INCREASING WATER PRODUCTIVITY AND SAVING ENERGY BY HIGH YIELD RICE RATOONING IN MYANMAR

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ABSTRACT

There are over one hundred countries globally in which rice is cultivated. Annual production of paddy rice is above 750 million tons (FAO, 2019) and 3.5 billion people who consume rice worldwide (IRRI, 2013). Rice is one of three major grain crops that act as the staple food for people all over the world, especially, the importance of rice in Asia, which contains 60% of the world's population cannot be understated, and recent increases in rice consumption in Sub-Saharan Africa are also noteworthy. However, rice needs more water for its cultivation; it is said that the water productivity of rice is about half of that of other two major grain crops i.e. wheat and maize. Tropical Perennial Rice (ToPRice) farming systems (SALIBU technology) originating from West Sumatra, Indonesia allow for harvesting rice grain up to 3.5-4 times annually and produce a yield for each ratoon crop at the same level as that of the main crop. ToPRice farming systems should revolutionarily increase water productivity because farmers can reduce the amount of irrigation water drastically by shortening cultivation periods and omitting seedling raising, puddling and transplanting. The systems also effective to save energies and input resources for such various activities above-mentioned. It is useful for adaptation against climate change and promotion of low input rice cultivation. Authors conducted trials on continuous cultivation of rice ratooning for nine generations including main crop in Myanmar.

The trials were done in large concrete pots (1.8m x 2.4m each) out door. While the yield of main crop was 5.3 t/ha, that of its subsequent SALIBU ratoon crop from the 1st to 8th generation were 9.1, 6.9, 11.5, 6.9, 11.0, 9.6, 5.7, 3.9 t/ha respectively. Authors also conducted other trials in test fields (3.5m x 9.3m each) in Myanmar. They were on continuous cultivation of rice ratooning for three or four generations including main crop to compare water productivity. Three rice cultivars were tested. Thee Htat Yin variety scored 4.5 t/ha in yield of main crop while it did 4.7, 5.4, 5.1 t/ha in that of its subsequent SALIBU ratoon crop from the 1st to 3rd generation respectively. It also scored 0.61 g/l in water productivity of main crop while it did 1.44, 0.89, 1.07 g/l in that of its subsequent SALIBU ratoon crop from the 1st to 3rd generation respectively. Water productivity of the same variety cultivated in conventional practice (transplanting) in parallel with the ratoon crop from the 1st to 3rd generation were 0.61, 0.57, 0.87 respectively. The average of them is 0.68 while that of SALIBU ratoon crop is 1.13 which is higher than the former by 66%. It means that farmers can produce by 66% more rice under SALIBU technology than conventional practice within the same amount of water available annually in certain area.

Keywords : Tropical Perennial Rice, high water productivity, continuous cultivation of rice ratooning, save energy

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1. INTRODUCTION

There are over one hundred countries globally in which rice is cultivated. Annual production of paddy rice is 770 million tons in 2017 (FAO, 2019) and 3.5 billion people who consume rice worldwide (IRRI, 2013). Rice is one of three major grain crops that act as the staple food for people all over the world, especially, the importance of rice in Asia, which contains 60% of the world's population cannot be understated, and recent increases in rice consumption in Sub-Saharan Africa are also noteworthy.In the 56 years from 1961 to 2017, the world rice crop area has expanded 1.45 times, meanwhile production has increased 3.57 times and the yield per unit area is 2.46 times (Figure 1). However, the annual increase rate of rice yield per unit areain the world average from 1962 to 2017 clearly shows a downward trend as shown in Figure 2.

