salibu	CN	Salibu	CN
AGRA	31.3	25.0	1.7	0.6
AMANKWATIA	32.5	23.2	1.8	0.6
AROMATIC SHORT	25.1	24.6	1.3	0.7
Ex BAIKA	30.8	22.9	1.4	0.6
JASMINE 85	27.9	23.3	1.3	0.6
SHWEPYIHTAY	29.1	19.5	1.8	0.5
SINTHUKHA	21.1	19.5	1.2	0.6
THEEHTATYIN	29.0	19.3	2.0	0.6
YADANARTOE	21.1	20.1	1.2	0.5

2) Comparing the yield of rice and water productivity in the first generation of SALIBU with the conventional rice farming system

Table 9-5. Yield and water productivity of rice under SALIBU rice ratoon cropping systems (first generation) and first conventional rice crop (CN)

Variety	Yield (t/ha)		Water Productivity (kg m^{-3})	
	Salibu	CN	Salibu	CN
AGRA	7.3	10.1	3.2	0.6
AMANKWATIA	7.5	9.9	3.4	0.5
AROMATIC SHORT	4.7	9.1	2.0	0.5
Ex BAIKA	6.6	6.8	2.2	0.4
SHWEPYIHTAY	5.8	7.8	3.4	0.4
SINTHUKHA	4.6	7.1	1.6	0.4
THEEHTATYIN	4.9	7.6	3.5	0.5
YADANARTOE	4.3	8.0	1.8	0.4
Mean	5.7	8.3	2.6	0.5
Lsd (5%) Mgmt(M)	0.73*		0.28*	
Lsd (5%) Variety(V)	0.62**		0.34**	
Lsd (5%) M × V	0.90**		0.47**	

* = significant at 5% significant level ** = significant at 1% significant level

Grain yield was significantly (p<0.05) different among varieties, farming systems, and their interactions. For the first generation SALIBU, *Amankwatia*, AGRA and *Ex Baika* were better than the Asian varieties. Generally, water productivity showed a significant difference (p<0.05) among varieties of farming systems and their interactions. SALIBU system recorded between as high as 4 to 7 times higher water productivity as the conventional. Under the SALIBU system, the varieties that recorded significantly highest water productivity were; *Theehthatyin* (3.5kg/m^3), *Shwepyihtay* (4kg/m^3) and *Amankwatia* (3.4kg/m^3) produced the highest water productivity among the varieties under SALIBU system (**Table 9-5**). *Shwethweyin* succumbed to diseases and was taken out and later replaced by Jasmine 85.

3) Comparing the yield of rice and water productivity in the second and third generations of SALIBU with the conventional rice farming system

Rice yield and water productivity of the second main crop under the conventional farming system and the second and third generations of SALIBU ratoon crops were compared. Generally, the yield of the third generation SALIBU was better than the second one. Water productivity followed the same trend. *Shwepyihtay* and *Theehtatyin* were the highest with water productivity of 3.9 kg/m^3. Jasmine 85 (replaced *Shwethweyin*) was as mother crop during third generation SALIBU.

Sinthukha had the lowest water productivity which may be due to its long time for taking mature, which thus required more water input. Water productivity of the second and third SALIBU was 4 to 7 times as much as was recorded from the conventional farming system (**Table 9-6**).

Table 9-6. Yield and water productivity of rice under SALIBU rice ratoon cropping systems (second and third generation) and second conventional rice crop (CN)

Variety	Yield (t/ha)			Water Productivity (kg m^{-3})		
	2nd Salibu	3rd Salibu	CN	2nd Salibu	3rd Salibu	CN
AGRA	6.0	6.4	9.0	2.6	2.7	0.7
AMANKWATIA	5.9	6.8	8.0	2.6	3.0	0.7
AROMATIC SHORT	4.3	4.7	8.1	1.8	1.9	0.8
Ex BAIKA	5.5	6.3	8.9	2.1	2.1	0.8
JASMINE 85	–	–	8.1	–	–	0.7
SHWEPYIHTAY	5.7	6.7	6.9	3.4	3.9	0.6
SINTHUKHA	4.2	4.8	7.6	1.5	1.7	0.7
THEEHTATYIN	4.4	5.5	7.6	3.1	3.9	0.7
YADANARTOE	4.2	4.8	7.4	1.8	2.0	0.6
Mean	5.0	6.0	7.9	2.4	2.8	0.7
Lsd (5%) Mgmt(M)	0.58*	0.77*				
Lsd (5%) Variety(V)	0.58*	0.55**		0.34**	0.22**	
Lsd (5%) M × V	0.81*	0.83**		0.46**	0.37**	

* = significant at 5% significant level ** = significant at 1% significant level

Comparing growth parameters of rice in various generations of SALIBU and conventional rice system

There was a significant difference ($p<0.05$) for days to flowering among varieties. Generally, the ratoons, AGRA, *Shwepyihtay*, *Sinthukha*, and *Yadanartoe*, took a relatively long time to flower than the other varieties.

Theehtatyin and Aromatic short were the earliest to come to flower. Varieties showed significant differences ($p<0.05$) in plant height. The tallest ratoons were AGRA, *Amankwatia,* and *Yadanartoe*, while *Theehtatyin* had the shortest ratoon. Concerning tillers per hill, *Shwepyihtay* and *Theehtatyin* had significantly ($p<0.05$) higher tillers for the ratoon than the other varieties. The trend was the same with the conventional system (**Table 9-7, 9-8, and 9-9**).

Table 9-7. Growth parameters of rice under SALIBU rice ratoon cropping systems (first generation) and first conventional rice crop (CN)

Variety	Days to 50% flowering		Number of tillers per hill		Plant Height (cm)	
	Salibu	CN	Salibu	CN	Salibu	CN
AGRA	46	93	11	12	105	115
AMANKWATIA	38	96	14	13	104	110
AROMATIC SHORT	35	93	13	15	98	107
Ex BAIKA	43	92	10	12	87	91
SHWEPYIHTAY	49	98	16	18	91	93
SINTHUKHA	47	103	13	12	99	104
THEEHTATYIN	26	63	17	19	84	82
YADANARTOE	50	108	13	16	105	106
Mean	42	88	13	15	97	101
Lsd (5%) Mgmt(M)	4.1**		ns		ns	
Lsd (5%) Variety(V)	2.4**		1.6**		2.8**	
Lsd (5%) M × V	3.9**		2.2*		3.7*	

* = significant at 5% significant level ** = significant at 1% significant level

Table 9-8. Growth parameters of rice under SALIBU rice ratoon cropping systems (second generation) and second conventional rice crop (CN)

Variety	Days to 50% flowering		Number of tillers per hill		Plant Height (cm)	
	Salibu	CN	Salibu	CN	Salibu	CN
AGRA	44	94	11	13	103	115
AMANKWATIA	39	94	13	11	99	110
AROMATIC SHORT	39	83	14	13	98	107
Ex BAIKA	43	88	10	13	89	91
SHWEPYIHTAY	46	85	15	21	93	93
SINTHUKHA	45	95	12	14	98	104
THEEHTATYIN	28	66	17	15	86	82
YADANARTOE	46	98	13	14	103	106
Mean	41	88	13	14	96	101
Lsd (5%) Mgmt(M)	1.4**		1.8*		2.3*	
Lsd (5%) Variety(V)	2.8**		1.8**		2.6**	
Lsd (5%) M × V	3.8**		2.6*		3.6*	

* = significant at 5% significant level ** = significant at 1% significant level

Table 9-9. Growth parameters of rice under SALIBU rice ratoon cropping systems (third generation) and second conventional rice crop (CN)

Variety	Days to 50% flowering		Number of tillers per hill		Plant Height (cm)	
	Salibu	CN	Salibu	CN	Salibu	CN
AGRA	45	94	12	13	101	115
AMANKWATIA	40	94	13	11	101	110
AROMATIC SHORT	38	83	14	13	98	107
Ex BAIKA	46	88	13	13	90	91
JASMINE 85	–	98	–	17	–	98
SHWEPYIHTAY	51	85	16	21	91	95
SINTHUKHA	49	95	14	14	99	104
THEEHTATYIN	28	66	18	15	90	82
YADANARTOE	50	98	15	14	104	106
Mean	39	89	15	15	96	101
Lsd (5%) Mgmt(M)	5.6*		ns		ns	
Lsd (5%) Variety(V)	2.2**		1.8**		2.8**	
Lsd (5%) M × V	ns		2.5**		4.5**	

* = significant at 5% significant level ** = significant at 1% significant level

Conclusion

In this field investigation, the average annual yield of rice in the SALIBU system was higher by 1–9 t/ha than in the conventional rice cultivation system. Water productivity in the SALIBU system with AWD for all the varieties of rice was more than twice as much as recorded under the conventional rice cultivation system. Note that the water productivity of the SALIBU system with AWD is a combination of the contribution of the SALIBU system (omission of water for puddling and transplanting) and the contribution of AWD (intermittent irrigation).

This experiment has proved beyond doubt that the amount of water required to produce good rice, without excessive tilling of land, could be reduced drastically if the SALIBU rice ratoon cropping system is adopted with AWD. Some of the locally adapted Oryza sativa indica varieties in Sub-Saharan Africa (Ex *Baika*, AGRA, and Jasmine 85) were comparable with Asian types such as *Shwepyihtay* and *Theehtatyin* in terms of yield and water productivity.

Recommendations

Perennial rice varieties such as *Shwepyihtay*, *Theehtatyin*, Jasmine 85, and AGRA could be adopted for SALIBU rice ratoon cropping systems, especially in areas where there is high pressure on the water for various human activities.

Considering the short maturity period of rice ratoon, the amount of fertilizer recommended for application should be reduced to save cost and prevent environmental pollution.

Anti-bird nets should be used to control the bird to avoid high labor costs for scaring birds. Simple harvesting tools for cutting the ratoons should be available to encourage the adoption of the technology.

Chapter 10: Cultivation by farmers in rain-fed paddy fields – Ghana II

This chapter illustrates the cultivation test conducted in the Ashanti region in Ghana to investigate the applicability of SALIBU rice ratoon cropping systems to rain-fed paddy fields.

Description of site

Banahenekrom is a village in the Ahafo-Ano South East District of the Ashanti region, Ghana. The soil is a Haplic Gleysol characterized by Asubonteng et al. (2001). The site is in a semi-deciduous forest agroecological zone with a bimodal rainfall pattern. The primary rainy season starts from mid-March to the end of July, whereas the minor season begins in September and ends in mid-November, followed by a long dry spell, which ends by mid-March. The site is an inland valley that comprises the topo-sequence or continuum from the uplands to the valley bottom. The ecosystems in this continuum vary from uplands in the highest parts, through hydromorphic conditions lower down the slopes, to swampy in the valley bottoms. The upper summit of the inland valley is occupied by cocoa plantations, whereas the crest or hydromorphic zone and valley bottom are used for rice cultivation.

In this area, double cropping is performed for rice using major and minor rainy seasons, but the cropping area for the second season is only 20% of the entire cropping season due to mainly water availability.

The problem with the cultivation of the regular second crop is that it needs sufficient rainfall at the time of sowing and that the end stage of its growth may last after the end of the minor rainy season in mid-November, and the dry season begins.

Therefore, depending on the year, it may not be possible to perform the second cropping. The yield of the second crop is approximately 30% compared to that of the first crop. SALIBU farming does not require sowing, which is time-consuming and requires high labor, nor does it need an additional seed requirement. It does not depend on rainfall for sowing. And the harvest can be done about a month earlier than usual.

Methodology

The on-farm SALIBU ratoon rice trial was conducted in the primary rainy season of 2019.

1) Main crop establishment

The yield of the second crop is approximately 30% compared to that of the first crop. The main crop of rice variety AGRA was sown on April 16, 2019, under rainfed conditions. Zero tillage practice was adopted using herbicides to kill weeds to make space for planting rice by dibbling in a straight line and at approximately 20 cm by 20 cm spacing. The total area of the farmer's field used for the demonstration was one acre.

2) Agronomic practice for main rice crop

Weeds were controlled using post-emergence selective rice herbicide in the rice farm 21 d after sowing rice. The farmer applied NPK (15-15-15) fertilizer in three-quarters of his field immediately after the weed control, followed by a urea application 30 d later. Poultry manure was applied to the remaining quarter of the rice field. The primary source of water for rice farming was rainfall.

Harvesting was done using a sickle on August 10, 2019, when the crop was at the physiological maturity stage.

3) Ratoon rice agronomic practice

Before the harvest of the main crop, a portion of the farmer's field was demarcated for ratoon rice evaluation. The compound fertilizer NPK (15-15-15) was applied 7 d before the main rice harvest at physiological maturity. At the physiological maturity stage, rice was cut to a height of 3 cm from ground level on August 18, 2019. The soil was kept in a moist condition by draining excess water from rainfall and run-off from the upper summit of the landscape. Second fertilization was done by urea application 7 d after the sprouting of rice ratoon.

Harvesting was done 65 d after cutting on October 26, 2019.

Data collection and results

Data on plant height, panicle length, grains per panicle, percentage filled grain, 1000-grain weight, and grain yield at 14% moisture content were collected and tabulated, as below.

Table 10-1. Summary of results from on-farm ratoon rice experiment in Banahenekrom, Ashanti region, Ghana

	Plant height (cm)	Length of panicle (cm)	No. of grains per panicle	Percent filled grains	1000-grain weight	Yield (t/ha)
Main rice crop	104	27.6	160	88	29.2	4.6
First-generation ratoon rice crop	90	24.2	144	85	29.1	4.2

A field day was organized where all members of *Banahenekrom* and a few representatives of *Yaw Boadi* participated during the harvesting or cutting of the main crop at physiological maturity and during the harvest of the first-generation SALIBU ratoon. The field day aimed to sensitize farmers to the benefits of the SALIBU rice ratoon cropping systems.

Conclusion and recommendations

The above data shows that the yield of rice ratoon is approximately 90% of the main crop, an additional income to the farmer without extra cost for land preparation and crop establishment. In addition, the shortness of time for the ratoon rice to reach maturity could reduce the risk of terminal drought in the rainfed system.

Adequate water management is particularly critical to enhancing the impact of SALIBU rice ratoon cropping systems in smallholder rainfed farming systems in the inland valley. Therefore, the construction of water control structures such as bunds with inlet and outlet canals for in-flow and out-flow of water is needed. These structures will facilitate rainwater harvesting and removal of excess water when needed.

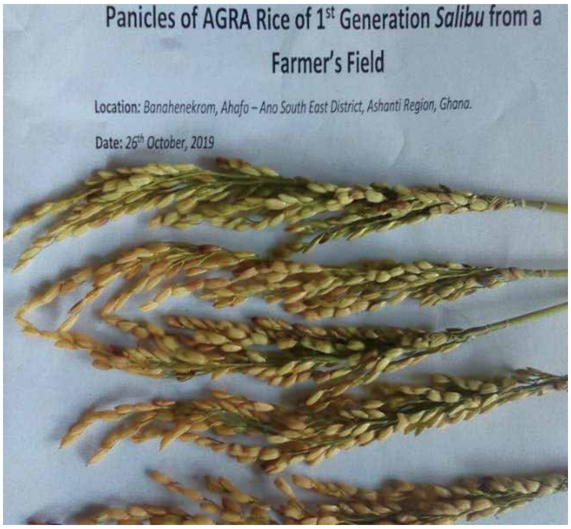
The availability of improvised harvesters, such as long-arm grass mowers, for harvesting/cutting the ratoon and threshers will be necessary to encourage the adoption of the technology.

Farmers will have to be encouraged to control weeds just before the harvest of the main crop to prevent the competition of weeds with the ratoon crop. An anti-bird, i.e., a fishing net used to cover rice during the grain-filling stage, will ward off birds and reduce human labor to scare birds.

Rainfed ratoon rice farming in *Banahenekrom* village (**in pictures**)

Farmers with the researcher during field day

Panicles of ratoon rice



Harvested ratoon rice with panicles

Panicles from ratoon rice

The first generation SALIBU ratoon crop of AGRA rice variety from a farmer's field

Chapter 11: Farmer-Based Organizations — Ghana III

Introduction

Ghana is a country in West Africa. It lies between latitude 4° N and 11° N and is traversed by longitude 0°. It is within the Greenwich Mean Time zone. It is perhaps the country closest to the center of the earth. It has a tropical climate with two seasons, wet and dry. Generally, the wet season is divided into two, i.e., a primary rainy season from about mid-March–July and a minor rainy season running from September–November. There is a long dry season from December–March. The vegetation is shrubby savannah covering the northern half, tropical rainforest in the middle belt and southwest, and coastal savannah in the southeast.

