INCREASING WATER PRODUCTIVITY THROUGH APPLYING TROPICAL PERENNIAL RICE CROPPING SYSTEM (*SALIBU* TECHNOLOGY) IN CDZ, MYANMAR

AUGMENTER LA PRODUCTIVITÉ DE L'EAU À TRAVERS L'APPLICATION TROPICALE VIVACE DE RIZICULTURE SYSTÈME (*SALIBU* TECHNOLOGY) DANS CDZ, MYANMAR

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ABSTRACT

Rice is grown as a monocarpic annual plant. However, in tropical areas it can survive as a perennial plant so that it can continue to produce ratoon crop grains over the generations. It is known that Japonica and Javanica in *Oryza sativa* subspecies has stronger characteristics as a perennial plant than Indica in the same subspecies and African varieties in the *Oryza glaberrima* species. Ratooning is a method of harvesting a crop which leaves the roots and the lower parts of the plant to grow the ratoon or the stubble crop. Ratooning is regarded as an established farming system in some crops like sugarcane, banana and sorghum with a reasonable yield while rice ratooning is regarded as just supplementary crop because of its low yield in general ranging 20 to 50% of its main crop.

The Central Dry Zone (CDZ) covers more than 54,000km^2, encompassing 58 townships and approximately 36% of Myanmar's population. Dry spells during the rainy season in CDZ are frequent, but their intensities vary geographically and over time. Substantial amount of rice production is generated in irrigated paddy fields along the edges of CDZ. However, water use efficiency of the irrigated rice production remains low and is expected to become worse along with in climate change. More rice crop per drop water, i.e. increase of water productivity, is an essential issue of this region.
Tropical perennial rice cropping system (*SALIBU* technology) is suggested for solving this issue.

This ratooning system developed in West Sumatra in Indonesia allows to harvest rice grain 3.5 to 4 times annually and realizes a higher yield of ratoon crop as well as main crop under the tropical or sub-tropical, winterless climate as well as the condition of irrigable paddies throughout the year but lesser volume of water per one crop season whether by surface or groundwater. The benefits of rice ratooning extend to not only shortening the period for crop maturity but also saving various resources such as water, labour, seed and topsoil as well as their associated costs owing to the omissible sowing and land preparation and the shortened period for growing. This technology is not well known among scientists; however, the government of Indonesia has started a program to spread this farming system to all over the county since January 2017.

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JIRCAS, DAR in Myanmar and IPB-FEM in Indonesia have started a research collaboration on "Improvement of irrigation water productivity for paddy rice production by means of *SALIBU* ratoon technology in CDZ, Myanmar." A preliminary study under the pot cultivation proved that a popular local variety namely *Thee Htat Yin* performed in yield 9.1 t/ha by ratoon crop while 5.3 t/ha by main crop. It also shows that the ratoon scores much higher number of tillers, panicle per hill and biomass weight than main crop while the number of spikelet per panicle, weight of 1000 grains and percentage of filled grains are lower.

The research project has released field experiments in the test fields of DAR for more precise study on the Tropical Perennial Rice cropping system and its water productivity. This system may contribute to realizing a New Green Revolution in terms of both increasing production and saving global resources.

Keywords: Ratoon Crop, Perennial Rice, Field Capacity, Water Productivity, Triangle Research Cooperation

RÉSUMÉ ET CONCLUSIONS

Le riz est cultivé comme plante annuelle monocarpique. Toutefois, dans les régions tropicales il peut survivre comme une plante vivace, afin qu'elle puisse continuer à produire des céréales de culture de repousses au fil des générations. On sait que Japonica et Javanica chez Oryza sativa sous-espèce possède des caractéristiques plus forts comme une plante vivace que Indica de la même sous-espèce et variétés africaines dans les espèces du genre Oryza glaberrima. Coupes successives est une méthode de récolte d'une culture qui laisse les racines et les parties inférieures de la plante de croître les repousses ou que la récolte de chaume. Coupes successives est considéré comme un système d'agriculture établie dans certaines cultures comme la canne à sucre, banane et le sorgho avec un rendement raisonnable, tandis que le riz coupes successives est considéré comme une récolte supplémentaire juste à cause de son faible rendement en général allant de 20 à 50 % de sa récolte principale.

La Zone sèche centrale (CDZ) couvre plus de 54 000 km^2, englobant des 58 cantons et environ 36 % de la population du Myanmar. Des périodes de sécheresse au cours de la saison des pluies en CDZ sont fréquentes, mais leurs intensités varient dans le temps et géographiquement. Une quantité substantielle de la production de riz est générée dans les rizières irriguées le long des bords des CDZ. Toutefois, de l'efficacité de la production de riz irrigué reste faible et devrait s'aggraver le long avec dans le changement climatique. Plus de riz récolte par goutte d'eau, c'est-à-dire augmentation de la productivité de l'eau, est un point essentiel de cette région. Tropicale vivace riziculture de système (Sassi technology) est suggérée pour résoudre cette question.

Ce système bien développé dans l'ouest de Sumatra en Indonésie permet de récolter du grain de riz 3.5 à 4 fois par an et réalise un rendement supérieur de repousses comme culture principale sous le tropical ou subtropical, climat winterless ainsi que l'état des rizières irrigables tout au long de l'année, mais moins de volume d'eau par une saison de récolte, que ce soit en surface ou souterraines. Les avantages du riz coupes successives vont non seulement raccourcir la période de maturité des cultures mais aussi sauver diverses ressources comme l'eau, du travail, semences et terre végétale ainsi que les coûts y afférents en raison de la préparation facultatifs de semis et de la terre et la période raccourcie pour la culture. Cette technologie n'est pas bien connue chez les scientifiques, cependant, le gouvernement indonésien a commencé un programme visant à répandre ce système d'élevage à travers le comté depuis janvier 2017.