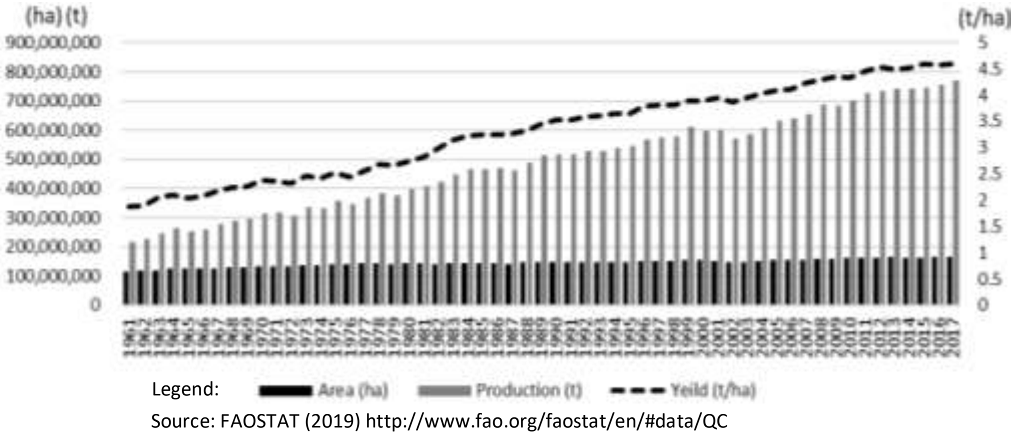

Figure 1. Harvested area, production and Yield per unit area of rice (1961-2017: world average)

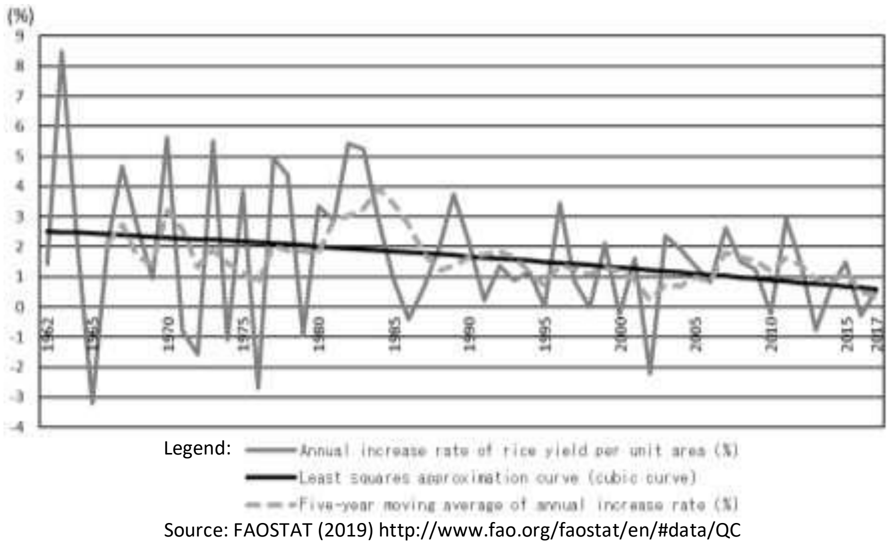

Figure 2. Annual increase rate of rice yield per unit area,its five-year moving average and trend curve (1962-2017: world average)

The equation of the approximate curve (cubic curve) by the least squares method for the annual increase ratefrom 1962 to 2017 is given below.

$$Y = -0.00000006315X^3+0.0001852X^2+0.022X-190.15$$

Where; Y is function of X and the approximation of annual increase rate of rice yield per unit area,and X is year.Assuming that this equation is correct, Y will eventually become zero when X is 2030.Even if this forecast is extreme, it is a fact that the annual increase rate of yield per unit area tends to decrease during the past 50 years and is already at a level of nearly 0.5%.In other words, as with some other crops, the increase in yield per unit area of rice is approaching its limit.It can be said that the future strategy of achieving increased rice production corresponding to the strong demand for rice in the world by increasing the yield per unit area is difficult to realize.

Moreover, rice needs more water for its cultivation than other cereals. The water productivity of cereals can compare year-to-year production 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, provided that WP is water productivity while GY is yield of grain and IW is amount of irrigation water.

$$WP = GY / IW$$

For example, because the value of water itself, in other words, the 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 regions.Thus, comparing the water productivity of different crops produced in different regions, though which is often found in research papers, is totally nonsense. Even in the same region the value of water alsovaries from time to time. However, after fully understanding this, if we compare the water productivity of rice with that of other two major grain crops i.e. wheat or maize, it is generally said that the water productivity of rice is about half of that of wheat and maize.

In order to solve the future food problems corresponding to world population explodes, it is urgently necessary to develop an innovative production method with higher water productivity that will increase production of rice under the condition of limit of increase in yield per unit.