Rice value chain in Ghana

Ghana is one of 23 member countries of the Coalition for African Rice Development (CARD), an initiative launched in 2008 by the Japan International Cooperation Agency (JICA) in partnership with the Alliance for a Green Revolution in Africa (AGRA). It supports the efforts made by African countries aimed at doubling rice production within ten years. CARD also runs a consultative group of donors, research institutions, and other relevant organizations to work with rice-producing African countries.

Rice has become the second-most important food staple after maize in Ghana, and its consumption keeps increasing owing to population growth, urbanization, and changes in consumer habits. Unfortunately, the rice industry is characterized by low production, low average yield, and poor grain quality, resulting in heavy import dependence. According to the US Department of Agriculture, Ghana consumed 980,000 tons of rice in 2015 yet produced only 330,000 tons, or roughly 34%, domestically. This substantial gap was filled by imported rice, primarily from the US, Vietnam, and Thailand. Nearly 698,570 metric tons of rice were imported by Ghana in 2016. Ghanaians have developed a strong appetite for imported rice over the years due to its availability and distribution reach in the market and its highly polished and fragranced nature.

The need to increase domestic production to meet growing consumer demand for disease-resistant and select local varieties cannot be overemphasized. In 2008, Ghana released the National Rice Development Strategy (NRDS) to double rice production by 2018 and improve quality to increase demand for domestic rice.

Rice is cultivated in Ghana under three major production systems, i.e., rainfed upland, rainfed lowland, and irrigation. The rainfed lowland ecology is dominant, covering over 78% of the total harvested area, whereas irrigated ecology and upland area cover 8 and 14% of the total rice area, respectively. Most farmers practice the nursery bed method, wherein beds are prepared, occupying almost 1/20 of the total field area. The paddy seeds are sown in beds. They are ready within 25 d of sowing in lowland areas, whereas in higher altitudes, they take almost 55 d to become prepared for transplantation. In terms of popularity, rice is second after maize in the world. The rice farming business in Ghana is profitable because of the high demand for rice in the market.

According to data released by the Ministry of Food and Agriculture (MoFA), Ghana, annual per capita rice consumption in Ghana during 1999–2001 was 17.5 kg on average, while it was expected to increase to 63.0 kg in 2015 (MoFA, 2009). Daily per capita supply on a calorie basis in 2013 indicates rice (304 kcal) as the first cereal and the fourth crop after cassava (642 kcal), yam (437 kcal), and plantain (311 kcal), while maize (222 kcal), wheat (109 kcal), sorghum (53 kcal) and millet (36 kcal) follow (FAOSTAT, 2020). Imported rice is consumed more by people in urban areas than rural areas because they prefer its taste, ease of cooking, high shelf stability, and nutritional value. The expected expansion of urban life hereafter must promise the trend of increasing demand for rice.

Figure 11-1 shows changes in the supply of the calories of major crops consumed in Ghana from 1961–2013. In the 1960s, cassava, yam, and plantain accounted for the most calories supplied. Today, these three crops remain a perennial favorite among middle-aged and older consumers, but the taste of younger consumers is rapidly shifting towards rice and maize, and the trend will continue.

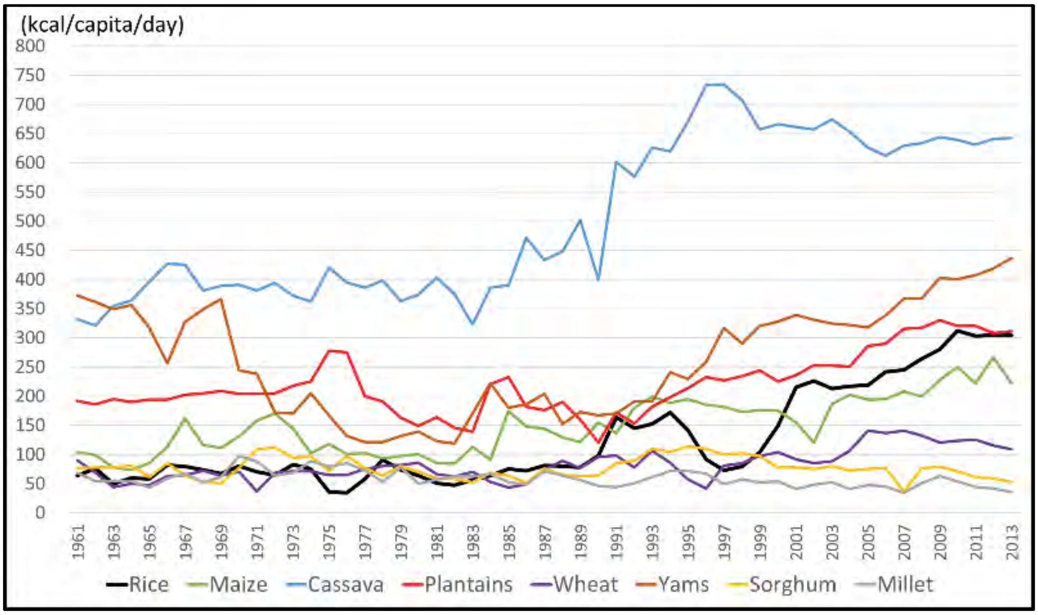


Fig. 11-1. Supply of the calories of major crops per capita per day in Ghana from 1961–2013

Source: FAOSTAT; Aggregated by author

Figure 11-2 shows changes in the supply index of the calories of major crops consumed in Ghana from 1961–2013. The supply of calories from rice has increased more rapidly than from other crops since the 1990s, as is evident from this supply index (1961 = 100).

Most Ghanaian consumers prefer unbroken whole long grain perfumed rice of pleasant taste, clean and uniform in size, which provides a substantial competitive advantage to imported quality rice rather than locally produced rice, despite the higher market price of the former, including almost 20% import levy.

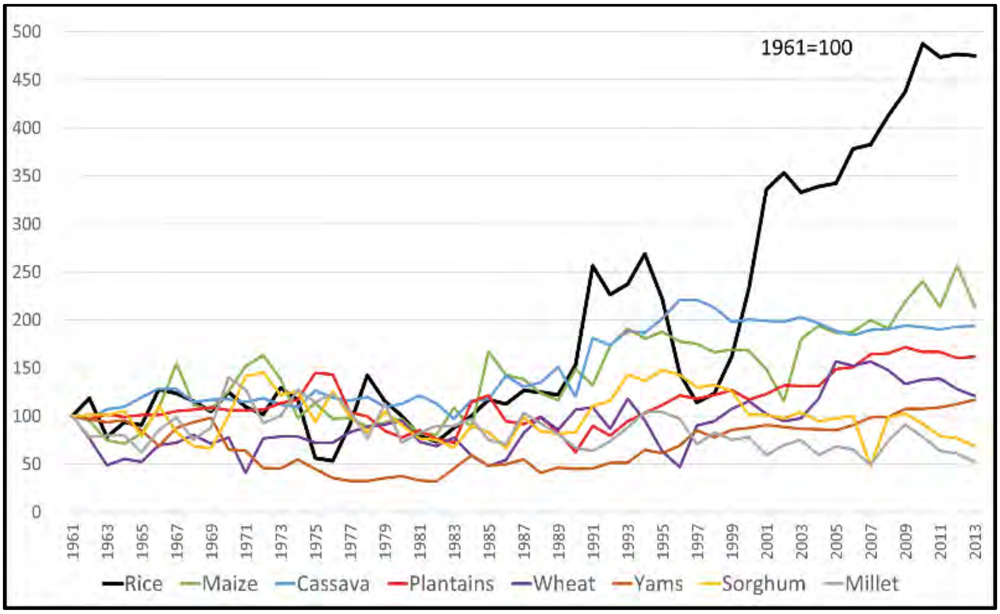


Fig. 11-2. Supply index of the calories of major crops per capita per day in Ghana from 1961–2013
Source: FAOSTAT; Aggregated by author

Figure 11-3 shows changes in the total area harvested, production, and yield per unit area of rice, in Ghana from 1961–2019. The yield per unit area was almost 1 t/ha until the first half of the 1980s. However, since the late 1980s, the yield per unit area has been increasing at 0.05 t/ha per year. The combination of such an increase in rice yield per unit area and total area harvested resulted in a steady growth in rice production since 1999, with an increase of almost 2.7 times in 20 years. However, the increase in domestic demand for rice since the 1990s far exceeded the increase in domestic production. In addition, as shown in **Figure 11-4**, the gap between the two, shown as the black line, rapidly widened, reaching 500,000 tons in the first half of the 2000s and 800,000 tons in the 2010s. Rice imports increased in the early 1990s, importing 200,000–300,000 tons annually. However, in the latter half of the 1990s, the exchange rate of the domestic currency, the Cedi, dropped against the US dollar, from 900 cedi/dollar in 1994 to 5,000 cedi/dollar in 2000, and during this period, rice imports decreased to tens of thousands of tons per year. Since 2001, the amount of rice imported has increased along with a rather stable exchange rate, importing 400,000 to 800,000 tons annually.

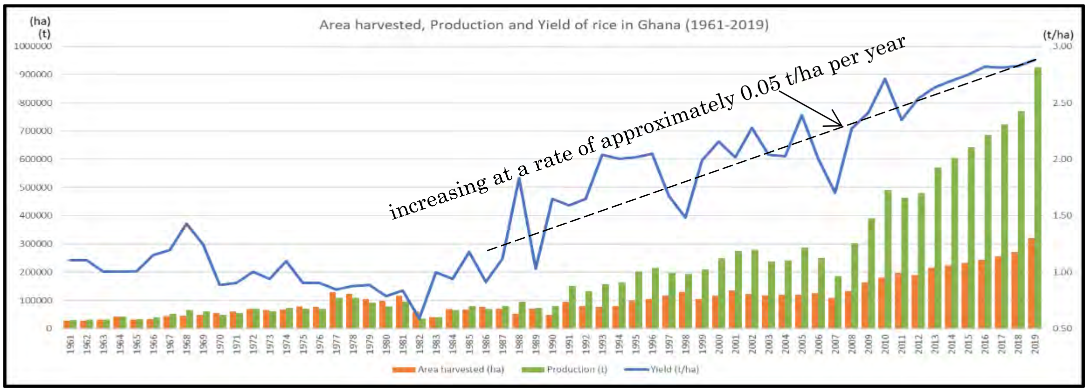


Fig. 11-3. Area harvested and the production and yield of rice in Ghana from 1961–2019)
Source: FAOSTAT; Aggregated by author

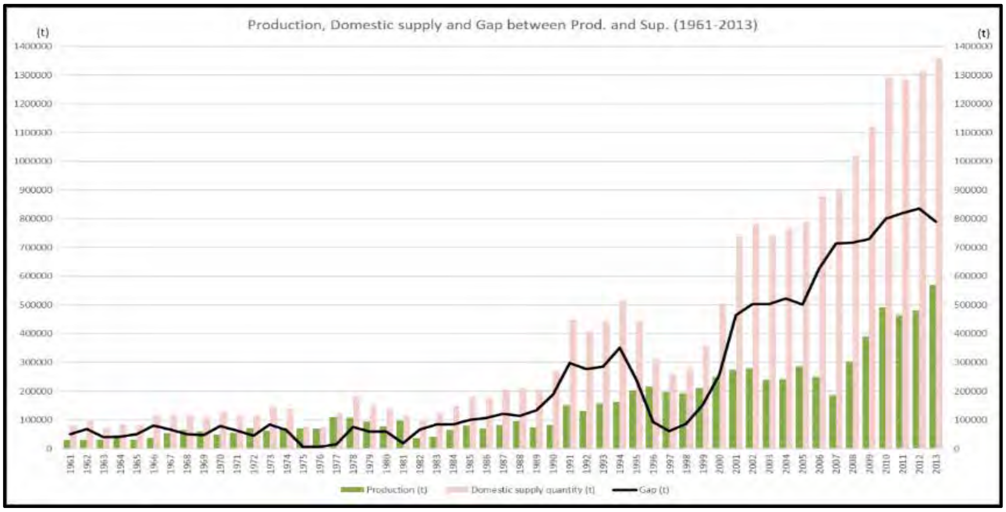


Fig. 11-4. Production, supply, and the gap between production and supply of rice from 1961–2013.
Source: FAOSTAT; Aggregated by author

The circumstance in Ghana epitomizes that in sub-Saharan Africa, which consists of Eastern, Central, Southern, and West African countries. The demand for rice in sub-Saharan African countries is also rapidly increasing. Consequently, the consumption of rice in these countries was estimated to increase from 19.8 million tons in 2010 to 34 million tons in 2020 (Africa Rice Centre, 2011), resulting in importing 14 million tons of milled rice in 2020 and consuming a large amount of foreign currency necessary for the economy of these countries. Boosting domestic production of rice is a commonly prioritized economic issue in sub-Saharan African countries, including Ghana.

Figure 11-5 shows changes in the total area harvested, production, and yield per unit area of rice in sub-Saharan African countries from 1961–2017. The yield per unit area was approximately 1.5 t/ha until the first half of the 1980s. However, since the late 1980s, the yield per unit area has been increasing at 0.01 t/ha per year. The annual increase rate in rice yield per unit area in Ghana is five times more than that of the average in sub-Saharan African countries. The policy adopted by Ghana for an increase in rice production since the 1990s and the resulting increase in rice production is an excellent example of a sub-Saharan African country.

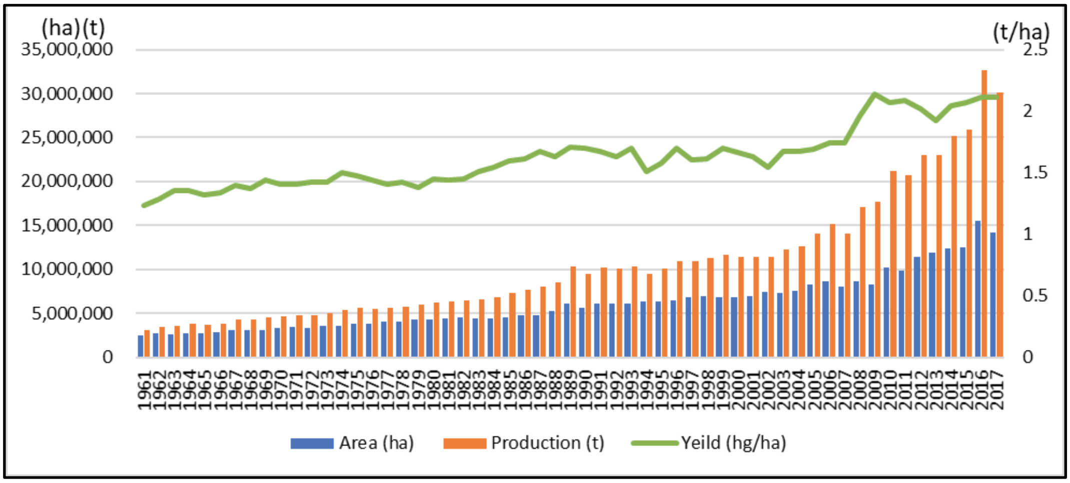


Fig. 11-5. Area harvested and the production and yield of rice in Ghana from 1961–2017.

Source: FAOSTAT; Aggregated by author.

However, the rice self-sufficiency ratio in Ghana has declined from 38–24% from 1999–2006 (MoFA, 2009). After this period, the government of Ghana initiated a series of policies for addressing food security and poverty reduction, such as the Food and Agriculture Sector Development Policy II from 2008–2010 and the Medium-Term Agriculture Sector Investment Plan from 2011–2015. MoFA, Ghana, announced in 2015 that the domestic production of milled rice between 2009 and 2014 increased from 235,000–417,000 tons, and the country attained a 56% self-sufficiency ratio of rice in 2015 owing to laudable policies. However, Ghana still depends largely on imported rice to make up the deficit in rice supply and it means that the country spends an average of about 290 million US dollars of its scarce foreign currency for the import of rice annually (MoFA, 2015). Promoting domestic rice production is continuously one of the most highly prioritized political and economic issues in Ghana.