JIRCAS, DAR au Myanmar et IPB-FEM en Indonésie ont commencé une collaboration de recherche sur « L'amélioration de la productivité de l'eau d'irrigation pour la production de riz paddy au moyen de la technologie de repousses Sassi dans CDZ, Myanmar. » Une étude préliminaire en vertu de la culture de pot s'est avéré qu'une variété populaire locale à savoir Thee Htat Yin interprété avec un rendement 9.1 t/ha par repousses tandis que 5,3 t/ha en culture principale. Il montre aussi que les scores de repousses beaucoup plus grand nombre de talles, panicule par hill et la biomasse de poids que la culture principale tandis que le nombre d'épillets par panicule, poids de 1000 grains et le pourcentage de grains remplis sont plus faibles.

Le projet de recherche a publié des expériences sur le terrain dans les domaines de l'essai de DAR pour une étude plus précise sur la tropicale vivace riziculture système et la productivité de l'eau. Ce système peut contribuer à la réalisation d'une nouvelle révolution verte en termes d'augmentation de la production et économie des ressources mondiales.

Mots clés: Repousses Crop, riz vivace, capacité au champ, la productivité de l'eau, Triangle recherche coopération

1. Introduction

Rice is one of the world's three major crops, cultivated in 162.3 million hectares, produced for 738.1 million tons as paddy, and grown as a monocarpic annual plant. Production and consumption of rice is dominated in Asia; however, rice becomes more popular in the rest of the world recently and especially the consumption (domestic supply) of rice in Sub-Saharan Africa has drastically increased in the last decade (2003-2013) by 9.8 million ton while its domestic production has done by 6.8 million ton. Many counties in this region are boosting the domestic rice production as one of major national economic issues because the rapid increase of the gap between domestic production and consumption, i.e. import of rice from Asian countries, forces the countries spend the precious foreign currency wastefully. Rice is believed to be a promising food crop to feed the next generation.

To achieve the target 2.1 of Sustainable Development Goals, describing that by 2030 end hunger and ensure access by all people, in particular the poor and people in vulnerable situations…, we must concentrate our efforts on Sub-Saharan Africa and South Asia where the target of eradication of hunger in Millennium Development Goals was not attained. FAO's report "How to Feed the World in 2050" said in 2009 that by 2050 the world's population will reach 9.1 billion, 34 percent higher than today and food production (without food used for biofuels) must increase by 70 percent due to accelerated urbanization and higher income level of people. FAO also expects that globally 90 percent (80 percent in developing countries) of the growth in crop production will come from intensification, in particular higher yields and increased cropping intensity. It means that in developing country only 20 percent will come from expansion of arable land but the rate of growth in yields of the major cereal crops in the world has been steadily declining, it dropped from 3.2 percent per year in 1960 to 1.5 percent in 2000. The challenge for technology is to reverse this decline at a global level.

On the other hand, agricultural production and distribution of food has been a major contributor to greenhouse gas emissions. The large increase in the use of nitrogen fertilizer to produce crops like corn, while it has happened hand in hand with Green Revolution since 1940's, has dramatically increased the emissions of nitrous oxide, a powerful greenhouse gas. The gasoline and diesel fuel that is consumed by tractors and trucks is also a large source of carbon dioxide emissions. Additionally, resources such as land, water, fossil oil and minerals available in the world are limited. We need much more food production in the future but at the same time we must reduce in using various resources relating the food production in terms of saving both carbon emission and use of resources.

And note that hunger can persist in the midst of adequate aggregate supplies because of lacking income opportunities for the poor and the absence of effective social safety nets. Growth originating in agriculture, in particular the smallholder sector, is at least twice as effective in benefiting the poorest as growth from non-agriculture sectors. The report said that this is not surprising since 75 percent of the poor in developing countries live in rural areas and their incomes are directly or indirectly linked to agriculture. The fight against hunger also requires targeted and deliberate action. Increase of the income of farmers, especially small holders, should be directly targeted to achieve the second goal of SDGs, i.e. “End hunger.”

This report also argues that the required increase in food production can be achieved if the necessary investment is undertaken and policies conducive to agricultural production are put in place. The required increase in developing countries is about 50 percent over current investment levels. These figures are totals for public and private investment, i.e. investments by farmers. So, it is essential for us to increase the income of farmers, even poor small holders, to ensure their investment for more food production.

We must tackle with the multi-faceted challenges such as for technology to increase in yields, for saving both carbon emission and use of resources, and for directly increasing income of small holder farmers in terms of both ending hunger and ensuring their investment.

2. Review of Studies on Rice Ratooning

Rice is cultivated as a monocarpic annual plant in conventional farming systems. However, in fact, in tropical areas it can survive as a perennial plant so that it can continue to produce ratoon crop grains over the generations. It is known that Japonica and Javanica in *Oryza sativa* subspecies has stronger characteristics as a perennial plant than Indica in the same subspecies and African varieties in the *Oryza glaberrima* species (Sakagami et al., 1999a and 1999b). Ratooning is a method of harvesting a crop which leaves the roots and the lower parts of the plant to grow the ratoon or the stubble crop. Ratooning is regarded as an established farming system in some crops like sugarcane, banana and sorghum with a reasonable yield while rice ratooning is regarded as just supplementary crop because of its low yield in general ranging 20 to 50% of its main crop (Krishnamurthy, 1988).