2. METHODS

Is there such a favorable and innovative rice cultivation method? Yes, the Tropical Perennial Rice (ToPRice) farming systems (SALIBU technology) which is an inovative rice ratooning cultivation originating from West Sumatra, Indonesia allow for harvesting rice grain up to 3.5-4 times annually. It also allows to produce a yield for ratoon crop in the following consecutive generations at the same level as that of main crop while past studies generally concluded that the grain yield of ratoon crop was within the range of 20 to 50% of that of main crop (Krishnamurthy, 1988).In other words, this farming systems bring about the effect as if the acreage increased, by increasing the number of harvest per year while maintaining the yield per unit area of each time.

ToPRice farming 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. Water amount used during puddling and transplanting is huge.

The systems can transform monocarpic annual rice plant into tropical perennial type which produce ratoon grains over generations. They do not force farmers to put additional investment while give them advantage of saving resources such as water, labor and seed. And they reduce the cost and adverse environmental effect of frequent mechanized land preparation and allow effective utilization of residual nutrients.

SALIBU technology was discovered by Mr. Erdiman, a researcher at the local office of the Assessment Institute for Agricultural Technology (BPTP: 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 technology at the test field in 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 climate and is located in the edge of Central Dry Zone (CDZ) in Myanmar. As CDZ is regarded to become vulnerable in water shortage by future climate change, we focused on the potential of high water productivity of rice cultivation under the SALIBU technology and explored the possibility of obtaining more production with less irrigation water.

2.1 Key Technology

The key part of this technology is a series of treatments before and after harvest. The main crop must be harvested at the time of physiological maturity, namely one week before the time of normal harvest, which is a time when the proportion of greenish spikelet in the panicles is about twice that of the normal harvest. Many of the leaves and stems are still half green at this stage. The height of the cutting stems at the harvest is 25-40 cm above ground level and the harvest is best performed manually or using a compact combined harvester.

The soil must be kept in high moisture condition among field capacity and saturation; it is defined as “optimum moisture condition” hereinafter, i.e. fully moist, but at the same time no water appeared on the ground surface, 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 the harvest, the second cutting of the stems should be performed at a height of 3-5 cm above ground level. Mr. Erdiman recommends that the second cutting must be done by mower, preferably a backpacking style machine, rather than manually.Subsequently, shallow irrigation in 1-3 cm depth of floodwater starts from one week after the second cutting.

2.2 Extra Indispensable Technology

Normal irrigation in a depth of 5-10 cm of floodwater starts from two weeks after the second cutting. Within one week of starting the normal irrigation, the following four tasks must be finished:

- Separation and addition: Transplant part of the bunch of culms with roots from rich-tillering hills to poor-tillering hills by leveling the size of the hills, i.e. the number of tillers on each hill.

- Insertion: Push stubble with naked aerial roots, if they are remarkable, into the soil, because the aerial roots will die in due course.
- Weeding: Remove weeds as well as buds emerging from the seeds dropped from the panicle and early heading culms because they should be considered weeds.
- Fertilizing: Apply the second round of fertilizing.

“Separation and addition” constitute treatment equivalent to that of supplemental transplanting to fill up the missing hills after rice planting via traditional farming practices. Leveling the size of the stubble, i.e. the number of tillers, helps prevent missing hills, uneven heading and the 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 regenerating tillers and it is desirable for tillers to be able to regenerate from the node at or closest to ground level, since such tillers can grow their own 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 old stems and roots to absorb moisture and nutrients. Such tillers 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 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 main crop, harvesting will take place at the stage of physiological maturity, one week before the normal harvest. And don't forget to fertilize for the next generation one or two weeks before the harvest.

2.3 Field Trials In DAR

Trials for continuous cultivation over generations via SALIBU technology in fifteen large pots (each 2.4 x 1.8m) have been conducted in the Water Utilization Research Section (WURS) in DAR since July 2016. Following this we constructed 36 split paddy test plots, each of about 32 square meters(3.5m x 9.3m), in WURS in June 2017 to conduct comparative tests for nine combinations by three rice cultivars and by three cultivation-water management methods, with four replications.