Current status of rice farmers in Ghana

Rice production in Ghana mostly depends on numerous small-scale rice farmers, keen to increase rice production but still putting up with lower yields. They need an effective extension service on rice production technology and fair access to finance for investment in resources.

NRDS of Ghana (G-NRDS), formulated in 2008 and revised in 2015, classifies rice farmers in Ghana into five large groups based on their economic conditions. It indicates that viable small-scale rice growers who are poor but potentially viable because of limited access to markets and technologies head the list of the groups and account for 40% of the total. They have the willingness to take a little risk to increase rice production. The poorer group of marginal rice smallholders, each one of emerging commercial rice growers and the poorest resource-poor rice growers, and the other one of established commercial ventures account for 25, 15, and 5%, respectively (**Table 11-1**).

Based on agroecology, rain-fed lowland covers 78% of the area under rice cultivation, and upland (14%) and irrigated (8%) follow. This study targets the villages mainly consisting of viable small-scale rice growers, the middle class of total rice growers, and partially marginal smallholders and emerging commercial growers under rain-fed lowland and irrigated ecology because it aims to maximize the impact of the policy recommendation on boosting rice production in Ghana.

The rice sector development in Ghana is very critical for the development of the Ghanaian economy. G-NRDS directs this and sets out strategic intervention areas with an ambitious target, which will lead to the government achieving its mission of increasing rice production by 20% per annum and attaining self-sufficiency by 2018. It aims to address the challenges of low agricultural production, focusing on a few bottlenecks along the rice value chain, which hitherto have inhibited the growth of rice industries.

Therefore, it identified the following thematic areas as constituting the greatest obstacle to increasing production, which need to be examined critically, and solutions provided. These include seeds, fertilizer marketing and distribution, harvesting, post-harvesting and marketing, irrigation and water control, equipment access and maintenance, research and technology dissemination, community mobilization through farmer-based organizations (FBOs), credit management, and monitoring and evaluation.

Among the thematic areas identified in the G-NRDS document, the target of this study, viable small-scale rice growers, mainly need adequate access to markets, research and technology dissemination, community mobilization through FBOs, and a credit management system. Their sustainable agricultural development will not only depend on material inputs, e.g., seeds, fertilizer, water, and machinery, but also people involved in their use. This study focuses on human resources and calls for increased knowledge and information sharing about agricultural production and appropriate communication, methodologies, channels, and tools. Many individual small-scale farmers, however, often lack the means and capacities to demand, organize or finance the information access and communication services they need for the development of their farm businesses. Addressing these challenges would require rural collective actions or organizing farmers into sustainable groups. Farmers in Ghana have been engaged in collective actions long before the introduction of formal farmer groups and cooperatives. For example, as far back as the pre-colonial period the farmers (usually relatives and friends) in a neighborhood organized occasionally to provide each other with reciprocal labor support on their fields, mostly weeding, planting, and harvesting (Owusu, 2015).

Table 11-1. Typology and percentage proportion of rice farmers in Ghana

Type	Main characteristics	% Proportion
1. Resource-poor rice growers	Subsistence: often female-headed or elderly-headed households. Face labor constraints: have no resources to fall on in the event of external shocks.	15
2. Marginal rice smallholders	Could produce a small marketable surplus; may have some resources on which to fall, including greater physical strength, better health, more land, and small savings. A significant proportion of adult household members may migrate during the off-season.	25
3. Viable small-scale rice growers	Poor but potentially viable small-scale farmers, not necessarily, factor-constrained, i.e., have land or labor or both. Often possess assets that are used inefficiently because of a lack of access to markets, poor infrastructure, weather-related risks, or limited access to technologies. Willingness to take little risks.	40
4. Emerging commercial rice growers	Grow rice mainly as a cash crop; market orientation; could own small equipment like tractors; use hybrid seed and fertilizer; few with irrigation; have household labor with a little hired labor.	15
5. Established commercial ventures	Grow and process rice as a cash crop. Market-oriented and owns medium to sophisticated equipment like tractors, graders, seeders, combine harvesters, and rice mills. Use improved/quality seeds, fertilizers, and irrigation facilities with improved land conditions using water harvesting and regulatory structures. They can hire labor or engage other farmers as outgrowers or both.	5

Source: MoFA, 2015.

Legend: [ ] First target group [ ] Secondary target groups

Current status of agricultural extension delivery services in Ghana

In Ghana, extension delivery was started by early missionaries and foreign-owned companies involved in export crop production, such as coffee, cocoa, cotton, and rubber. In Ghana a range of approaches to extension delivery (from top-down commodity-based approaches to more participatory approaches) have been promoted over the years by the various extension service providers, including the government (MoFA, the main actors in extension), non-governmental organizations (NGOs such as Finatrade, Actionaid, Care, Plan), producer organizations (BOPP, TOPP, GREL, COCOBOD) and other farmer organizations (DAES/MoFA, 2011b). Approaches/methodologies such as Training and Visit (T&V), Participatory Approaches, Farmer Field Schools (FFS), and the Commodity Approach have been tried and used. These also include extensions under the farmers' cooperative movement and several donor-assisted projects. In the 1970s and 80s, Agricultural extension was fragmented among the various departments within the same ministry. In 1987 however, MoFA established the Directorate of Agricultural Extension Services (DAES) to bring all fragmented MoFA extension services under one unit. (Ekepi, 2009, DAES/MoFA, 2011b)

DAES is the headquarters of the main actors in extension in Ghana. It is headed by a National Director and assisted by three Deputy Directors heading the different Departments of Livelihood, Training & Communication, and Field Services. Ghana is divided into 16 regions, and these regions are divided into 216 administrative districts, including 145, 109, and 6 ordinary, municipal, and metropolitan districts, respectively. Each Regional Office is headed by a Regional Director and assisted by nine Regional Officers of which one is engaged in extension services. Each District Office of DAES (Regional Agricultural Development Unit – RADU) is also headed by a Regional Director and assisted by sixteen Regional Agricultural Officers responsible for various aspects of agriculture, of which one is engaged in extension service. Each District Agricultural Development Unit (DADU) is also headed by a District Director of Agriculture (DDA) and assisted by four District Agricultural Officers (DAO). On average, there are 10 Agricultural Extension Agents (AEA), who are assigned under the DAOs. On the whole, there are approximately 3,000 AEAs country-wide who take care of 4 million farmers. It means that one AEA must cover 1,300 farmers on average. This number is enough to make adequate contact with all the farmers at least once every two weeks during the three months of each cropping season while the ideal one is 700 at maximum. Furthermore, extension officers are responsible for all agricultural production, from cereals, vegetables, and fruits to livestock in their areas of operation. Rice is a rather minor crop among them, so extension workers cannot put a big effort into rice farmers. Our target rice growers rely heavily on AEAs regarding the delivery of extension services. However, DAES has suffered dwindling budget allocations over the last decade or so and this seriously affected its ability to deliver effective extension services to farmers. For example, the government supply of motorbikes and oils has diminished over the years even though they are indispensable for AEAs' activity ranging over villages. Now AEAs mobilized themselves based on the demands of farmers who want to solve certain problems while they used to make regular rounds of visits among villages.

Enormous investment is required to strengthen the agricultural extension service itself. However, this is not feasible in the foreseeable future, and thus, this study came up with the idea of organizing farmers, recipients of agricultural technology, to stock up on technology in a group, creating a system for sharing it among farmers. It was based on the experience of Japan, where the economy and society collapsed after the Second World War and the government needed to protect the people from hunger. Most of the rice farmers in Japan at that time were peasants who had just been given cultivated land by the land reform policy and were poorer than the rice farmers in Ghana today. Village-scale agricultural cooperatives established by farmers became the limbs of agricultural extension workers and worked together with them. Using this example from Japan as a reference, an FBO with a highly centripetal force established by a Ghanaian rice farmer should be able to do the same. The FBO will become a village platform to spread rice cultivation technology.

Establishment of the field study formation in Ghana

Here the author wants to mention the green revolution again. According to the formula *Green Revolution = irrigation development (X) × introduction of high-yielding varieties (Y) × fertilizer input (Z)*, it indeed happened that the Green Revolution improved the world food situation, realized only in the regions that could put this formula into practice. If one of XYZ is missing, the realization of the Green Revolution will not occur. Without X, farmers are hesitating to invest in Y and Z because it could become wasteful. Actually, from the perspective of poor small-scale farmers, their destiny greatly depends on whether their field is inside or outside the beneficiary area of public irrigation projects.

Consumers worldwide have benefited the most from the Green Revolution because of improving their access to cheaper foods compared to the pre-Revolution period. The next was farmers in developed countries blessed with X, Y, and Z, followed by those in developing countries, only farmers inside of the beneficiary areas of public projects who had the capacity for investing in Y and Z.

If we launch a second Green Revolution in this century, it needs to happen in the way of providing the most benefit to numerous poor small-scale farmers excluded from economic development during the first Green Revolution. Otherwise, the inequality will be widening. Remember the facts that most of the rice production in Sub-Saharan African countries depends on an enormous number of small-scale rice farmers.

However, governments of many developing countries have reduced their investment in

X. They are also reducing overall public support and services for agriculture, including agricultural extension services. The situation calls on poor small-scale farmers to increase self-investment. Then, how can they find and build a path to increase their investment?

Rice farmers doing double cropping have the opportunity of primary income only twice a year. Under this situation, their investment failure is directly linked to putting their family at a high risk of hunger. Such is something unimaginable for us office workers who have more than 12-time stable income opportunities a year. For this reason, poor small-scale rice farmers are very conservative in their investments. Not to mention about investing in X, they are also nervous about investing in Y and Z.

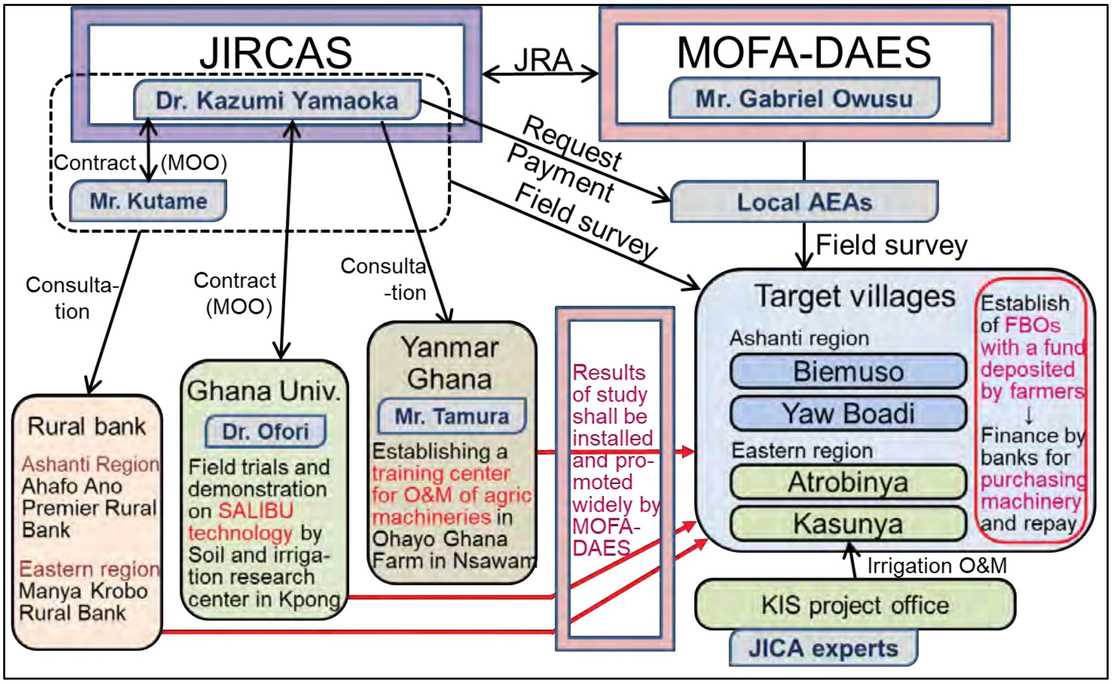
First, it is necessary to rid the fears of poor small-scale rice farmers on investment and accumulate their successful experiences. Moreover, if individuals do not invest in pieces but work together as a group toward a single goal, they can do far beyond what individuals can do. In addition, it creates more solid unity among farmers.

Generally, investment in irrigation development is immense and takes a long time. No benefit will be generated until irrigation facilities are completed. Therefore, it is not suitable for the first investment of farmers.

The study was originally planned for two locations — an irrigated site under the Kpong Irrigation Scheme in the Shai-Osudoku district in the Greater Accra Region and a lowland valley site in the Ahafo Ano South-East district in the Ashanti Region. Two villages were chosen in each Atrobinya and Kasunya villages in Greater Accra and Biemso No. 1 and Yaw Boadi villages in the Ashanti Region. A baseline survey was conducted using an administered questionnaire. The object of the survey was to obtain data on what rice farmers currently wanted most for improving their rice farming. The analysis of responses showed that the topmost requirements were for power tillers for puddling paddy fields, rice threshers, and irrigation pumps.

They were most eager for agricultural machinery that would benefit them immediately. Buying agricultural machinery with individual investment is impossible for a poor small-scale rice farmer. They need to unite and make investments together. Getting an agricultural machine is their lifetime dream. The authors were convinced that the joint purchase and use of power tillers must be the best initial investment experience for them.

The study was designed initially, as shown in **Figure 11-6**. The project sponsor was to work hand in hand with the DAES. They signed a memorandum of understanding (MOU) for the involvement of the AEAs in organizing the groups at the chosen sites and also to ensure the groups paid back loans granted to them. Through the DAES the sponsor recruited a local assistant. The sponsor signed another agreement with a researcher at the University of Ghana Research station at Kpong in the Eastern region of Ghana to research the suitability of local rice varieties for SALIBU technology and to supervise the uptake of the SALIBU technology by the farmers. A company dealing in the import and sale of required agricultural machinery was contacted to join the project. The project, with the assistance of the AEAs, also recruited the services of local rural banks to provide financing to the groups for the purchase of machinery. The farmers were to deposit a stated sum at the selected bank.



Notes: MOFA-DAES: Ministry of Food and Agriculture, Directorate of Agricultural Extension Services; JRA: Joint Research Agreement MOO: Memorandum concerning Overseas Outsourcing; and AEAs: Agricultural Extension Agents FBO: Farmers Based Organization.

Fig. 11-6. Design of field survey for social experiment in Ghana

It is most important to set clear goals if rice farmers in a village want to establish an FBO with firm solidarity. The joint purchase and use of power tillers, threshers and irrigation pumps can be a clear goal for Ghanaian rice farmers. If the average paddy area per rice farmer is about 0.4 to 0.8 ha (1 to 2 acres), it is considered appropriate to share one machinery with 10 to 20 people in terms of machine capabilities. The farmers wanted high-performance and durable Japanese-made machinery, and its price was around US$ 4,000. To share this with 10 to 20 people, they need to pay US$ 200 to US$ 400 per person. However, the burden was too heavy for them. According to the questionnaire survey, reasonable payment per person was revealed as between US$ 50 and US$ 100.

Policy target: Autonomous technology up-taking by FBOs with high centripetal force

Different alternative approaches have been adopted to develop farmers' organizations other than cooperatives, allowing other types of rural and farmers' self-help organizations for income-generating activities to be formed, commonly referred to as FBOs recognizing collective actions as critical instruments for agricultural and rural development. FBOs could be defined as groups of rural producers (mostly farmers) coming together to found organizations, based on the principle of free membership, to pursue specific common interests of their members. (Owusu 2015) Ghana has witnessed many governmental and nongovernmental institutions, NGOs, churches, and other private groups seeking to promote FBO development for different reasons/objectives. They range from informal loose farmer groups at the village level, pre-co-operative societies being organized and prepared for registration, and organized and registered farmer groups, to rural associations or unions of farmers, processors, and producers. The informal village-level groups form the greater proportion of FBOs in Ghana.