Rice ratooning has often been a subject of researches since 1950’s and been analysed from various aspects such as morphology, physiology, ratoon development earliness, varietal potentiality, capacity of making tillers, growth duration of main crop, plant height, land preparation and spacing for main crop, timing of harvest of main crop, cutting height of the stubble, fertilizer management, water management, temperature and light intensity. The authors had made excerpts of F.C.Oad *et al.* (2002) reviewed well on rice ratooning, as follows.

2.1 Morphology, physiology and ratoon development earliness

Oad et al. (2002) said such as, "Usually plant height (Balasubramanian *et al*., 1970) is lower and effective tillers are fewer in the ratoon crop than the main crop (Bahar and De Datta, 1977). Stem thickness is correlated with higher carbohydrate content in the stubbles, which results in more vigorous regeneration of ratoon tillers and grain yield (Palchamy and Purushothaman, 1988). Cultivars and practices, including cutting height and fertilizer management, which provide a large quantity of reserves at harvest, may be advantageous for rice ratooning (Ichii, 1984). High cutting of main crop stubbles helps increase of the amount of Total Carbohydrate Content (TAC) in the stubbles and ratoon growth of rice depends upon the amount of TAC in the stem base, which results in producing many tillers (Ichii and Ogaya, 1985). Several studies showed that ratoon tiller development depends upon the carbohydrates that remain in the stubbles and root after the main crop is harvested (Cuevas Perez, 1980; Ichii and Sumi, 1983; and Samson, 1980).” It implies that cultivation trials using Carbon tracer with different cutting heights for ratooning may be useful.

And said such as, "The ratoon tiller regeneration and growth depends on the buds that remained on the stubbles and exist in various stages of development (Nair and Sahadevan, 1961). In Kagi Ban2 cultivar, the C:N ratio was 17.0 in tillers from upper nodes, 13.88 in those from the base and 10.80 from those below the soil, and the tillers from the upper nodes with high C:N matured faster like old seedlings and were shorter in culm than those tillers emerging from the lower nodes which behaved like young seedlings (Iso, 1954). Early tiller regeneration may encourage tillering by providing nutrients to the developing buds (Chauhan *et al*., 1985).” It implies that the relation between the growth speed of ratoon tiller and the node of which the tiller regenerates must be studied precisely.

2.2 Varietal potentiality, tillering capacity and main crop growth duration

Oad et al. (2002) said such as, "The prospect of successful ratoon cultivation depends largely on ratooning of a variety. Ratooning ability has been found to be a varietal character (Bahar, 1976, Balasubramanian *et al*., 1970, Bahar and De Datta, 1977; Haque, 1975; Nadal and Carangal, 1979). Further, Nadal and Carangal (1979) identified three rice selections without standing tillering capacities and high ratoon yields under varying soil moisture regimes. Haque (1975) found out that IR2061- U23, IR2145-20-4 and IR1924-36-22 possessed high ratooning ability. In India, C3810, Ratna, CR20-66, and CR156-5021-207 showed superiority in ratooning and yield ability (Das and Ahmed, 1982). The hybrid Zaishelgyou produced the highest main and ratoon crop yields resulting in a significantly higher total yield (11.0 t/ha).” It implies that the ratooning performance depends largely on varieties.

And said such as, "Tillering ability is probably the most important genetic factor affecting ratoon performance of grasses. In ratoon crop the effective tillers are fewer compared to the main crop, however, the actual number of tillers may be higher in the ratoon crop than in the main crop (Balusubramanian *et al.*, 1970). Varietal differences exist with respect to emergence of ratoon tillers from different nodes of the stubbles. The tillers may emerge from all nodes of the stubbles or from only the lower nodes or from any specific node number. Many findings suggested that ratoon crop is better if the main crop stubble is cut with 2-3 nodes left.” It implies that the difference of variety may strongly affect tillering ability and the node number from which the tillers emerge resulting in ratooning performance.

And said such as, "Main crop growth duration has been reported to influence ratooning ability (Bardhan Roy *et al*., 1982; Cuevas Perez, 1980) Growth duration and grain yield was correlated strongly. Varieties with longer growth duration tended to have stronger ratooning ability. However, very early maturing cultivars were recommended for ratoon crops in temperate areas because they do not require early seeding and allow a favourable growth period for the ratoon crop. Zandstra and Samson (1979) found significant correlation between ratoon crop yield and ratoon crop duration ($r = 0.71$) and between ratoon crop duration and main crop duration ($r = 0.65$).” It implies that prolonging ratoon crop duration may become a key technology for its high yield.

2.3 Timing of harvest of main crop and cutting height of the stubble

Oad et al. (2002) said such as, "The best time to harvest the main crop for raising a good ratoon crop is when culms are still green (Parago, 1963b). The best time to harvest the main crop for maximum ratoon yield is before the crop is fully matured (Nagai, 1958; Balsubramanian *et al.*, 1970). Optimum cutting height should be 30-40 cm above grounds (Zhang Jing Guo, 1991). Haque, (1975) and Reddy *et al*., (1979) proposed that harvesting at 30, 35, 40, and 45 days after main crop flowering did not significantly affect ratoon yields, however, Mahadevppa *et al*., (1988) mentioned that because senescence is a varietal character, the time of main crop harvest might depend upon the variety and location." It implies that harvest of main crop in the timing of physiological maturity when its roots and stems are still vital is better for ratooning.