Regarding the former trials the rice plants for the main crop using a locally popular rice cultivar “Thee Htat Yin” were sown on 19 July 2016, cultivated through conventional practices and harvested on 11 November 2016. Planting density was 90 hills per pot (20.8 hills/m2); age of seedlings for transplanting was 23 days; water management was continuously flooded; number of samples was 4 hills per pot; 1000 grain weight was converted to a moisture content equivalent to 15% after weighing directly.

Regarding the latter trials started on 24 June 2017 with sowing rice cultivars; namely Shwe Thwe Yin, Thee Htat Yin and Sin Thu Kha, which were transplanted on 14 July 2017 into 36 carefully designed test field plots in the WURS, DAR. Figure 3 shows a plane plan of the water productivity test fields, each of which is equipped with pipeline irrigation systems including tube wells and independent drainage canal systems to ensure separate irrigation and drainage for each plot. The entire band is covered by a water-impermeable plastic sheet, part of which is inserted into the soil for suspending the horizontal percolation of water into the same. A detachable portable digital flow meter is equipped in a rotational way at each discharge port of the pipeline irrigation systems to measure the amount of water irrigated for each plot.

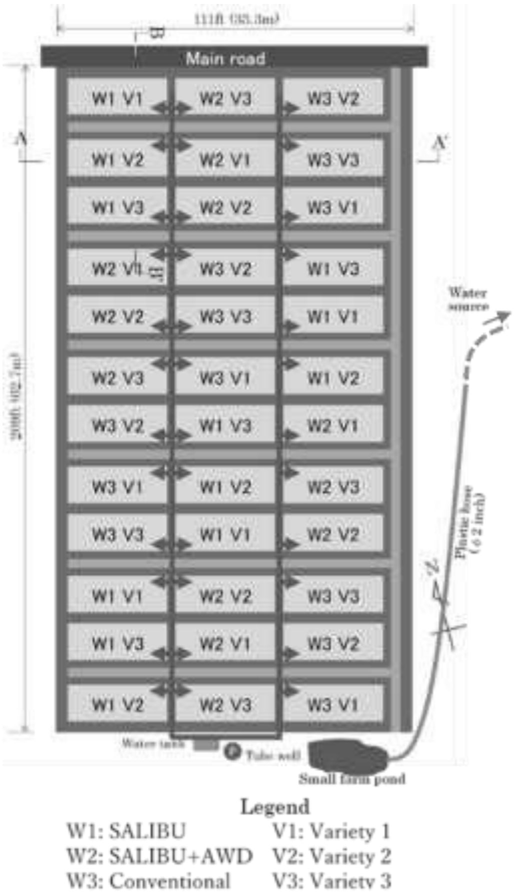

Figure 3. Scheme of test fields

3. RESULTS AND DISCUSSION

3.1 Trials For Continuous Cultivation Over Nine Generations

The 6thgeneration of ratoon crop was harvested on 28 July 2018; demonstrating how a locally popular rice variety cultivated under the technology was harvested seven times in two years under the Myanmar climate. Since this showcases multiple-year-rice cultivation so well, we named the technology “Tropical Perennial Rice (ToPRice) farming systems.” The continuous cultivation test ended with the 8thgeneration of SALIBU ratoon crop harvested on 8 January 2019. Nine harvests have been obtained by continuous 903 days of cultivation from 19 July 2016, showing that cultivation period for each generation is about 100 days.

While main crop recorded a yield per unit area of 5.3 t/ha, that of its subsequent SALIBU ratoon crop from the 1stto 8thgeneration were 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 of each generation while there is a low correlation between plant height and yield (Figure 4).