DAES established an FBO Secretariat in 2003 under the Agriculture Sub Sector Investment Programme (AgSSIP-World Bank) for implementing an FBO Development Fund and an Extension Development Fund. FBOs formation and strengthening are also consistent with the national agricultural extension policy decision, aiming at enhancing the quality of extension to farmers and other operators along the value chain to improve productivity and production as well as the quality and safety of produce and products from the sub-sectors. Many FBOs were formed under the program to access funds for equipment, credit, and other "material" support. National, regional, and district steering committees were formed to receive and assess proposals from FBOs for funding and equipment. Other Development Partners (DP) like the Canadian International Development Agency (CIDA) contributed to the fund. After the AgSSIP program and others were terminated, many of the FBOs formed under the program were no longer active and equipment was not used or obsolete. The national FBO Secretariat however has been institutionalized and is part of the DAES under the Deputy Director for Field Services.

Despite the right intention and promising interventions offered by programs such as Engineers without Borders (EWB) and "Farmer Business School" conducted by MoFA, international development partners, and NGOs, FBO development initiatives have yielded mixed results. The 2009 Annual Progress Report of MoFA said that out of the total number (24,514) of formed FBOs, 46% is functional, 22% is accessing financial and/or market information service, 9% is accessing credit and 4% is successfully repaying loans. The regional and district steering committees do not function anymore, but the National Steering Committee (NSC) does approve work plans and budgets of the FBO Secretariat and manages the funds that are allocated to the FBO account for funding of activities of other DPs (only CIDA at the moment) (DAES/MoFA, 2011a).

In Japan, village-scale agricultural cooperatives established by farmers, equivalent to FBOs in Ghana, have been functioning well and have become the limbs of farming extension workers working together. In contrast, why are many of Ghana's FBOs stagnant?

In Ghana, a few FBOs are still active, such as the *Dangme* West Mango Farmers Association in *Dodowa*, central Greater Accra Region. This FBO conducts joint fruit sorting by FBO members, which is indispensable for shipping highly value-added mango to earn a stable income. They ship the highest quality mango overseas, the next one to the local market, and the last in quality parameters to juice manufacturing companies. What Japan's village-scale agricultural cooperatives and *Dangme* West Mango Farmers Association have in common is that the FBOs are carrying out joint projects by their members.

In the example of early agricultural cooperatives in Japan, rice farmers jointly invest money to create funds in their cooperatives, and the cooperatives obtain loans from banks using the collected funds as collateral. Then, cooperatives conduct joint activities, including the purchase of agricultural materials such as fertilizers and selling them to FBO members, usually cheaper than it would have been when an individual farmer had purchased items on their own, the purchase of agricultural machinery and renting it to members, and storage and shipment of rice. The most important point is the high centripetal force of the FBO — the fact that each member has invested a considerable amount of money means that if they do not trust each other nor unite, their invested funds will disappear. Additionally, cooperatives will carry out a larger joint business with the loan obtained from the bank using the funds as collateral, and various profits will be returned to the members. In addition, the cooperatives' ability to act as a bridge between agricultural extension workers and member farmers makes it become an organization that members rely on.

A farmer in *Atrobinya* village in the Kpong Irrigation Scheme project area in Eastern Region cultivates twice the paddy field area compared to that in *Biemso* village and can perform double cropping. The results of the questionnaire survey conducted in both villages are shown in **Figure 11-7** and **Figure 11-8**. The average annual income per household is GHS 5,821 for *Biemso*, GHS 9,912 for Atrobinya, and GHS 972 and GHS 1,727 per member of the household, respectively. The average amount of money to be invested per household is GHS 136 (US $ 35) for *Biemso* and GHS 300 (US $ 75) for *Atrobinya*, and the ratio of investment to average annual income is 2.3% and 3.0%, respectively. **Figure 11-7** compares the number of farmers by their investable amounts of money in both villages. **Figure 11-8** compares the distribution of investable amounts of money by the annual income of farmers in both villages.

The questionnaire survey in both villages was conducted using simple questionnaire forms. The functions expected of an FBO are shown at the beginning in this form. Then, it asks the amount of money to be invested by each farmer in the FBO. It does not show the cost required to perform that function. Therefore, it is supposed that the farmers showed a slightly restrained willingness to pay. The ratio of the amount of money to be invested to the average annual income is only 2–3%, supporting this idea.

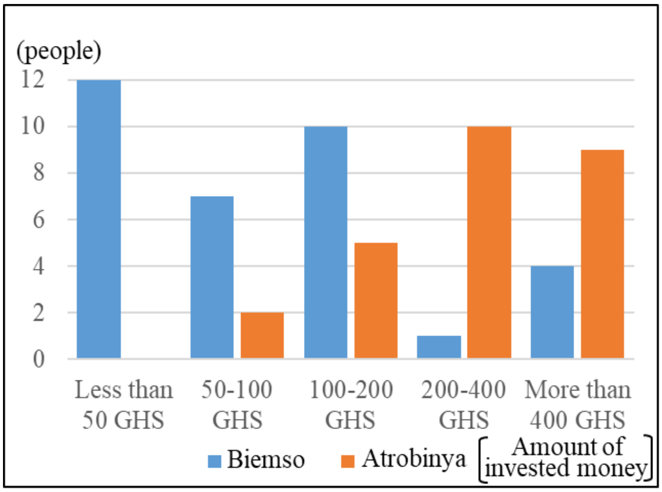


Fig. 11-7. Number of people based on the amount of money to be invested in each village

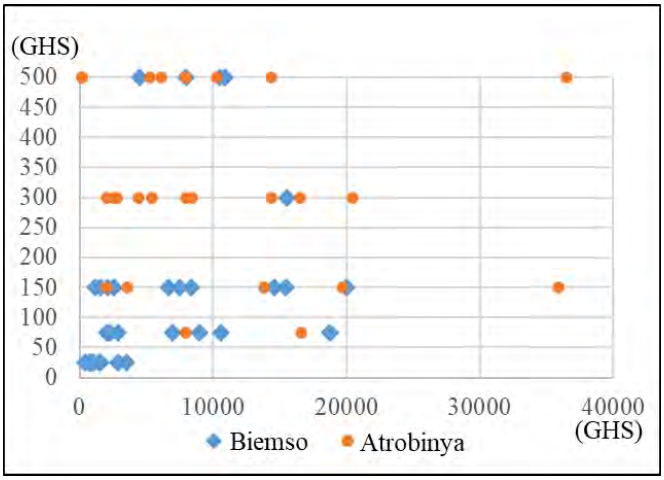


Fig. 11-8. Annual income vs. the amount of money to be invested in each village in the area

Strengthening rice farmers' FBO: Jointly invest funds in FBO and use them as collateral to get a loan from a bank to jointly purchase agricultural machinery

If they can invest approximately 5% of their annual income, the possible investment amount will be GHS 300–500 (US$ 75–125) per household. However, this still falls short of the GHS 800–2000 (US$ 200–500) per unit payment required for the group purchase of agricultural machinery.

This problem can be solved by investing GHS 300–500 (US$ 75–125) per household in FBO, opening a bank account in the name of FBO, depositing total investment to the FBO account, collateralizing deposit and agricultural machinery to be purchased, and receiving an amount of loan from the bank equal to GHS 800–2000 (US$ 200–500) times the number of FBO members.

As an example, consider the case where ten members jointly invest GHS 500 per person, i.e., a total of GHS 5,000 (US$ 1,250), and receive a loan of GHS 2,000 per person, i.e., a total of GHS 20,000 (US$ 5,000), a reasonable amount to buy a high-performance Japanese-made power tiller or a threshing machine. Therefore, ten farmers will collaboratively invest making a fund of GHS 5,000 (US$ 1,250) in FBO and offer it as collateral to the bank, and in exchange, receive a loan of GHS 20,000 from the bank, purchase an agricultural machine of GHS 20,000 price and offer it as collateral. Consequently, the total value of the collateral at the beginning of the loan is GHS 25,000 (GHS 5,000 as cash and GHS 20,000 as materials).

There is currently no scheme in Ghana to provide long-term repayment finance to farmers. Banks are wary of granting loans to farmers because there have been several defaults in the past when banks made such loans. The current repayment period of the loan to farmers is only 6 months and the annual interest rate is 30 to 35%. We negotiated to realize a loan scheme with a low-interest rate and repayment period of 3 years under the scheme described in **Figure 11-9**.

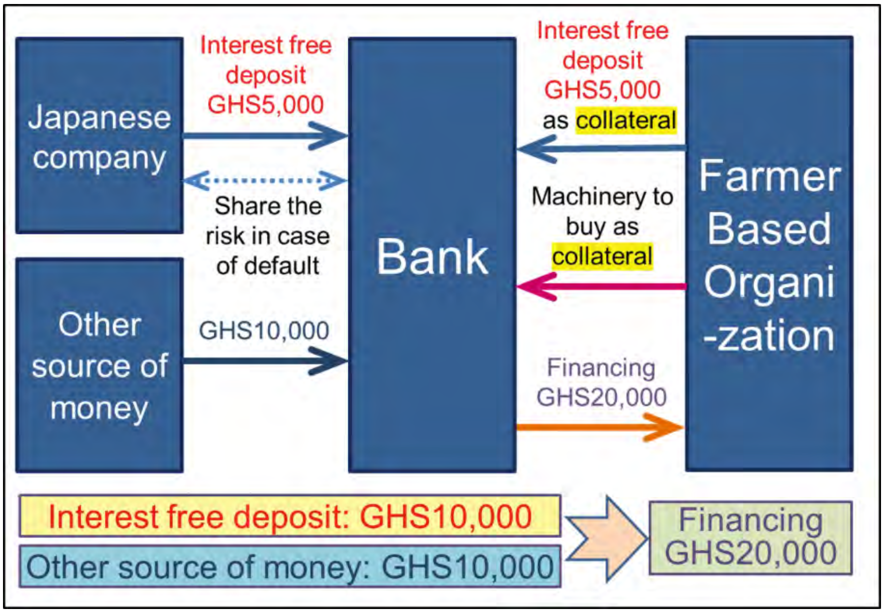


Fig. 11-9. Proposal of the pilot project for the new finance scheme

Banks in Ghana, in general, have to set high lending interest rates because they have to spend a high cost to raise funds for loans. In this scheme, banks raise interest-free

GHS 5,000 from a company that sells agricultural machinery to the FBO in addition to the GHS 5,000 cash provided by the FBO as collateral. As a result, banks can apply a total of GHS10,000 interest-free funds as a source of money to the GHS20,000 loan amount. As banks raise only GHS 10,000 in high-cost resources, they can keep a lower lending interest rate for the loan amount of GHS 20,000.

The most worrying issue for Ghanaian banks is to keep losses in the event of defaults low, a problem that the author strongly felt after discussing with executives such as presidents at many banks. The provision of interest-free funds from some companies to banks contributes to the reduction of bank lending rates as mentioned earlier. At the same time, this also serves to keep the bank's loss low in the event of a default by splitting the loss between the bank and the company. This means that certain companies and banks share the risk of default.

When the company cannot do that, this interest-free funding to reduce lending rates and share risks may be provided by the government of Ghana or NGOs. In this case, farmers can buy cheaper agricultural machinery other than Japanese-made, such as made in China. If there are no problems with the performance and durability of such agricultural machinery as Chinese-made, the FBO can more reliably repay the loan by purchasing cheaper agricultural machinery.

Under this scheme, the project sponsor provided the simulation of redemption to banks to minimize losses due to default and calculated the amount of loss when defaults occurred at any time during loan redemption (**Figure 11-10**).

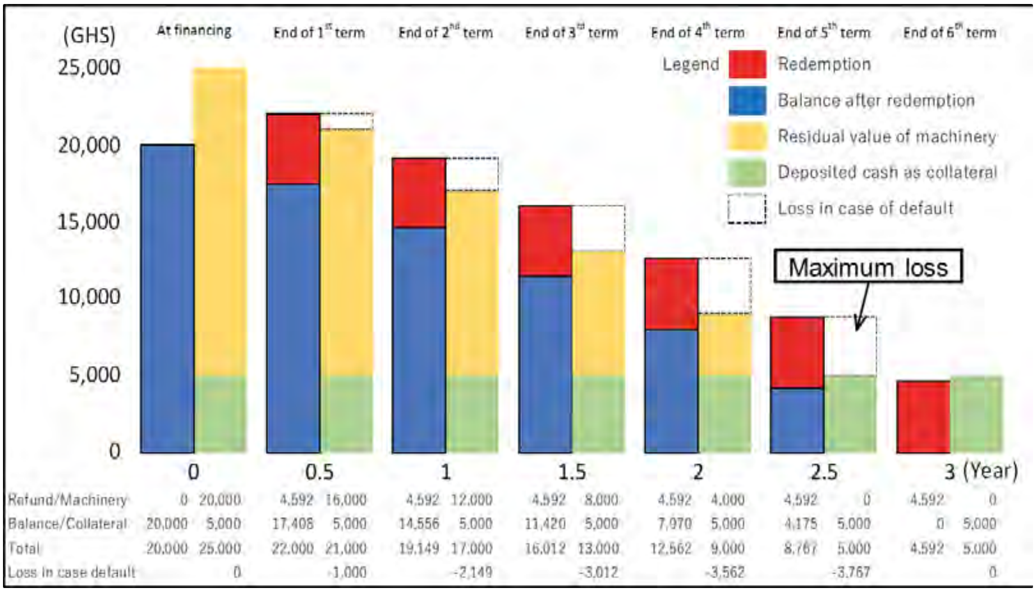


Fig. 11-10. Simulation of repayment and loss in the case of default

In the simulation, a bank provides a GHS 20,000 loan with a 20% annual lending interest rate over a 3-year redemption period, and FBO redeems every half year. The red bar graph in Figure 10 shows the equal redemption amount for each period, and the blue bar graph shows the redemption balance after redemption for each period. The green bars represent the value of the collateral of GHS 5,000 in cash and the yellow bars of that of agricultural machinery after depreciation (initial value of GHS 20,000). The depreciation rate for agricultural machinery is set at a fairly high level of 40% per year so that it is safe for banks.

When a default occurs, the bank will confiscate agricultural machinery, sell it and aggregate it with cash GHS 5,000 initially provided by FBO as collateral to fill in the remaining redemption and determine the amount of loss. According to the simulation the loss maximizes at GHS 3,767 if the default occurs two and a half years after the financing, at the time of the fifth redemption. The loss amount of the bank is GHS 1,884 because the bank and the company split the loss amount equally. However, in reality, it is highly unlikely that the FBO will violate in default here, as it completes to pay off in only two more redemptions. By default, the FBO will lose the cash GHS 5,000 offered as collateral and will not be able to use agricultural machinery anymore, so it is believed that it will do its utmost to carry out the planned redemptions. In addition, when the FBO defaults, it will lose credibility and will not be able to receive the next loan.

Table 11-2. Maximum loss in the case of default based on specific interest/depreciation rate

			Annual interest rate (%)				
			15	20	25	30	35
Maximum loss in case of default	Annual depreciation rate (%)	33.3	-341.5	-1,012.1	-1,682.2	-2,351.0	-3,018.0
		40.0	-3,224.5	-3,766.8	-4,319.0	-4,880.2	-5,538.2
		50.0	-6,911.6	-7,562.0	-8,217.2	-8,876.2	-9,538.2
Each period redemption			4,260.9	4,592.1	4,933.6	5,284.7	5,645.1
Total repayment			25,565.4	27,552.9	29,601.6	31,708.4	33,870.5
Gross interest amount			5,565.4	7,552.9	9,601.6	11,708.4	13,870.5

Establishing an FBO and sharing its own money creates a sense of responsibility not to violate defaults and a sense of pressure to monitor each other. They learn that planned redemption is needed to secure their credit from the bank, leading to the next acquisition of further loans, and opening up a bright future for the next generation of the village. Setting the goal of investing a significant amount of their own money in the FBO, trusting each other, and working together to complete planned redemptions is the very driving force behind maintaining a highly centripetal FBO.

Farmers need to choose a bank relatively close to their village and therefore does not incur high travel costs. Rural banks in Ghana now do not allow small rice farmers to open personal accounts. However, the banks welcome the opening of a bank account by a group of farmers called FBO, established under the written terms and conditions. The authors prepared a prototype for the written terms and conditions for the FBOs (**see Annex 1**) and urged agricultural extension officers to take a leading role in the process of rice farmers establishing FBOs and opening bank accounts.