And said such as, "Cutting height determines the origin of the ratoon tiller and growth duration of ratoon crop (Sun Xiaohui *et al*., 1988). The effect of cutting height on ratoon vigour varied. Some cultivars ratooned from high node, others produced basal ratoon that are unaffected by cutting height (Volkova and Smetanin, 1971). Bardhan Roy and Mondal (1982) reported that cutting height did not significantly affect ratooning ability, reproductive tillers and ratoon yields. In the Philippines ground level cutting was suggested to prevent growth of unproductive tillers (Parago, 1963). It was reported that in the Philippines wet season rain fall is heavy, and cutting close to the ground level may risk a high tiller mortality rate and poor ratoon crop stand density (Zandstra and Samson, 1979; Samson, 1980; Chauhan *et al*., 1985). In Cambodia, plant cut at 15 cm gave higher yields than plants cut at ground level (Szokolay, 1956). However, Iso (1954) recommended that main crop cutting should leave 1.25 cm of the stubble above the water level. Submerged stubble may rot and tall stubbles may put forth vary weak tillers. Andrade *et al*., (1985) evaluated 10 irrigated rice cultivars at 10, 20 and 30 cm cutting heights. They observed that 30 cm cutting height gave the best results including plant height in all cultivars. Hsieh *et al*., (1959) recorded a rate of tillering of 89.1, 80.6 and 71.9% at 24, 15 and 6 cm cutting height respectively. Reddy and Pawar (1959) conducted studies at Karnataka and noted that cuttings 8, 13 and 18 cm did not affect ratoon yields. In Japan ratoon stand varied with cutting height but these did not affect grain yield (Ishikawa, 1964)." It implies that the relations between cutting height and the node number emerging tillers, ratooning ability, number of effective tillers and yield of ratoon crop are varied. However, those studies did not apply two steps cutting but only once and maintain stems of stubbles as cut until harvest.

2.4 Water management and fertilizer management

Oad et al. (2002) said such as, "Water management before and after main crop harvest affected ratooning ability (Votong, 1975; Hague, 1975). To promote ratooning, the field should be moist but not flooded for weeks at the end of the main crop ripening. Draining the field several days after harvest also encourages ratooning. Irrigation water must be kept shallow in the early ratooning stages. It is essential to have irrigation immediately after the first fertilizer application. Fields drained during harvest of the main crop to promote tillering of ground level cuttings had more weeds. Furthermore, ground level cutting with continuous 5-7 cm flooding produced very few ratoons and increased percentage of missing hills. Such a problem was not observed with 15 cm or higher cutting height (Bahar and De Datta, 1977). Ichii (1983) reported that water management did not affect percentage of ratoon tillers or a ratoon height irrespective of height of cutting. Draining the main crop at harvest is generally suggested to promote ratooning and prevent death of hills due to flooding. However, under rain fed situation where water must be retained as much as possible, the main crop should be cut at 15 cm higher to reduce the number of missing hills in the ratoon crop (Zandstra and Samson, 1979). If flooded water is not maintained, main crop grain that fell to the ground during mechanical harvest will germinate and compete with the ratoon crop for light and nutrients (Mengal and Wilson, 1981). Many hills died when the crop was cut at ground level and water remained 5 cm deep (Ichii and Ogaya, 1985)." It implies that water condition in several key stages of growth of main crop and ratoon crop is crucially important such as; irrigation for main crop and ratoon crop is necessary in general and keeping soil moisture without flooded water in some period before and after its harvest is highly recommended, however, it brings more weeding works and the stubbles with very short length submerged by flooded water may cause more missing hills.

And said such as, "Soil fertility may directly or indirectly affect ratoon crop growth and yield (Plucknett *et al*., 1978). At IRRI, Philippines grain yield significantly increased as

N rate increased. N level was optimal at 60 kg/ha (Bahar and De Datta, 1977). Post-harvest nitrogen application to main crop consistently increased ratoon crop yield. Besides amount of applied N, application method in the main crops affects the ratoon crop (Quddus, 1981; Samson, 1980). Palchamy and Purushothaman (1988) reported that N split application at maximum tillering and at panicle initiation increased the ratoon crop grain yield up to 86.6% of the main crop. Lack of acceptance of rice ratooning by commercial farmers has been attributed to low yields, lack of good ratooning varieties, uneven maturity, disease and insect problem, lack of location-specific cultural practices, inferior grain quality and lack of assured return from investment (Chauhan et al., 1985)." It implies that fertilization to both main crop and ratoon crop is important for a higher yield of ratoon crop and rice ratooning for commercial farming is a big challenge.