In the past, agricultural extension workers thought their job was solely to teach farming technologies to farmers. However, now they help farmers to establish FBOs, open bank accounts and get loans from banks. They can get more trusting relationships with the farmers. FBOs with investment by farmers strengthen the social capital (trust) among them, and the process from the establishment of the FBO to the realization of bank loans with help of extension workers strengthens the social capital (trust) between farmers and agricultural extension officers.

FBOs need to repay the loans on schedule, and after it has been paid off, they are expected to repeat the process by acquiring a new loan — a larger loan than the previous one — and purchasing new agricultural machinery. During repaying the loan, FBO's rice farmers are forced to help each other. This is because a repayment default will make the loss of their invested money as collateral, the power tiller will be seized as collateral, and the opportunity to receive the next loan will disappear.

Agricultural extension officials strongly hope that FBOs will pay off the loan. This is because the officials have signed the recommendation letter that the FBO submits to the bank when opening an account. They will focus on guidance so that the rice farmer's FBO will work well, and they will use the agricultural machinery together to make a profit. The agricultural extension officials will be responsible for monitoring the FBO activities that originally should be done by bank officials.

Figure 11-11 describes the establishment of an FBO by rice farmers and the path of its step-by-step development, with the strength of unity and mutual trust of the member farmers on the vertical axis. After the FBO establishment based on written terms and conditions, FBO opens its bank account. Model byelaws that can be adapted to guide the interpersonal relationships of members of the group as well as govern members' dealing with the group are shown in **Annex 1**. The form application for registration is shown in the First Schedule. Then the FBO collects money from member farmers to create a fund and deposit it into the bank account. Bank can recognize the existence of the FBO and its united power to collect money from members. It makes the bank give a credit to the FBO. Based on this credit and the collateral offered by the FBO it receives a loan from the bank and purchases agricultural machinery. The FBO does its utmost to carry out the planned redemptions as scheduled because it doesn't want to lose the cash and agricultural machinery offered as collateral. The member farmers trust and help each other and work together to complete planned redemptions with a sense of tension to monitor each other. After perfect redemption, the FBO will be entitled to receive other larger loans from the bank. For the bank, the FBO is already a good lender customer. By repeating this loan and repayment, the FBO will increase the credit from the bank and eventually be able to obtain a large amount of financing needed to build an irrigation facility.

One can imagine the future of a multifunctional FBO that starts with getting a loan for a power tiller, pays off, and purchases more, including expensive combine harvester and rice mill purchases. Multifunctional FBOs will prepare the funds to build irrigation facilities as the next step. Eventually, poor small-scale rice farmers will realize the X investment and be willing to invest Y and Z. A multifunctional FBO is an organization with various functions, such as becoming a community platform that spreads agricultural technology, doing joint purchases of various materials, joint sales of agricultural products, and giving individual farmers credit guarantee (**Figure 11-11**).

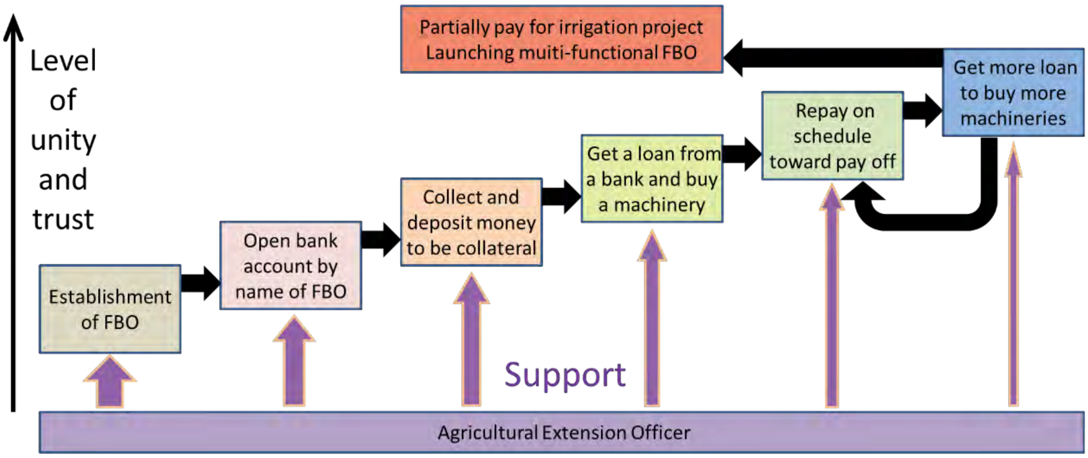


Fig. 11-11. The sustainable development of multifunctional FBOs

The SALIBU rice ratooning technology is particularly noteworthy as one of the possible technologies for accelerating the income increase of rice farmers in the initial stage of their development. This is a cultivation technique that skillfully takes care of ratoon that grows from the stump left after the rice was harvested so that the yield of this second crop reaches the same level as that of the first crop. Normally, the yield obtained by growing ratoon is 20–50% of that of the first crop. SALIBU rice ratoon cropping systems raise this to 70–100%. Moreover, farmers can eliminate the rice seeds and nursery preparation, paddy field puddling, and a large amount of water for it and can also leave out transplanting rice seedlings. Farmers benefit from a large amount of saving labor and resources as well as an extra income from the second crop.

SALIBU rice ratoon cropping systems enable continuous cultivation and harvest 3–4 times a year in irrigated paddy fields within a year-round irrigation area. In contrast, farmers in rainfed paddy areas can cultivate and harvest the second rice crop with lower risk than in non-rainfed paddy areas, and under certain conditions, they can harvest three times annually.

Multifunctional FBOs will prepare funds to build more expensive irrigation facilities as the next step. A multifunctional FBO is an organization with various functions, such as becoming a community platform that spreads agricultural technology, doing joint purchases of various materials, joint sales of agricultural products, and giving individual farmer credit guarantees.

Establishing multifunctional FBOs is only one example leading local poor small-scale farmers to develop, and the key is to find ways to realize their investment. We believe that irrigation engineers with expertise in organizing collective water management by farmers can work together with agricultural extension officers to open this path of investment for poor small-scale farmers.

Results Achieved

The experiment with farmers at Atrobinya and Kasunya villages under the Kpong Irrigation Scheme had to be abandoned for several reasons. Most importantly, the leaders of the groups were unable to mobilize a critical mass of members. They did not show much enthusiasm towards the project because their expectation was different from what the project was trying to introduce – whereas the project sought to get them to contribute money towards the acquisition of agricultural machines, the leaders and their members were expecting dole out of money from the project. The leaders were also more interested in individual ownership of the machines than group ownership. The problem here seemed to be that the leaders were generally more well-to-do and commanded great respect in the communities.

Contrast this with the situation we found in the Ashanti region. The groups consisted of people at about the same level of development and were more amenable to forming FBOs to contribute money and buy machinery to improve their farming work and raise themselves out of poverty. Yaw Boadi and Biemso No. 1 rice farmers' associations were already loosely organized and so it was fairly easy to obtain their buy-in to the concept. Five other groups have since then joined the scheme – Banahenekrom, Yaw Kobi Shed, Biemso No 2, and Fedie Yeya. The project was able to negotiate with the Amanano Rural Bank to facilitate the process of providing financing to the groups. The Project Sponsor deposited a sum of money to be used as part of the collateral for loans to the groups. Each group opened a bank account with the said bank and deposited a fixed interest-free amount to be used as collateral. The individual members have also opened personal accounts with the bank. In 2021, the bank facilitated two groups to acquire threshing machines. The bank has also been dealing with the individual members in granting them short-term small loans for their pre-season farming activities, including land preparation and procurement of seed. The recovery rate for such loans has been quite appreciable. The uptake of SALIBU technology has been slow but progressing steadily. This might be because there is only one AEA handling this area with no access to a motorbike to facilitate his movement.

Chapter 12: General considerations and conclusions

Characteristics of SALIBU rice ratoon cropping systems considering plant physiology

1. When the rice plant reaches the physiological maturity stage, i.e., the average water content of unhulled rice grain is approximately 28%, almost 75% of the rice ear has turned yellow from the tip, and roughly 25% of the greenish unhulled paddy remains, the nutrients stop flowing and stay at the base of the culm. The nutrients produced by photosynthesis in leaves or absorbed from roots cannot flow into grains in panicles anymore and fill the culm base, which may trigger the formation of a young panicle at the bottom of the culm. Perhaps the nutrients filled in the culm base act as a kind of plant hormone. For this reason, in the normal ratoon crop cultivation method in which harvesting is performed about one week after the physiological maturity period, young panicle formation has already started in many culms by the harvesting time when the average water content of unhulled rice grain is about 24 to 25% / about 85-90% of the rice ear has turned yellow from the tip, and about 10-15% of the greenish unhulled paddy remains. And the ear emergence of the ratoon crop starts only 30 d after the harvesting of the main crop. After all, the vegetative growth of ratoon continues for only 30 d such that it makes the plant height and length of leaves and panicles short, and thus the number of spikelets per panicle decreases. Moreover, some of the ear emergence from culm is delayed so that it makes the heading disjointed, and over-mature rice and immature rice coexist during the harvest season.

2. Furthermore, in the case of normal ratooning, as the soil is dried, draining the standing water one week before harvesting, the vitality of the roots of the main crop plant decreases. In addition, the vitality of roots arising from germinated shoots in the ratoon crop plant may be reduced when not flooded after harvesting.

3. In addition, in varieties with relatively long internodes in the lower part of the culm, nodes where regenerated shoots germinate may be located at several centimeters or more height above the ground surface, and in this case, roots from nodes become aerial roots. As these eventually decay in due course, shoots have to rely on the old roots and culms of the main crop to absorb soil moisture and nutrients. For this reason, water and nutrients may not be sufficiently supplied and the yield may be reduced.

4. On the contrary, SALIBU rice ratoon cropping systems are characterized as follows.
   1) The crop is harvested at physiological maturity. Thus, the production and flow of nutrients stop, and nutrients do not fill the base of the culm, causing a lack of trigger for young panicle formation at the culm base. Therefore, the vegetative growth of leaves continues for nearly 30 d, and after this period, the young

panicles are formed, and 30 d after the formation of panicle, ears start emerging. After all, the vegetative growth of leaves continues for nearly 60 d, and then reproductive growth starts.

2) Therefore, plant height and shape, the number of tillers, spikelets per panicle, panicle length, and crop yield are almost the same as that in the main crop.
3) As the soil is kept at field capacity condition, i.e., moist without flooding, from two weeks before to two weeks after harvesting, the vitality of the roots of the main crop is maintained, regenerated shoots germinate actively, and the vitality of roots emerged from these shoots is also maintained.
4) As the culm is re-cut at 3–5 cm height above the ground one week after harvesting, regenerated shoots germinate from dormant nodes near the ground surface. In addition, roots that emerged from regenerated shoots supply nutrients directly to ratoon crops.

5. Thus, the SALIBU regenerated rice cultivation method is a basal shoot farming method but a cultivation method that manages the physiological characteristics of rice well and makes the growth process as close as possible to that of the conventional transplant farming method. In other words, it is a cultivation method that creates a friendly and easy-to-grow environment for rice. Moreover, in the tropics where the temperature and sunshine conditions are suitable for the growth of rice throughout the year, it is very reasonable that the almost same yield as the main crop can be continuously obtained by the ratoon crops.

Conclusion and recommendations

Farmers can repeatedly cultivate ratoons for several generations after harvesting under the tropical climate. This cultivation method shortens the growth period of rice and can eliminate sowing, puddling, and transplanting. The input of water resources necessary for cultivation can be halved, and the input of labor and various costs is reduced.

As this cultivation technology is continuous year-round cultivation, if the growing period of ratoon is approximately three months, a farmer can divide his paddy fields into three parts, and he can harvest every month through cultivating at an interval of one month at the three places. His income opportunity, initially twice a year, will increase dramatically to twelve. This farming method will not only increase the annual incomes of poor small-scale rice farmers but also increase income opportunities dramatically, turning a conservative and cautious attitude towards their investment into a positive attitude.

Perennial rice varieties such as *Shwepyihtay*, *Theehtatyin*, Jasmine 85, and AGRA could be adopted for SALIBU farming practices, particularly in areas with high pressure on water usage for various human activities.

The amount of fertilizers recommended for application is to be reduced to save cost and prevent environmental pollution considering the short maturity period of rice ratoons.

Anti-bird nets may have to be used to control birds to avoid high labor costs for scaring birds. Simple harvesting tools for cutting ratoons need to be available to encourage the adoption of the technology.

Strengthening social capital and introducing such a breakthrough agricultural technology, the second Green Revolution will primarily benefit poor small-scale farmers left behind in economic development in the first Green Revolution. The realization of such a second Green Revolution is desired deeply.

Other points to keep in mind for the practical application of SALIBU rice ratoon cropping systems

1. It is necessary to consider whether double-cutting at harvesting is needed in SALIBU rice ratoon cropping systems. In the original SALIBU systems, the first cutting of rice stems is performed manually at 15–40 cm above the ground one week before the expected harvest date, and the second cutting is done to at 3–5 cm above the ground using a power mower one week after the first cutting, recommended in developing countries where manual harvesting is standard. In contrast, in developed countries and a few developing countries where combine harvesters are used widely, double-cutting at harvest is unnecessary, and single-cutting is recommended at 3–5 cm height one week before the expected ordinary harvest date. The timing of harvesting one week before the regular harvest date is more important than the number of cuttings, and the difference between single and double cutting hardly affects crop yield. In addition, at this time, it is not a big problem for the caterpillars of the combine harvesters to trample the rice stubbles. There is only some damage where the combine harvester turns during harvesting. However, to reduce damage caused by the trampling of caterpillars as much as possible, it is preferable to use a 2-row cutting small riding combine harvester weighing 1 ton or less rather than a large harvester such as a 6-row cutting large riding combine harvester weighing of 3–4 tons.

2. In Sumatra, Indonesia, the rice grain cultivated under SALIBU rice ratoon cropping systems is indistinguishable from conventional transplanted main crop rice grain in the market, and both are sold at the same price, which does not seem strange as the appearance of both rice plants during the growing period and at harvest are similar. For example, in Miyazaki Prefecture in Japan, there are areas where rice grown from basal shoots has long been prized as a better-tasting new rice for the New Year celebration.

3. In low-lying wetland paddy fields in Indonesia, there were cases where yield decreased with each generation due to the phenomenon of soil sickness. It is considered that certain microorganisms with specific properties predominate in the soil under reduced conditions due to poor drainage all year round, and plant roots are damaged by harmful hydrogen sulphide generated in such soil.

4. In Sumatra, Indonesia, there is a village where almost all village farmers had once adopted the SALIBU rice ratoon cropping system, but to deal with the menace of rats, more than half of the farmers introduced bite-tolerant varieties. However, as these varieties were not suitable for rice ratooning, many farmers withdrew from the SALIBU rice ratoon cropping system, and the practitioners of the system became a minority in the village.

5. In Asia, irrigated paddy fields are mainstream for paddy rice cultivation. Irrigated paddy rice cultivation has attained a certain level of rice yield. Therefore, it is rational to introduce labor-saving combine harvesters in SALIBU rice ratoon cropping systems and achieve 100% yield compared to that in the main crop, which will help realize triple cropping annually, saving resources and labor inputs. In addition, it will bring almost 1.5 times the annual crop yield compared to that in current double cropping, which will also increase income opportunities and profits for farmers annually and contribute to the poverty alleviation of small-scale farmers.

6. In contrast, in sub-Saharan Africa, the mainstream of paddy rice cultivation is in rainfed rice fields. Therefore, focusing on stabilizing the unstable second crop in rainfed paddy fields is essential. In the current second crop, yield is greatly affected by the presence or absence of rainfall at sowing time. In this respect, in the SALIBU rice ratoon cropping systems, roots existing with stubbles at the sowing period of the standard second crop can mitigate the influence of the presence or absence of rainfall at the time of germing basal shoots.

7. In irrigated paddy fields in Ghana, the growing period of the SALIBU ratoon crop shortened to 60–70% (65–80 d) of that in the main crop (115–135 d). However, the yield in the former was limited to approximately 70% of that in the latter due to unclear reasons. This fact may lead to a concept that, in sub-Saharan Africa, it is rational to reduce the amount of fertilizer applied during a cropping period to approximately 70% of the amount of fertilizer used in standard SALIBU rice ratoon cropping systems. In addition, under the conditions of this shortened planting period and reduced yield, if four crops, i.e., one main crop and three shoots (125 + 75 x 3 = 350 d), are cultivated in a year, yield is 40% higher than in standard double cropping.