3. An Encounter with New Rice Ratoon Cropping System

There are so many arguments on rice ratoon crop but no article affirmed that the yield of rice ratoon crop could be equivalent to or more than that of main crop. Lower yield of rice ratoon crop has been a common sense and brought researchers to have assumption that perennial cultivation of rice must be a useless attempt. So, rice ratoon crop has always been treated as one-generation supplementary crop with no successors. The common sense and assumption also have made researchers ignore the study on saving irrigation water for rice ratoon cropping system while farmers may reduce their use of irrigation water because the ratooning makes shorter period of cultivation and omissible water use for seedling nursery, puddling and transplanting.
On the contrary, the new rice ratoon cropping system with special stubble treatment developed in West Sumatra in Indonesia, namely Tropical Perennial Rice Cropping System (*SALIBU* technology), allows to harvest rice grain 3.5 to 4 times annually and realizes an equivalent or a higher yield of ratoon crop grain than main crop under the tropical or sub-tropical, winterless climate. It requires the condition of irrigable paddies throughout the year as well but lesser volume of water per one crop season whether by surface or groundwater. Introduction of this technology to rice farming small holders must allow to solve the multi-faceted challenges described in "1. Introduction." The benefits of rice ratooning extend to not only shortening the period for crop maturity and allowing farmers to harvest and sell more annually but also saving various resources such as water, labour, seed and topsoil as well as their associated costs owing to the omissible sowing and land preparation and the shortened period for growing. This technology is not well known among scientists; however, the government of Indonesia has started a program to spread this farming system to 10,000 ha of paddy fields all over the county since January 2017.

In January 2014, chance brought the first author of this paper to visit the rice paddy fields under the *SALIBU* technology and to meet Mr. Erdiman who was the inventor of this technology. The visit to *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 and water resources management. The author made interviews to village people and Mr. Erdiman explained of the essence of this technology. The author was greatly interested in the focus of his attention and the mechanisms of increasing yield of ratoon crop grain. The wonder was that farmers, mostly women, actually enjoyed the technology and made a success of ratoon rice cultivation under this technology. The author felt then the great potential of this technology's impacts on our future society but at the same time supposed that other scientists such as agronomists must put this technology out into the world.

In June 2016, two years and half after the visit to *Tanah Datar*, the author discovered the *SALIBU* technology was still in the position of a local technology and not yet well introduced to researchers nor overseas.

4. Collaborative Research Plan

The Central Dry Zone (CDZ) covers more than 54,000km^2, encompassing 58 townships and approximately 36% of Myanmar's population. Dry spells during the rainy season in CDZ are frequent, but their intensities vary geographically and over time. Substantial amount of rice production is generated in irrigated paddy fields along the edges of CDZ. However, water use efficiency of the irrigated rice production remains low and is expected to become worse along with in climate change. More rice crop per drop water, i.e. increase of water productivity, is an essential issue of this region.

The author believes that the Tropical Perennial Rice Cropping System (*SALIBU* technology) must solve this issue because farmers can reduce their use of irrigation water per harvest under this system. First, this system makes the period of cultivation shorter by 20-35 days (from 120-140 days in conventional to 90-105 days under *SALIBU* technology), and it doesn't require the irrigation water for puddling and transplanting. It means the increase of water productivity. We should identify suitable rice species for this technology and develop a cropping system under the climate, soil, water and labour conditions in CDZ. In this regard JIRCAS (Japan International Research Center for Agricultural Sciences), DAR (Department of Agricultural Research, Ministry of Agriculture, Livestock and Irrigation) in Myanmar and IPB-FEM (Faculty of Economy and Management, Bogor Agricultural University) in Indonesia have started a research collaboration on "Improvement of irrigation water productivity for paddy rice production by means of *SALIBU* ratoon technology in CDZ, Myanmar" since 2016 under the JIRCAS's research project on "Development of Agricultural Technologies for Reducing Greenhouse Gas Emissions and Climate-related Risks in Developing Countries."

Objectives of the research collaboration are to verify improvement of irrigation water productivity for paddy rice production to cope with the impact of climate change by means of *SALIBU* ratoon technology in CDZ, Myanmar. The suggested research plan is given in Table1.

Table 1. Collaborative Research Plan (2016-2020)

Year	Annual plan
2016	Collecting basic data on irrigated paddy rice production and preparing for preliminary demonstration of *SALIBU* ratoon technology in test fields
2017	Equipping water measures for data collection in test fields and carrying out the first experimental study on improving irrigation water productivity for paddy rice production by means of SALIBU ratoon technology
2018	Elucidating general trend on the balance of between effects of *SALIBU* ratoon technology for increasing production and saving irrigation water use through preliminarily comparative studies in test fields
2019	Elucidating precise characteristics on the balance of between effects of *SALIBU* ratoon technology for increasing production and saving irrigation water use through fully comparative studies in test fields and drafting a manual for adopting technology
2020	Verifying the contents of the manual on improvement of irrigation water productivity for paddy rice production by means of *SALIBU* ratoon technology in farmers' fields and modifying the manual for its finalization

5. Design of Study and Results of Preliminary Tests

5.1 Tropical perennial rice cropping system (*SALIBU* technology)

SALIBU technology was progressively developed since 2007 when Mr. Erdiman, who is the inventor of the technology, visited *Matur* village located in a suburb of *Bukittinggi*, West Sumatra. His wife had been born in this village and he was a staff of West Sumatra office, Assessment Institute for Agricultural Technology (BPTP), Indonesia at that time. The village is in an elevation of 1,100 meters and the high-altitude brings a cool climate for its equatorial topography. Rice ratoon crop farming was traditionally common here because farmers planted only two cold-tolerant varieties, i.e. *Kurik Kusuik* and *Lumut Kurik Kusuik*, which needed about 145 days from sowing to harvesting and they wanted to have another earlier opportunity of harvest by ratoon crop to secure foods in case of a poor harvest.

The farmers had been adopting a rice ratoon crop farming practise recommended by IRRI (International Rice Research Institute), which required cutting rice stubbles at 15-20 cm height above ground surface. However, they had two complains about this farming practise; i) Ununiformed maturity forcing them to harvest the rice twice or three times, and ii) Badly low yield compared to main crop. They asked Mr. Erdiman to solve these problems and he found a solution in 2010 after repeated observation and trial and error to ratoon crop; he got an inspiration and conceived an idea of cutting the rice stubbles at the lowest height above ground surface and keeping soil moisture in the field capacity condition. His trial made much better results on the both problems than the practise recommended by IRRI. He named the new rice ratoon crop farming system as *SALIBU* technology because the local farmers called ratoon *SALIBU*. He continued the growing tests on rice ratoon crop and the extension of the technology to farmers in *Matur* and in *Parabek* village located in 5km away from *Bukittinggi*.

He must bear the cost for the test and the extension to farmers because Research and Development Department, Ministry of Agriculture, Indonesia terminated the budget for rice ratoon research by 2010. However, in 2012 West Sumatra office, BPTP acknowledged *SALIBU* technology as a new technology to support its development and appropriated a budget for it while other offices of BPTP didn't. He stayed in a hotel nearby villages during critical periods while he went by car from his house in Padang to the villages.

The recommended procedure of Tropical perennial rice cropping system is given in Table 2 including a rotational 10 steps.

Table 2. Recommended Procedure of Tropical perennial rice cropping system (*SALIBU* technology)

No	Cultivation techniques
1	Carefully levelling paddy fields for main crop and transplanting seedlings in a locally conventional way or Indonesian "Legowo" system is recommended
2	Fertilizing an a locally conventional way but additionally the 1st fertilizing for ratooning 7-14 days before harvest
3	Stopping irrigation 14 days before harvesting, and keeping the soil moisture in field capacity condition (humid as much as possible) until 14 days after harvesting to stimulate the growth of buds and tillers
4	Harvesting the main crop 7 days earlier than conventional harvest timing, under the physiological maturity not harvest maturity, to keep the lower part of stubbles fresh for vital ratooning
5	If the soil becomes too dry, flooding for 1-2 days, then draining until the soil is humid.
6	Cutting-off lower part of stubbles 7 days after harvesting at 3-5 cm height above ground surface
7	Starting shallow irrigation when the height of tillers reached 5-7 cm
8	Moving (separation and addition) of part of stubbles, inserting floating stubbles into the soil, the first weeding and the 2nd fertilizing 15-22 days after cutting-off
9	Stopping irrigation 29 days after cutting-off, and keeping the soil moisture in field capacity condition (humid) for 15 days

10	Resuming irrigation 44 days after cutting-off
11	The 3rd fertilizing and the 2nd weeding 44-49 days after cutting-off
12	The 1st fertilizing for ratooning 7-14 days before harvest
13	Repeating steps from 3 to 12 (rotational 10 steps) for next generations of *SALIBU* ratoon crop

The procedure is a prototype and to be appropriately modified per variety, soil type and climate condition. The most critical steps are 3, 4 and 6 followed by 8, 11 and 12. Note that in 8th step "moving" means digging a small number of tillers with roots in a larger stubble out of soil by hand and replanting it to a poor stubble to avoid unevenness of growth, and "inserting" means pushing tillers and roots sprouted from a higher node into the soil by toe to avoid naked roots in the air. The cutting-off is always done by power grass mower. Knapsack power mowers with two blades are recommended.

5.2 Application of *SALIBU* technology to test fields in DAR

A comparative study on rice ratooning is designed as Figure 1 and the ratooning is conducted per the procedure above-mentioned with variety *Manawthukha.* Figure 2 shows more specific manual for the cultivation of main and ratoon crop. Sowing was done on 7 January, 2017 and seed-lings were transplanted on 30 January, 2017 to the test field allocated in DAR. The study compares; a) SALIBU ratooning, b) Ratooning with cutting off the stubbles at 25cm height above ground surface (IRRI), and c) Non-ratooning conventional transplanting (control). It also compares; d) Indonesian Legowo 2:1 system for transplanting, e) Legowo 4:1 system, and f) Locally conventional transplanting.

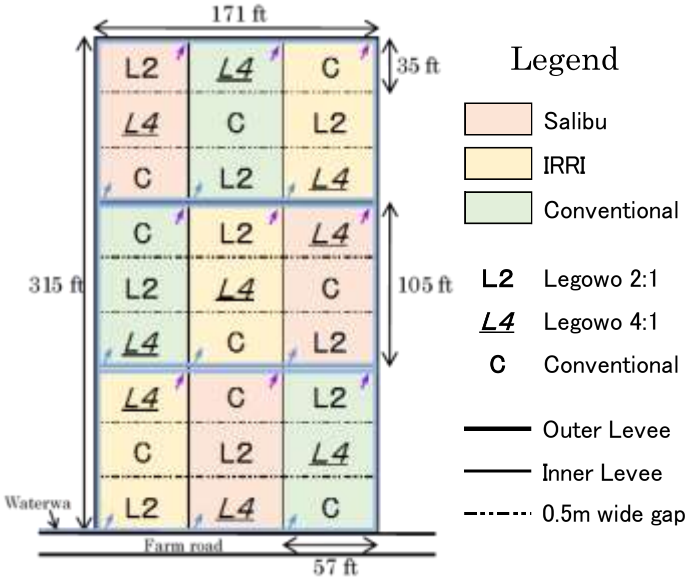

Figure 1. Field design for comparative study on ratooning

The collaborative research project has decided to conduct field experiments in the test fields of DAR for more precise study on this technology and its water productivity. Another comparative study is designed as Figure 3 to compare water productivity between a) SALIBU ratooning with recommended water management, SALIBU ratooning with AWD, and c) Non-ratooning conventional transplanting (control). It also compares water productivity between varieties. Sowing and transplanting will be done in July, 2017.