8. Based on the reports of researchers at *Huai Hong Khrai* Royal Development Study Center in Thailand and Irrigation Development Institute, Irrigation College in

Thailand, SALIBU rice ratoon cropping systems can be applied to breeding through pure seed propagation. After harvesting the main crop, stubbles are dug up from the soil with their roots, and the adhering soil is washed off. Dividing the stubble with roots into roughly three to four parts and transplanting them to paddy fields as seedlings, seed propagation with a purity of 99% or more was practically realized.

Annex 1

PROTOTYPE FOR THE WRITTEN TERMS AND CONDITION FOR FBOs

THE …………… RICE FARMERS ASSOCIATION
ARRANGEMENT OF BYLAWS AND ARTICLES OF ASSOCIATION

PART I: ARTICLES OF ASSOCIATION

Article 1: Preamble

In the name of Almighty God, we the members of the …………… Rice Farmers Association, all of legal age, and residents of ………………………… in the ……………………………………………… District of the ………………… Region of the Republic of Ghana, having realized the value of unity and working together as a group and the need to establish rules to guide our interactions with each other and for the good management of our group enterprise, hereby adopt, enact, and give ourselves these bylaws.

Article 2: Name of Association

The name of the association shall be THE …………… RICE FARMERS ASSOCIATION (hereinafter referred to as "the Association").

Article 3: Common Bond and Field of Membership

The common bond of this Association is rice farming, and the Association shall be open to all natural persons who are engaged in rice farming in the catchment area of the ………………………….

Article 4: Mailing Address and Office Location

The Association's office shall be located at …………………, and the address to which all correspondence shall be directed is:

……………………………………………………………………………………………

……………………………………………………………………………………………

Article 5: Area of Operation

The Association's area of operation shall be within the catchment area of the ……………………………

Article 6: Objects of the Association

The objects of the Association shall be to help improve the quality of life of its members, and in pursuance of this, it shall aim:

1) To facilitate the supply of rice farming inputs to its members
2) To encourage group marketing of members' produce
3) To promote the adoption of better methods of farming and produce the highest quality rice
4) To facilitate the provision of training on best agronomic practices to members on a regular basis
5) To provide a means of savings and loans for its members

6) To ensure proper maintenance and management of the water resources and associated facilities of the …………………………
7) To carry on any other business as may be incidental or conducive to the attainment of the aforesaid objects

Article 7: Powers of the Association

In the pursuit of its objects, the Association shall have full powers to:

1) hold and deal in its name such property, including freehold land, as it may consider necessary to further its objects;
2) borrow money in such manner and on such terms as the Committee acting in accordance with the provisions of these bylaws shall determine;
3) negotiate and enter into contracts with any person or persons, corporations, or institution for the acquisition of land, materials, or equipment;
4) accept deposits from members on such terms as the Committee shall determine from time to time;
5) amend these bylaws in accordance with the provisions of the Decree;
6) create standing committees or ad-hoc committees as the Committee may deem fit from time to time; and
7) do all other things necessary or expedient for the accomplishment of any or all the objects specified in these bylaws.

PART II: MEMBERSHIP

Article 8: Qualification for Membership

Membership shall be open to all natural persons within the field of membership described in these bylaws.

Article 9: Requirements for Membership

To qualify for membership, a person must:

1) be a rice farmer or other water user;
2) be capable of entering into a legally enforceable contract, that is, be eighteen years and above and be of sound mind;
3) own land or reside within the catchment area of the …………………………;
4) submit an application for registration on a prescribed form as shown in the First Schedule; the Committee must respond to the application within thirty (30) days of receipt;
5) pay the prescribed fees as may from time to time be determined by the Management Committee, specifically:
   a) Entrance Fees: GH₵ ………
   b) Share capital: GH₵ ………..
   c) Monthly Dues: GH₵ ………
   d) Other fees as may from to time be agreed upon by the general membership
6) subscribe to a written statement that he/she agrees:
   a) to be bound by these bylaws and any other relevant local, regional, and national laws as existed at the time of application for membership, and from time to time amended;

b) to the principle of collective marketing; and
c) to submit to any arrangement entered into by the Association for the collective marketing of all members' produce as approved by not less than two-thirds of the members in the general meeting.

Article 10: Duties of Members

The duties of the members of the Association shall be:

1) To demonstrate total commitment to the affairs of the Association, that is:
    a) devote quality time to ensuring the progress of the association;
    b) attend meetings punctually and contribute to discussions;
    c) patronize the Association's business and services; and
    d) be prepared to take up responsibility.
2) To hold the Committee accountable
3) To listen to and respect their leaders
4) To abide by the association's rules and regulations
5) To sell (advertise/market) the Association to non-members and the public
6) To approve/disapprove major investments
7) To pay in full the share capital subscription as it falls due and to participate in the capital build-up and savings mobilization activities of the Association
8) To promote the goals and objectives of the Association, the success of its business, and the welfare of its members

Article 11: Membership Rights

1) Members in good standing have the right to:
    a) receive notice of and attend and vote at meetings;
    b) elect the Association's Management Committee;
    c) approve amendments to these bylaws;
    d) approve major investments;
    e) approve any borrowing beyond GH₵10,000;
    f) requisition of a meeting if 20% of active members (or lesser percentage if specified in the rules) so decide; and
    g) inspect various financial records and other documents.
2) Each member shall have one vote and no more on all matters submitted to members, provided that the Chairperson shall have a casting vote to break a tie in voting.
3) The rights of members shall be understood to apply only to active members in good standing.
4) All rights and responsibilities of members are subject to these bylaws as they may be amended from time to time.
5) The Committee must make available to each person who intends to apply to be a member a copy of the bylaws, a copy of special resolutions, which would apply to the prospective member, and a copy of the last financial information reported to members.

Article 12: Meaning of "Good Standing"

1) Only active members (or members in good standing) can exercise voting rights.

2) A member is considered to be in good standing if:
    a) his/her name appears in the register of members;
    b) he/she has acquired shares or interests according to these bylaws;
    c) he/she has paid the membership dues and other financial obligations prescribed in these bylaws up-to-date; and
    d) he/she has not defaulted in meeting attendance for the immediate three consecutive meetings preceding the current one.

Article 13: Liability of Members

1) The capital of the Association shall be raised in equity shares each of GH₵ ....
2) Each member shall hold at least .... shares in the Association.
3) A member may withdraw his/her shares only in such manner as is provided for in these bylaws.
4) Shares shall not be transferable except with the approval of the Committee.
5) At least .... shares shall be paid for in full on admission to membership and subsequent shares may be paid for in full as and when the Committee deems fit.
6) Limited interest may be paid on members' capital annually and in any case not exceeding five percent per annum.
7) A member may be entitled to a dividend where the Association makes a profit on its operations in any given year.
8) A member may hold any number of shares but not exceeding 20% of the paid share capital of the Association.

Article 14: Register of Members

A register containing the following shall be maintained at the registered office of the Association:

1) The name and address of each member
2) The date on which each member was admitted to the membership
3) The date at which any member ceased to be a member
4) The number of shares acquired by each member and the date the share or shares were acquired
5) The date and circumstances when a member's membership was canceled (if applicable)
6) Any interest on capital, dividend, bonus on patronage paid, and dates on which they were paid

Article 15: Ending a Membership

A membership can end if:

a) the membership was canceled due to inactivity; or
b) by a resolution of two-thirds of the members of the General Assembly in good standing; or
c) the member withdraws of his/her free will, having given three months' prior notice of such intention; or
d) the member is expelled or resigns under these bylaws; or

e) the member becomes bankrupt or insolvent (unless these bylaws state otherwise); or
f) the member dies or becomes incapacitated such that he/she cannot physically be present at meetings;
g) the Association becomes defunct.

Any member so expelled may be approved by not less than two-thirds of the number of members present in the general meeting.

Article 16: Re-Admission to Membership

A member who has withdrawn from membership or who has been expelled in accordance with these bylaws may be re-admitted to membership on such terms, which must include the repayment of all dues standing against him/her at the time of his/her ceasing to be a member, as may be approved by not less than two-thirds of the number of members present at a general meeting.

PART III: GOVERNANCE OF THE ASSOCIATION

Article 17: Election of Management Committee

1) The supreme decision-making authority in the Association shall be the members participating in the general meeting (hereinafter called the General Assembly).
2) The General Assembly of members shall, at an Annual General Meeting (hereinafter called the AGM) or special meeting called for the purpose, elect such a number of members as is specified in these bylaws to constitute the Management Committee (hereinafter called the Committee).
3) Each member, on being elected, shall serve for a period of one year and be eligible for re-election thereafter for another term of one year.
4) A Committee member may stand again for election after the expiry of two years after he/she has finished the maximum two consecutive terms.
5) A member who is a paid officer or servant of the society shall not be a member of the Committee. Provided that such a person may be nominated for membership, and if approved, shall thereupon resign from service in the Association.
6) Such a paid staff who has been duly admitted to membership shall not be allowed to take any part in the deliberations of the Committee until such resignation has become effective.

Article 18: Composition of Management Committee

1) The Management Committee shall consist of seven members.
2) The Committee shall be made up of the following officers:
    i) Chairperson
    ii) Vice Chairperson
    iii) Secretary
    iv) Assistant Secretary
    v) Treasurer

vi) Men's Organizer
vii) Women's Organizer

Article 19: Duties of the Committee

1) The Committee's key purpose is to ensure the Association's prosperity by collectively directing the Association's affairs, whilst meeting the appropriate interests of its member-shareholders and other stakeholders.
2) Specifically, the Committee shall perform the following functions:
   a) to set the Association's mission, and purpose(s), and engage, on a regular basis, in strategic planning
   b) to review, monitor, and report to the membership regularly regarding the critical operating and financial performance of the Association
   c) to ensure effective planning and adequacy of resources
   d) to arrange for and approve an annual independent financial and management audit
   e) to ensure that proper books of account are kept
   f) to ensure that the relevant local, regional, and national laws and these bylaws are complied with, that the business of the Association is properly conducted, and that the resolutions of the general meetings are carried out
   g) to represent the Association in all its dealings and transactions with power to institute and defend suits brought in the name of, or against, the Association
   h) to admit new members as and when it deems fit
   i) to control and generally watch over the interest of the Association

Article 20: Responsibilities of the Committee

The Committee members must:

a) control and generally watch over the interest of the Association
b) work as a collective, not as individuals;
c) always exercise their powers for a "proper purpose" – that is, in furtherance of the reason for which they were given those powers by the shareholders;
d) act in good faith in what they honestly believe to be the best interests of the Association, and not for any collateral purpose; in other words, particularly in the event of a conflict of interest between the Association's interests and their own, the Committee members must always favor the Association;
e) act with due skill and care, that is, with the care an ordinarily prudent person in a like position would exercise under similar circumstances;
f) be transparent and accountable;
g) observe rules and regulations;
h) tolerate opposing views; and
i) be prepared to take a calculated risk.

Article 21: Removal from Committee

A Committee member may be removed during his/her term of office:

a) by a majority of votes obtained at a general meeting; or
b) if he/she:

i) absents himself/herself from three consecutive meetings without reasonable excuse; or
ii) is declared insolvent, or becomes of unsound mind; or
iii) is convicted of any offense involving dishonesty or imprisoned for three months or longer; or
iv) defaults for more than three months in respect of repayment of a loan taken by him/her from the Association, but a general meeting of the society may reinstate him.

Article 22: Filling of Vacancies on the Committee

1) Vacancies occurring on the Committee shall be filled as far as is practicable and in any case within three months of their occurrence.
2) Should it prove impossible to fill any vacancy in such a manner, the Committee may co-opt for the remainder of the period before the next AGM any person who is a member of the Association in good standing.

Article 23: Calling a Committee Meeting

1) The Committee shall meet as often as the business of the Association shall require and, in any case, not less frequently than once in any period of three consecutive months, that is, at least once every quarter.
2) The Chairperson, or the Secretary at the request of at least three Committee members, may call a Committee meeting.
3) Each Committee member must be given reasonable notice of the meeting, stating its date, time, and place. What is "reasonable" depends in last resort on the circumstances

Article 24: Conflict of Interest

1) A conflict-of-interest transaction is a transaction with the Association in which a Committee member has a direct or indirect interest.
2) A member of the Committee who has an interest in a matter for consideration by the Committee:
   a) shall disclose in writing the nature of that interest and the disclosure shall form part of the record of the consideration of the matter; and
   b) shall not participate in the deliberations of the Committee in respect of that matter.
3) A member who contravenes subsection 2) ceases to be a member.
4) A conflict-of-interest situation shall not arise in the following circumstances:
   a) where the material facts of the transaction and the Committee member's interest were disclosed or known to the Committee or its sub-committee and the Committee or its sub-committee authorized, approved, or ratified the transaction;
   b) where the material facts of the transaction and the Committee member's interest were disclosed or known to the general members in good standing and entitled to vote and they authorized, approved, or ratified the transaction; or
   c) the transaction was fair to the Association.

Article 25: Sub-Committees

1) The Committee may appoint from amongst its own members, and by co-option, such sub-committees as it may deem necessary or expedient; provided that no decision of any sub-committee shall be binding upon the Association or its members until it is approved by the Committee.
2) The Association shall maintain the following permanent sub-committees:
    a) ***Disciplinary Sub-Committee***: This sub-committee shall be made up of the Vice-Chairperson, the Women's Organizer, and one ordinary member of the Association. All matters of conflict and indiscipline within the Association shall be referred to the sub-committee. A member aggrieved by any ruling of the sub-committee may appeal to the larger Committee. If the aggrieved person is still not satisfied with a ruling by the larger Committee, he/she may appeal to the General Assembly, whose ruling shall be final.
    b) ***Land and Water Management Sub-Committee***: Membership of this sub-committee shall comprise a Men's Organizer, Assistant Secretary, and one ordinary member of the Association. The sub-committee shall ensure the day-to-day sustainable management of the irrigation facilities and equitable allocation of the land and water resources of the …………………..
    c) ***Equipment and Machinery Sub-Committee***: This sub-committee shall be made up of the Assistant Secretary, the Women's Organizer, and one ordinary member of the Association. They shall be custodians of all the equipment and machinery of the Association and ensure equitable access to them by all members of the Association.
    d) ***Audit Sub-Committee***: The Committee shall appoint two persons with some knowledge of accounting, and independent outsiders, as members of this sub-committee to audit the accounts of the Association at the end of every year. At the end of their audit, the auditors shall submit the audited financial statements, together with a report containing their observations during the audit and their recommendations, to the Committee for further action.
3) The proceedings of any sub-committee shall not be valid unless there shall be at least one member of the Committee present throughout such proceedings.
4) The Disciplinary Committee shall not use intimidating tactics.
5) Any member appearing before the disciplinary committee on any charge shall have a notice of three (3) days.
6) At the disciplinary committee's sitting, the member's offense shall be read to him/her for him/her to defend himself/herself.
7) The disciplinary committee shall present their reports, including recommendations, to the Committee which shall take decisions.

Article 26: Duties of the Chairperson

1) The General Assembly shall empower the Committee to appoint one of their own members as Chairperson.

2) The Chairperson shall hold office for a period of six months and may be re-elected for a second term of six months after which he/she shall not be eligible for election until a period of two years has elapsed.
3) If the Chairperson is not present within thirty minutes of the time fixed for a meeting or is unwilling to preside, those Committee members in attendance shall elect one of their members as Chairperson of the meeting.
4) The Chairperson shall have a second or casting vote in the case of equality of votes.
5) The Chairperson shall perform the following functions: preside over all meetings at which he/she is present.
6) In the absence of the Chairperson, the Vice Chairperson shall preside.
7) In the absence of both, the Committee shall appoint one of its own members to perform the duties of the office.

Article 27: Duties of the Manager

1) The Manager shall perform the following duties:
    a) to coordinate day-to-day activities of the Association;
    b) to disseminate relevant information to stakeholders on a timely basis;
    c) to supervise paid staff;
    d) to ensure regular preparation of reports;
    e) to ensure proper custody of the Association's assets;
    f) to advertise the Association to outsiders;
    g) to play an advisory role;
    h) to be creative and innovative; and
    i) to represent the Association where necessary.