Besides these field studies a preliminary study under the open-air pot (8ft x 6ft) cultivation proved that a popular local variety in CDZ namely *Thee Htat Yin* performed in yield 9.1 t/ha by ratoon crop while 5.3 t/ha by main crop under the tropical perennial rice cropping system (*SALIBU* technology) as given in Table 3. The main crop was harvested on 11 November 2016 and cut off stubbles on 17 November, 2016 for *SALIBU* ratooning. The 1st generation of *SALIBU* ratoon crop was harvested on 22 February, 2017, 103 days after the harvest of main crop. It showed that the ratoon scores much higher number of tillers, panicle per hill and biomass weight than main

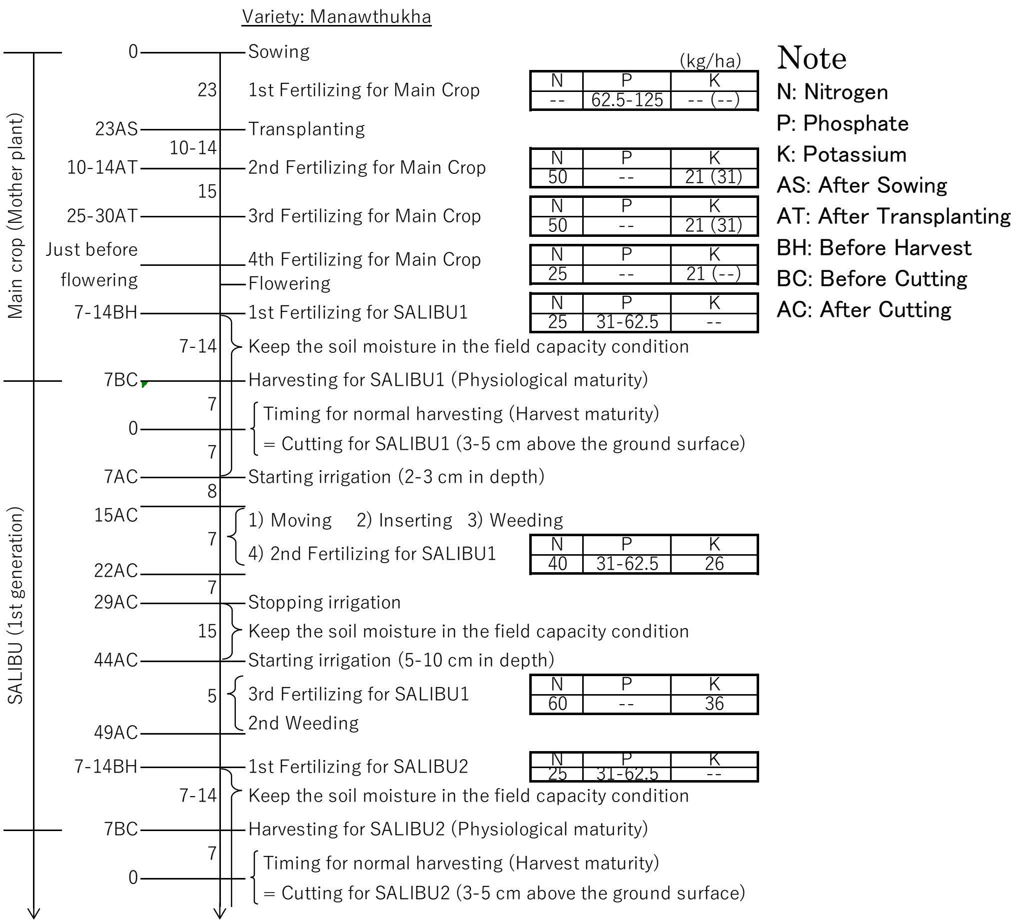

Figure 2. Manual for cultivation of main and ratoon crop

crop while the number of spikelet per panicle, weight of 1000 grains and percentage of filled grains are lower.

The 2nd generation of SALIBU ratoon crop was harvested in early June 2017. It is also around 103 days after the harvest of the 1st generation of SALIBU ratoon crop. The preliminary test results were given in Table 4. Those preliminary tests in DAR, Myanmar show that the yields of SALIBU ratoon crop are higher than that of main crop and the duration of growth of SALIBU ratoon crop are shorter than that of main crop by about 10 days.

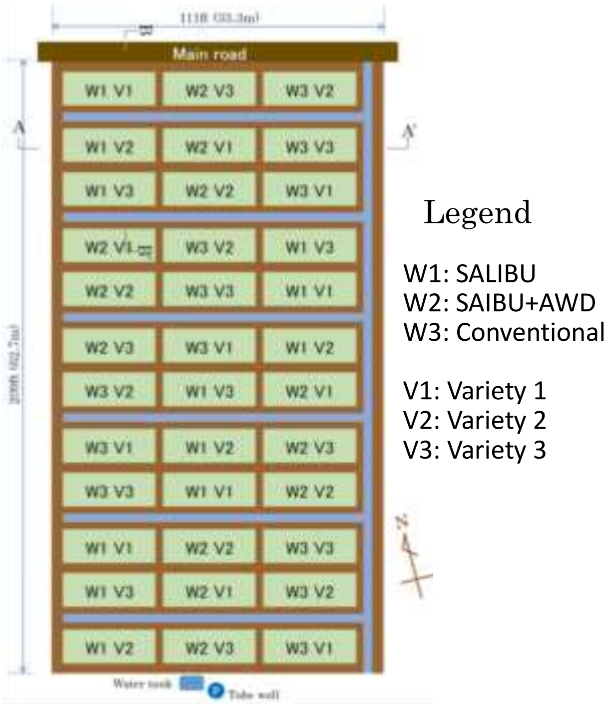

Figure 3. Test design for comparative study on water productivity

Table 3. Preliminary test results of open-air pot (8ft x 6ft) cultivation (Main crop and 1st generation of *SALIBU* ratoon crop)

Item	Main crop	*SALIBU* 1st generation
Date of sowing	19 Jul. 2016	-
Date of transplanting	9 Aug. 2016	(Cutting) 17 Nov. 2016
Date of flowering	5 Oct. 2016	20 Jan. 2017
Date of harvesting	11 Nov. 2016	22 Feb 2017
Plant height (cm)	92.70	68.20
Panicle length (cm)	22.95	19.89
No. of effective tillers	10.00	38.60
No. of Spikelet / panicle	126.94	92.37
No. of panicle / hill	9.78	36.00
1000 grain weight (g)	21.68	18.92
Fill grain (%)	81.94	60.15
Biomass weight / hill (g)	22.41	73.74
Harvest index	0.49	0.51
Yield (t/ha)	5.28	9.09

Table 4. Preliminary test results of open-air pot (8ft x 6ft) cultivation (2nd generation of *SALIBU* ratoon crop)

Item	Plot1	Plot2	Plot3	Plot4	Plot5	Ave.
Pl. height (cm)	88.00	94.00	103.00	99.00	75.00	91.80
Pa. length (cm)	26.70	23.10	25.50	25.90	18.20	23.88
Effective tillers	22.00	12.00	15.00	15.00	40.00	20.80
Spikelet / panicle	100.00	83.00	73.00	115.00	86.00	91.40
Panicle / hill	22.00	12.00	15.00	15.99	40.00	20.80
1000 grain weight (g)	19.00	21.00	20.30	19.60	19.00	19.78
Fill grain (%)	77.90	65.00	58.60	70.40	65.79	67.56
Biomass wt. / hill (g)	82.80	40.70	40.70	51.60	76.70	58.50
Harvest index	0.55	0.48	0.47	0.60	0.35	0.49
Yield (t/ha)	10.78	4.69	4.49	7.37	8.36	6.74

Figure 4. A preliminary study for the 2nd generation of *SALIBU* under the pot cultivation with the local variety namely *Thee Htat Yin*

The site for demonstration of rice ratooning cultivation in various stages under this technology has also been developed in DAR. This is a preparation work for rapid extension activity of the technology to farmers. Another possibility of this technology is proposed by scientists in DAR. They want to apply the new rice ratooning system to the seed propagation. The system may allow the conditions for producing more purified seed in a simpler field settings.

6. Field Survey in West Sumatra Province

The authors of this paper together with 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 an interview to farmers in the villages on 20 and 21 May 2017. The first author collected following information through the interview to 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* technology is applied by 100% of farmers of the village
- His group consist of 52 farmers, and men/women is about 50:50
- Women are engaged in transplanting, weeding, fertilizing and post-harvest processing
- Men are engaged in land preparation, paddling and levelling, cleaning ditches, harvesting, and cutting off (trimming) for *SALIBU* ratooning
- Water management is done by each land owner
- Free charge of irrigation and no water shortage all the year around
- Ratoon cropping was started in 2006 and *SALIBU* technology in 2011

The leader felt after introducing *SALIBU* technology in 2011;

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

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

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

The first author also discovered through the interview in *Tigo Bahea, Sungai, 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 diversification of risk of pest and disease and the latter must contribute to increase the opportunity of income. And group activity such as harvest are maintained in the village. So, each farmer of the village can get cash income around 8 times in a year and enjoy more dispersive group activities. This increase of opportunity of income and the increase of annual income must strongly encourage farmers to invest more to farming.

7. Conclusion and recommendations

The new rice ratoon cropping system with special stubble treatment developed in West Sumatra in Indonesia, namely Tropical Perennial Rice Cropping System (*SALIBU* technology), allows to harvest rice grain 3.5 to 4 times annually and realizes an equivalent or a higher yield of ratoon crop grain than main crop. The benefits of rice ratooning under *SALIBU* technology extend to not only shortening the period for plant growth and allowing farmers to harvest and sell more annually but also saving various resources such as water, labour, seed and topsoil as well as their associated costs owing to the omissible sowing and land preparation. The collaboration study started to proof that it needs lesser volume of irrigation water per one crop season. It means the increase of water productivity. Introduction of this technology to rice farming small holders must allow to solve the multi-faceted challenges such as increasing yields, saving both carbon emission and use of resources, directly increasing annual income of small holder farmers, ending hunger and ensuring their investment to farming. So, researchers are recommended to conduct study on this ratooning technology from various aspects.

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