PART IV: MEETINGS OF THE ASSOCIATION

Article 28: Annual General Meeting

1) The ultimate authority in all the affairs of the Association shall be the general body of members (otherwise known as the General Assembly).
2) The Association shall hold an Annual General Meeting (hereinafter referred to as the AGM) on a date not less than four, and not more than eight, weeks after receipt of the report on its audited accounts.
3) An AGM shall have the following powers and duties:
    a) to confirm the minutes of the previous AGM and any intervening special general meetings;
    b) to receive the report of the past year's operations;
    c) to receive the audited statement of accounts for the same period, prepared in accordance with these bylaws, and decide the manner of disposal of any excess of income over expenditure disclosed in such accounts;
    d) to consider such motions as are properly put before it, and resolve them as it deems fit;
    e) to amend or rescind any existing bylaws or make new bylaws;
    f) to elect new officers when the term of the current officers expires; and

g) to approve the budget for the ensuing year.

4) At least two weeks' notice of the AGM shall be given to all members eligible to attend and vote at the meeting.

5) The Agenda for the AGM shall be attached to the notice.

Article 29: Special General Meeting

1) A Special General Meeting may be called at any time either:
   a) by decision of the Management Committee; or
   b) upon written demand by at least two-thirds of the members in good standing.
2) At least seven (7) days' notice shall be given to all members.
3) The purpose of such meetings shall be clearly stated in the decision of the Committee or demand of the petitioners; this shall be incorporated in the notice calling the meeting.
4) No other matter shall be dealt with at the special meeting except for the stated purpose.
5) No matter on which a decision was made by the immediate previously held annual general meeting shall be put before any special general meeting unless circumstances have arisen such as to make the previous decision inoperable.

Article 30: Quorum at General Meeting

1) For the decisions of any meeting of the Association to be binding on all members, there must be at least 20 or half of the total number of members in good standing, whichever is lesser, present and voting.
2) If the number present is less than this number, the meeting shall be adjourned to another date.
3) Until such time as the adjourned meeting is held, the affairs of the Association shall remain unchanged insofar as that is possible and consistent with justice, equity, and common sense.

Article 31: Voting at Meetings

1) Any issue submitted to the decision of the members at a meeting, unless otherwise dealt with in these bylaws, shall be decided by a simple majority of the votes cast.
2) At any meeting of the Association, a motion put to the vote shall be decided by any of the following methods:
   a) on a show of hands; or
   b) by secret balloting.
3) The method to be used shall depend on the particular situation and the weight and sensitivity of the decision to be made.
4) The Chairperson, as a member of the Association, shall have an ordinary vote on any proposition before the meeting; and, in the event where the votes are equally divided, the Chairperson shall have a casting vote to decide in what manner the motion has been resolved.
5) A decision made on the basis of the Chairperson's casting vote shall be recorded as a decision of the meeting and shall not be called into question by any member.

6) In respect of every motion put to the vote, the Chairperson shall declare whether it has been agreed or not agreed, and whether on a simple majority or by a particular majority when such is required by the bylaws.
7) An entry to that effect shall be made in the Minutes Book, and it shall stand thereafter as a true record.

Article 32: Minutes of Meetings

1) Minutes of any meeting of the Association shall be recorded in a Minutes Book by the Secretary or by a person, other than the Secretary appointed by the members for the purpose.
2) Minutes shall contain the following particulars:
   a) Title, date, and venue of the meeting
   b) Agenda of the meeting
   c) The name of the officers and members of the Committee and the total number of members present
   d) The name of the Chairperson at the meeting
   e) The time the meeting commenced and ended
   f) A concise statement of the matters discussed, and the decisions of the meeting thereon
   g) Signature of the Chairperson of the meeting
   h) Name and signature of the person who recorded the minutes
3) These minutes, when confirmed by the next following meeting, shall be signed by the presiding member at the meeting at which they were confirmed, and the Secretary or other person who recorded them, and thereafter shall stand as a true record of the proceedings of the meeting to which they refer.

Article 33: Procedure at Meetings

1) At each meeting of the Association, the Secretary shall:
   a) Read the minutes of the preceding meeting, provided that where reproductions of such minutes have been circulated to and received by each member prior to the meeting, the meeting may resolve to dispense with this requirement.
   b) Produce in a form previously approved by the Committee, a statement showing the income and expenditure of the Association since the last meeting, and the balance remaining after such transaction have been recorded in the accounts.
   c) Submit for the consideration of the members present such other business as has been included in the agenda prepared for the meeting circulated to each member; and such items not being included in the agenda, as the meeting may of its own motion resolve to consider.

PART V: MISCELLANEOUS PROVISIONS

Article 34: Bank Accounts

1) The Committee shall open a bank account (or accounts) with any Commercial Bank (or banks) determined by the Committee.

2) The Treasurer shall ensure that all monies received by the Association while saving for such amounts as may be approved by the Committee to be kept by the Treasurer as imprest, shall be lodged into such account or accounts.
3) The Trustees of the account or accounts shall be the Chairperson, the Treasurer, and the Secretary.
4) All cheques drawn on such account or accounts shall be signed by at least two Trustees, one of whom shall always be the Treasurer.
5) The Treasurer shall keep an imprest account not exceeding at any particular time the sum of GH₵ ....
6) When the imprest is spent, the Treasurer must submit a statement of account, together with supporting documents, on how the imprest was spent before it can be reimbursed.

Article 35: Audit of Accounts

1) The financial year of the Association shall be from January to December of every year.
2) The Committee shall arrange for the audit of the Accounts of the Association at the end of every year and in any case not later than three months after the end of the financial year.
3) For the purpose of the audit, the Committee shall ensure that:
    a) all income and expenditure are properly accounted for and documented;
    b) all payments made are properly documented, authorized, and for genuine expenses of the Association;
    c) all allowances, salaries, and benefits are paid in accordance with the bylaws, rules, and regulations of the Association;
    d) stocks of materials and finished products are properly recorded;
    e) all assets are properly accounted for;
    f) the imprest account is properly run and authorized;
    g) all contracts are conducted in accordance with the bylaws of the Association; and
    h) no member of the Committee or paid member of staff benefits unduly from sales or purchase contracts.
4) At the end of the audit, the auditor shall present the audited accounts and his/her report indicating his/her observations and recommendations.

Article 36: Funds of Society

The funds of the Association may be derived from any or all of the following:

1) Entrance fees
2) Shareholding of members
3) Monthly dues
4) Savings and deposits by members
5) Special contributions to meet contingent expenditures as may be determined by the Committee and approved by the general meeting
6) Borrowing as provided for in these bylaws

7) Miscellaneous income not specified above arising out of the conduct of business in accordance with these bylaws

Article 37: Disposal of Surplus

1) Any excess of income over expenditure, that is, profit, disclosed in the accounts presented to the annual general meeting as provided for in these bylaws shall be disposed of as follows:
    a) create a Reserve Fund into which one-fourth of the profit shall be paid as saving for a rainy day; this amount shall not be available for day-to-day operations;
    b) dividend on members' shareholding at a rate determined by the Committee and approved by the General Assembly in an AGM;
    c) bonus on patronage;
    d) not more than one-eighth or GH₵ …………… whichever is higher, may be used to pay honoraria, to the employees or officers of the Committee as the general meeting may decide; or otherwise dealt with in accordance with any scheme accepted by the annual general meeting by which the accounts giving rise to the surplus are approved.

Article 38: Annual Reports

The Committee shall, in every year, and as soon as conveniently possible, within such time as may be considered reasonable:

1) Cause the Treasurer to prepare a report of the year's Income and Expenditure Statement and Balance Sheet of the Association to be presented at the AGM, which report shall be signed on behalf of the Committee by the Treasurer and the Secretary;
2) Cause the Secretary to prepare a report of the year's operations, detailing progress or otherwise in meeting targets set during the previous AGM, the issues, the opportunities, and the prospects for future growth, which shall be signed by the Chairperson and the Secretary
3) Cause the Secretary and the Treasurer to prepare and submit to the AGM a budget for the ensuing financial year.

Article 39: Offenses and Sanctions

1) The following shall constitute offenses punishable by an appropriate sanction to be determined by the Committee:
    a) use of abusive language on or by a member of the Association:
    b) disobeying the orders of any elected or appointed officer of the Association:
    c) misbehavior during meetings; the ordinary meaning of misbehavior shall apply;
    d) aiding an outsider to violate the rules of the Association.
2) The following offenses shall constitute grounds for summary dismissal of a member:
    a) fighting with a member of the Association;

b) involving oneself in any dishonest or criminal act such as stealing, defrauding, misappropriation of monies received on behalf of the Association, and so on;
c) acting or misbehaving in such manner as to bring the name of the Association into disrepute;
d) receipt of three (3) consecutive warning letters within a period of one calendar year.

3) The following shall constitute offenses pertaining to meeting attendance, which shall be punishable by a fine as determined from time to time by the Committee and approved by the members in general meeting:
   a) drunkenness;
   b) lateness;
   c) absence without permission;
   d) defaulting in the payment of monthly dues or other fees agreed upon by the general meeting;
   e) asking permission to be absent for three consecutive meetings:
   f) behavior that disrupts the flow of a meeting

Article 40: Welfare Benefits

1) The Association shall set up a contributory Welfare Fund (hereinafter referred to as the Fund) to cater to the social needs of its members, which shall not be compulsory
2) Members who agree to join the Fund shall be required to pay monthly dues to be determined by the Committee and agreed upon by its members in general meeting
3) The Fund shall be managed by a Welfare Committee comprising three (3) members, including one member of the Committee and one woman.
4) A member in good standing shall benefit from any of the following entitlements:
   a) outdooring of newly born babies, provided that the number of babies to which this shall apply shall not exceed three;
   b) marriages, provided that in the case of a male member, this shall not exceed two wives;
   c) sickness resulting in the member being bed-ridden for at least two weeks either at home or in a recognized hospital;
   d) death of a member;
   e) death of a member's spouse;
   f) death of any of a member's parents;
   g) death of a member's children, not exceeding three children.
5) The Fund shall determine in advance the appropriate amount to be paid to a beneficiary in each of these situations, provided that it is approved by members of the Fund
6) On the death of a member, the donation shall be given in the following order of preference.

a) If married, to the surviving spouse and children, provided that where a deceased male member has more than one wife or where a female member is not the only surviving wife of a deceased male member, the benefit shall be shared among the spouses and children;
b) If unmarried, to the children if any.
c) If there are no children, to the next of kin who shall be nominated by the member at the time of joining the Fund.
d) If none of the above-mentioned relatives had been provided, then the donation shall go to the head of the family.

Article 41: Amendment of Bylaws

1) These bylaws may be amended by the General Assembly by addition of new clauses or removal of clauses that have become irrelevant to the needs of the Association with the passage of time
2) Proposals for the amendment of the bylaws shall be presented to the Committee at least three months before the general meeting that will discuss and adopt or reject it.
3) The Committee shall table the proposals at the general meeting for discussion and adoption or rejection
4) No amendment to the bylaws can be made unless the proposed amendment was specified in the notice calling members to the meeting.
5) The bylaws may be amended by not less than three-fourths of the total number of members in the good standing present, provided that not less than two-thirds of the general members of the Association in good standing are present.

We the undersigned hereby certify that the foregoing bylaws were drawn up and adopted by the members of the …………… Rice Farmers Association located at ………………………… in the ………….. Region of Ghana for the good governance of the Association and to achieve the objectives for which the members joined together.

Dated this ………………. day of ……………………….. in the year of Our Lord ……………..

Signature …………………………………	Signature……………………………………
Name: ………………………………………	Name: ………………………………………..
Status: Chairperson	Status: Secretary
Signature …………………………………	Signature……………………………………
Name: ………………………………………	Name: ………………………………………..
Status: Member	Status: Member

Witness:
Signature ....
Name: ....
Status: ....

FIRST SCHEDULE
APPLICATION FORM FOR MEMBERSHIP OF THE ....

SURNAME: ....
FIRST NAME: ....
OTHER NAMES: ....
GENDER: .... Male .... Female
MARITAL STATUS (TICK ONE): ....Married ....Single ....Divorced
NUMBER OF SHARES: .... AMOUNT OF SHAREHOLDING: GH₵ ....
OCCUPATION: .... CROP GROWN: ....
HOW LONG HAVE YOU BEEN FARMING: .... years
ACREAGE OF FARM: .... NUMBER OF ASSISTANTS: ....
NUMBER OF HARVESTS PER YEAR: ....
NUMBER OF BAGS OF PRODUCE PER HARVEST: .... (50 kg. bags)
UNDERTAKING:
I, ..., being desirous of becoming a member of the .... Rice Farmers Association and having been apprised of the rules and regulations of the said Association, do hereby undertake to abide by the said rules and regulations and to abide by all decisions taken in accordance with those rules and regulations.
Signature of Applicant .... Date: ....

For Office Use Only:
Date of receipt of application .... Date Considered: ....
Date approval ....
Signature of authorizing officer: ....

References

1. Abdulrachman S., E. Suhartatik, Erdiman, Susilawati, Z. Zaini, A. Jamil, M. J. Mejaya, P. Sasmita, B. Abdullah, Suwarno, Y. Baliadi, A. Dhalimi, Sujinah, Suharna and E. Septianingrum, 2015, *Panduan Teknologi Budidaya Padi Salibu. Badan Penelitian dan Pengembangan Pertanian. Kementerian Pertanian*

2. Abdulrachman M., M. I. Wahab, L. M. Zarwazi, N. Agustiani and M. Sujinah, 2017, *Verifikasi Komponen Budidaya Salibu, Acuan Pengembangan Mendukung Ketahanan Pangan Berkelanjutan. Balai Besar Penelitian Tanaman Padi, Badan Penelitian dan Pengembangan Pertanian, Kementerian Pertanian*, Republik Indonesia

3. Africa Rice Center, 2011, Boosting Africa's Rice Sector. A research for development strategy 2011-2020, Cotonou, Benin, 3p.

4. Andrade, W. E. de B, S. A. Neto, A. B. de Olivera and M. B. Fernandez, 1985, Height of cutting the crop influences ratoon yield (in Portuguese), 173-178, In: irrigated Rice Workshop, 14 Pelotas.

5. Antara News, 2016, *Ngawi tingkatkan produktifitas padi dengan sistem SALIBU*. https://jatim.antaranews.com/berita/158398/ngawi-tingkatkan-produktivitas-padi-dengan-sistem-salibu, Accessed 23 Aug 2018

6. Asubonteng O. K., 2001, Characterization and evaluation of inland valley watersheds for sustainable agricultural production: case study of semi-deciduous forest zone in the Ashanti Region of Ghana, Tropics

7. Bahar, F. A., 1976, Prospects for raising productivity of rice by ratooning, Unpublished M.S. Thesis, UPLB, Luguna, Philippines,102p.

8. Bahar, F. A. and S. K. De Datta, 1977, Prospects of increasing total rice production through ratooning, Agron. J. 69, 536-540.

9. Balasubramanian, B., Y. B. Morachan and R. Kliappa, 1970, Studies on ratooning in rice, I. Growth, attributes and yield. Madras Agric. J. 57(11), 565-570.

10. Bardhan Roy, S. K. and J. Mondal, 1982, Ratooning ability of some photoperiod sensitive rice. IRRI Newsletter, 7(6), 5.

11. BPTP Jambi, 2016, *Bupati Kerinci panen perdana teknologi padi* SALIBU. http://jambi.litbang.pertanian.go.id/ind/index.php/berita/764-bupati-kerinci-panen-perdana-teknologi-padi-salibu. Accessed 23 Aug 2018

12. Bulukumba T., 2017, *Keren, petani Batuasang Bulukumba perkenalkan sistem tanam* SALIBU. https://makasar.terkini.id/keren-petani-batuasang-bulukumba-perkenalkan-sistem-tanam-salibu/ Accessed on August 23, 2018

13. Chauhan, J. S., B. S. Vergara and F. S. Lopez, 1985, Rice Ratooning, IRRI, Res.

Pap. Ser, 102-119.

14. Cuevas Perez, F. E., 1980, Inheritance and associations of sis agronomic traits and stem-base carbohydrate concentrations on ratooning ability in rice *Oryza sativa* L. Ph.D Thesis, Oregon State University, 102p.

15. Directorate of Agricultural Extension Services, Ministry of Food and Agriculture (DAES/MoFA), Ghana, 2011a, Farmer Based Organizations Capacity Development Project

16. Directorate of Agricultural Extension Services, Ministry of Food and Agriculture (DAES/MoFA), Ghana, 2011b, Agricultural Extension Delivery Approaches Being Implemented in Ghana

17. Ekepi, G. K., 2009, Report on A Comparative Study on Large Scale Extension Methods Used in Ghana, Challenge Program on Water and Food (CPW&F): Enhancing Rainwater and Nutrient Use Efficiency for Improved Crop Productivity, Farm Income and Rural Livelihoods in the Volta Basin. African Union/Semi-Arid Africa Agricultural Research and Development.

18. Erdiman, Nieldalina, Misran and Y. Mala, 2013, *Peningkatan produksi padi dengan teknologi spesifik lokasi Sumatra Barat (teknologi salibu). Laporan Hasil Pengkajian Tahun* 2013. BPTP Sumatra Barat

19. Erdiman, Nieldalina, Misran, Y. Mala and Ekamirnia, 2014, *Pengembangan teknologi salibu pada padi sawah di tiga agroekosistem zone (AEZ) di Sumatra Barat. Laporan Hasil Pengkajian Tahun* 2014. BPTP Sumatra Barat

20. FAO, 2019, 2020, 2022 FAOSTAT Database. Rome: Food and Agricultural Organization (2019, 2020, 2022) http://www.fao.org/faostat/en/#data/QC

21. Haque, M. M., 1975, Varietal variations and evaluation procedures for ratooning in rice, Unpublished MS thesis, UPLB, Philippines, 110p.

22. Ichii, M., 1984, Studies on the utility of ratoon traits of rice as the indicator of agronomic characters in breeding, Mem. Fac. Agric, Kagawa University, NO. 44, 49p.

23. Ichii, M. and N. Ogaya, 1985, Application of ratoon traits obtained by higher cutting for estimation of percentage of ripened grains in rice plants, Jpn..J..Breed, 35, 311-316.

24. Ichii, M. and Sumi, 1983, Effect of food reserves on the ratoon regrowth of rice plant, Jpn. J. Crop Sci. 52(1), 21-75.

25. IRRI, 1988, Rice Ratooning, International Rice Research Institute, Los Baños, Laguna, Philippines, 279p.

26. Ishikawa, T., 1964. Studies on the ratoon of rice plant in early cultivation (in Japanese, English summary). Bull. Fac. Agric., Uni. of Miyazaki Japan, 10(1), 72-

78.

27. Iso, E., 1954, Ratoon culture of Horai varieties, 197-200, In: Rice and Crops in its rotation in sub-tropical zones, Japan-FAO Association, Tokyo.

28. Krishnamurthy, K., 1988, Rice ratooning as an alternative to double cropping in tropical Asia, RICE RATOONING, IRRI, Los Baños, Laguna, Philippines, ISBN 971-104-190-1, 3-15

29. Kusnadi and Nunung, 2017, What I know about Salibu. Report on field visit to Tanah Datar, West Sumatera. Bogor Agricultural University

30. MOA, 2015, *Pedoman Umum Pelaksanaan* UPSUS PJK. Ministry of Agriculture, Jakarta.

31. MoFA (Ministry of Food and Agriculture, Ghana), 2009, National Rice Development Strategy of Ghana

32. MoFA (Ministry of Food and Agriculture, Ghana), 2015, National Rice Development Strategy of Ghana

33. Mulyani, A., D. Kuntjoro, D. Nursyamsi and F. Agus, 2016, Analysis of Paddy Field Conversion: The Utilization of high resolution spatial data shows an alarming conversion rate. *Jurnal Tanah dan Iklim* Vol. 40, No. 2. 121-133.

34. Mustapha M. C., 2004, Management of Rice Production Systems to Increase Productivity in the Gambia, West Africa; A Dissertation Presented to the Faculty of the Graduate School of Cornell University

35. Nadal, A. M. and V. R. Carangal, 1979, Performance of the main and ratoon crops of 13 advanced rice selections under dry seeded rainfed bunded conditions. Philipp. J. Crop. Sci. 4(2/3), 95-101.

36. Nagai, I., 1958, Japonica rice, its breeding and culture, Yokendo Ltd.,Tokyo, 834p.

37. Nair, N. R. and P. C. Sahadevan, 1961, A note on vegetative propagation of cultivated rice, Curr. Sci. 30, 474- 476.

38. Oad F. C. and P. S. Cruz, 2002, Rice varietal screening for ratoon ability. Pakistan Journal of Applied Science. 2. 114-119.

39. Owusu, G., 2015, Developing Multifunctional Farmer-Based Organizations (FBOs) in Ghana: The Role of FBOs in the Agricultural Development, Workshop on Research Output of Collaboration in Ghana 2011-15 and Future Prospect, DeriptA: 1-3

40. Palchamy, A. and S. Purushothaman, 1988, Grain yield and duration of ratoon rice varieties, Agril. College and Res. Inst. (ACRI), Tamil Nadu Agril. Uni. Madurai 625104, India, IRRN 13:5(Oct. 1988), 9p.

41. Parago, J.F., 1963, Rice ratooning culture, Agric. Ind. Life, (2598)15, 45, 47.

42. Pasaribu, P. O., Triadiati and Anas, 2018, Rice ratooning using the Salibu system and the system of Rice Intensification Method Influenced by Physiological Traits. Pertanika Journal of Tropical Science. Vol. 41, Issue 2. 637-654

43. Plucknett, D. L., R. G. Escalada and P. Dela, 1978, Crop Ratooning, J. Ser. 2266 of the Hawaii Agril. Expt. Station, Honolulu, Hawaii, USA. 40p.

44. Quddus, M. A., 1981, Effect of several growth regulators, shading and cultural management practices on rice ratooning.

45. Fitri, R., Erdiman, N. Kusnadi and K. Yamaoka, 2019, Salibu Technology in Indonesia: An Alternative for Efficient Use of Agricultural Resources to Achieve Sustainable Food Security, Paddy and Water Environment, 17(3), 403-410

46. Sakagami, Jun-ichi, A. Isoda, H. Nojima and Y. Takasaki, 1999a, Growth and survival rate after maturity in *Oriza sativa* L. and O. *glaberrima* Steud, Japanese Journal of Crop Science, 68(2), 257-265 (in Japanese)

47. Sakagami, Jun-ichi, A. Isoda, H. Nojima and Y. Takasaki, 1999b, Annuality and perenniality characteristics and variation in *Oriza sativa* L. and O. *glaberrima* Steud, Japanese Journal of Crop Science, 68(4), 524-530 (in Japanese)

48. Samson, B. T., 1980, Rice ratooning effects of varietal type and some cultural management practices. Unpublished MS Thesis, UPLB, Los Baños, Philippines, 166p.

49. Sun X., Z. J. Guo and L. Yujiu, 1988, Ratooning with rice hybrids, 155-161, In: Rice Ratooning. IRRI, Philippines.

50. Tribun News, 2018, *Petani Buleleng Sukses terapkan Teknologi SALIBU, Tanam sekali, panen berkali-kali*. http://www.tribunnews.com/tribunners/2018/01/15/petani-buleleng-sukses-terapkan-teknologi-salibu-tanam-sekali-panen-berkali-kali Accessed on 23 August 2018

51. Volkova, N. P. and A. P. Smetanin, 1971. On ratooning characters of rice Cv. Adopted to the Kuban region, Bulletin *Nauchno-Tekchnicheskoi informatsii*, Usoyuznyi, Nauchro-issle, Dovatili Skii Inst. Risa, 3, 21-24.

52. Votong, V., 1975. The effect of time of drainage and time of rewatering on the yield of ratoon rice. Unpublished MS Thesis, Uni. of Sydney, Australia

53. Wahyuni and Indraningsih, 2003, *Dinamika program dan kebijakan peningkatan produksi padi". Forum Penelitian Agro Ekonomi*. Vol. 21, No. 2. 143-157

54. Yamaoka, K., K. M. Htay, Erdiman and R. Fitri, 2017, Increasing water productivity through applying tropical perennial rice cropping system (salibu technology) in CDZ, Myanmar. Proceeding of the 2third Congress on Irrigation and Drainage, 8-14 October 2017, Mexico City, Mexico. 1-15 (in flash memory)

55. Yamaoka K., K. M. Htay, Erdiman, R. Fitri and J. Ofori, 2018, Applying Tropical Perennial Rice Farming Systems (SALIBU Technology) and Increasing Water Productivity in Myanmar and Ghana, Proceedings for PAWEES-INWEPF International Conference 2018 in NARA, Nara city, Japan, 20-22 Nov. 2018, pp.1-12

56. Yamaoka K. and J. Ofori，2020, Changing the Nervous Mind of Small-scale Farmers Who Are Reluctant to Invest for Their Development, Irrigation and Drainage, Special Issue, 1-16

57. Zandstra, H. G. and B. T. Samson, 1979. Rice ratoon management, Paper presented at the Int. Rice. Res. Conf., 17- 21 Apr. IRRI, Philippines. 10p.

58. Zhand Jing Guo, 1991, Hybrid rice ratoon exploited in Sichuan, China, IRRN 16: (5) (Oct. 1991)

Postscript

Only God knows whether it is accidental or inevitable. I came across SALIBU technology, starting with connections with unexpected people first. If I had specialized in breeding or plant physiology, I could have been a different approach, perhaps silence, to SALIBU. I was becoming slightly suspicious of what I saw with my own eyes on the remote island of Sumatra, and I was silent for two years. However, suddenly at one time, I was struck by the thunder of my inner voice, and I decided to act nonetheless, with success or failure as a secondary matter. And SALIBU rice ratoon cropping systems has become a study that will excite my short closing years as a researcher.

Ensuring continuous rice cultivation as a high-yielding perennial plant in the tropics will increase grain production to support the world population in the future, promote sustainable food production with minimum resource usage, and alleviate the poverty of rice farmers in Asia and Africa. It will have to be a key to solving them. Specialists may call it a daydream, but the future will be very bright if similar high-yielding perennial continuous cultivation becomes possible in other crops, such as maize and wheat, through the development of new varieties and cultivation methods.

I hope that the society and era in which our future generations will live is the one in which it is permissible to draw such dreams and chase them without saying taboo. Let us terminate the bad habits of professionals brandishing common knowledge in their field and ignoring and disdaining non-professional efforts. Unlike in the past, the next generation will not be able to afford to spend their time on such extra work. No matter by whom the idea is raised, it needs to be thoroughly and creatively used for humanity if it is practical, or else a bright future will not open.

Crops have a variety of unused potential that has been truncated for human convenience. We must try to know their true feelings about what they want to do with their abilities, and do they want to fully demonstrate their abilities if the environment is suitable. Rather than completely controlling crop growth only for the convenience of humans, it is necessary to take up the original capabilities of the crop carefully and thoroughly demonstrate their abilities. The reverse idea is required that human beings use crop capacities based on the requirements of the crops and not human beings.

I believe the future society that the SDGs are looking for is not a civilization dominated and reigned by humans, but a society in which humans coexist well with each other and with other living things. Efficiency scaled by and benefits pursuit for only the human allow the limited people to monopolize them and develop society while widening the gap between rich and poor. Beyond humans, we are to be pursued on a scale that includes other creatures and the global environment. We hope that introducing the SALIBU rice ratoon cropping systems to the readers of this book will become a milestone. We would appreciate it if you could give us your frank opinions.

About authors with photos

Kazumi YAMAOKA, Ph.D

He started working for the Ministry of Agriculture, Forestry, and Fisheries, Japan, in 1982. He has had various diplomatic and official postings and has been engaged as a professor at the UT and a senior researcher in national institutes. He has been widely involved in international discussions on water issues and received the PAWEES (International Society of Paddy and Water Environment Engineering) 2015 International Award.

Mr. Erdiman

He was born in Padang, Indonesia, on October 9, 1958. He received a bachelor's degree from UMMY University, Indonesia. He worked as a researcher at the Agricultural Technology Research Center in West Sumatera, Indonesia, from 1995 -2016, as a GTZ Consultant at the critical land rehabilitation project (2000-2005), and as a project coordinator of AEZ mapping in West Sumatera (2002-2007). His research interests are paddy farming and agroecology.

Khin Mar Htay, Ph.D

She started working for DAR), of Myanmar in 1984 and has been engaged in research for a varietal improvement program of rice. She also developed an effective water-saving technique for farmers' fields and Climate Smart Agriculture Technique and published seventeen papers on water management of different crops. In 2016-2017, she received Technology Award for Water Saving Technology of Alternate Wetting and Drying (AWD) in Rice production.

Joseph Ofori, Ph.D

He has served as a researcher in Agronomy at the Soil and Irrigation Research Center of the UG. Previously, he was on the staff of the Crops Research Institute of the Council for Scientific and Industrial Research of Ghana. He received a Ph.D. Degree from Tottori University, Japan, in 2005 and has an experience of over 20 years in teaching, research, and extension and has published nearly 20 scientific articles in national and international journals.

Resfa Fitri, Ph.D

She started working for the Ministry of Agriculture of Indonesia in 1989. In 2017 she transferred to the IPB University, Bogor as a lecturer. She received her Ph.D. degree from Massey University, New Zealand, in 2006 and her master's degree from the University of Queensland, Australia, in 1996. She is involved in research programs in Indonesia and overseas. Her research interests are Sustainable Agriculture, Microfinance, and Islamic Finance.

Mr. Kyaw Myaing

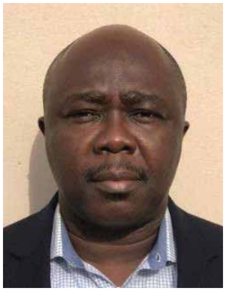
He is the head of the Agricultural Natural Resources Research Section, DAR, Myanmar. He started his career in 2004 as a research technician, specializing in crop water management and greenhouse gas emission research. He holds a bachelor's degree in agricultural science from Yezin Agricultural University and emphasizes developing new rice ratooning technology in Myanmar. He has published more than 11 research papers in research journals.

Naing Kyi Win, Ph.D

He has a position as the Director General of DAR, Myanmar, and is responsible for all the departments. With over 32 years in both agricultural extensions and research sectors, he has had experience in farm management, plant breeding, rice quality seed production and management, professional development, strategic implementation, and international collaboration. He earned a Ph.D. in Agricultural Extension from Yezin Agricultural University.

Mr. Kofi Kutame

He worked at the Department of Cooperatives; the government institution responsible for cooperatives development. He has also worked with DAES, Ghana, in the development of farmers-based organizations (FBOs) and the administration of the FBO Development Fund, which disbursed funds to eligible FBOs to purchase simple farm machinery under World Bank-sponsored AgSSIP. He has developed a few manuals on FBO management.



Mr. Gabriel Owusu

He has been an expert agricultural practitioner in extension work, training, planning, and organizing agricultural programs and projects for over 18 years. He is engaged in the formulation and implementation of agricultural extension policy in Ghana. Mr. Owusu is currently coordinating the activities of Farmer Based Organization Development at the National Level in the Ministry of Food and Agriculture in Ghana.

Harjito, Ph.D

He started his career in the Ministry of Agriculture Indonesia in 1991 and has been actively involved in various international forums since 1997, both bilateral, regional, and multilateral. He is also heavily involved in preparing Environment Impact Analyses of various project activities in Indonesia and is active in Argo Eco Universe, a company engaged in services, education, training, feasibility study, and environmental constructions.

The PDF file of the manuscript of this book can be downloaded from the URL below.
Japanese version:
https://www.sridonline.org/documents/KazYama/SALIBU.jp.pdf

English version:
https://www.sridonline.org/documents/KazYama/SALIBU.en.pdf

Any comments or inquiries (in English or Japanese) regarding the contents of this book are encouraged to be directed to the first author below.
mailto:kaz59@fmail.plala.or.jp

JIRCAS International Agriculture Series No.26 (ISSN 1341-3899)
Unconventional and sustainable high-yield rice ratooning with the lowest use of time and resources
SALIBU Rice Ratoon Cropping Systems
Perennial rice cultivation using low-positioned ratoons
March 2023
Kazumi Yamaoka et al.
Published by Japan International Research Center for Agricultural Sciences
Tsukuba, Ibaraki, 305-8686 JAPAN
Tel. +81-29-838-6313
https://www.jircas.go.jp/en

JIRCAS