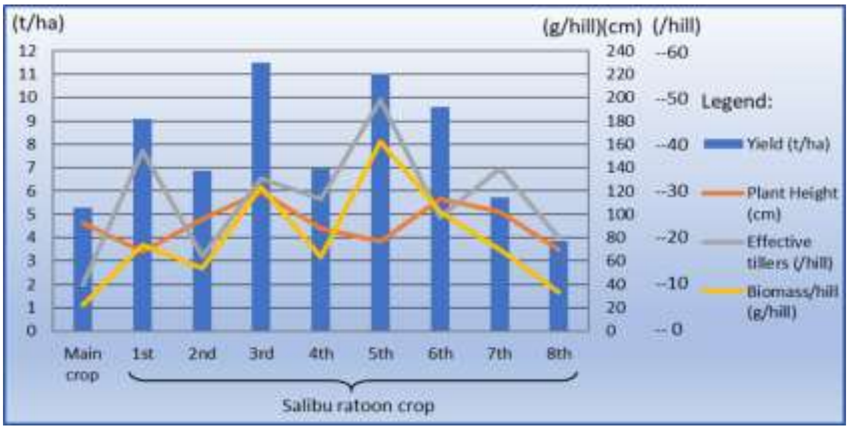

Figure 4. Change of yield and selected yield component data over nine generations

Table 1. Yield component and relevant data over nine generations

Yield (t/h)

Variety regime	Cultivation and water management regime	Generation of rice plant				
		Main crop (Conventional practice)	1st ToPRice ratoon crop	2nd ToPRice ratoon crop	3rd ToPRice ratoon crop	4th ToPRice 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	-	-

3.2 Trials For Comparative Cultivation Test By Varieties/Cultivation Management On Water Productivity

The main crop was harvested in September and October 2017 but Shwe Thwe Yin (V1) was affected by the accidental event whereby its stubble was submerged just after the second cutting of the main crop for 7-10 hours. Given the substantial damage, we decided to remove it and replant it from the main crop again.

Table 2. Yield per unit area

Characteristics	Main crop	Generation of SALIBU ratoon crop							
		1st	2nd	3rd	4th	5th	6th	7th	8th
Plant Height (cm)	92.7	68.2	96	119.9	87.8	76.5	113.3	102.5	70
Panicle Length (cm)	22.95	19.89	25.3	25.23	21.86	19.59	23.76	25.5	17.95
Effective Tiller (/hill)	10	38.6	16	32.6	28.4	49.4	24.33	34.85	20
Spikelet / Panicle	126.94	92.37	92.75	127.2	112.43	117.9	112.74	112.58	68.45
Panicle / hill (/hill)	9.78	36	16	32.6	21	49.2	22.67	17.6	18.71
1000 grain Wt (g)	21.68	18.92	19.9	22.26	19.8	17.87	24.1	22.23	19.62
Fill grain (%)	81.94	60.15	68	64.37	62.22	56.08	74.12	67.04	63.13
Biomass / hill (g/hill)	22.41	73.74	53.88	123.85	63.41	161.91	102.57	69.59	33
HI	0.49	0.51	0.53	0.47	0.46	0.35	0.44	0.4	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

Table 3. Total water use

Total water use (mm)

Variety regime	Cultivation and water management regime	Generation of rice plant: Main crop (Conventional practice)	1st ToPRice ratoon crop	2nd ToPRice ratoon crop	3rd ToPRice ratoon crop	4th ToPRice 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 4. Water productivity

Water productivity (g/l)

Variety regime	Cultivation and water management regime	Generation of rice plant: Main crop (Conventional practice)	1st ToPRice ratoon crop	2nd ToPRice ratoon crop	3rd ToPRice ratoon crop	4th ToPRice 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	-	-

In all tested varieties, ToPRice farming systems with continuous floodwater management (SLB) and the same systems with Alternate Wetting and Drying water management (SLB+AWD) recorded the yield of the first and second generations of ratoon crop respectively (4.59-5.91 and 4.45-6.46 t/ha). These were equivalent or superior to that of the main crop (4.07-5.71 t/ha) preceding the ratoon crops and exceeded the yield recorded by trials using conventional practices (CP) of cultivation; carried out in parallel with the trials of the first and second generations of SLB and SLB+AWD (Table 2).

In terms of water productivity, SLB and SLB+AWD show the same level as conventional in Shwe Thwe Yin(See the red dotted square in Table 4). In Thee Htat Yin and Sin Thu Kha, SLB and SLB+AWD in the 1stgeneration of ToPRice (1.40-1.92) / scored 2.3 to 2.6 times higher water productivity than conventional (0.61-0.73)(See the purple dotted square in Table 4). And the same in the 2ndgeneration of ToPRice (0.84-1.30) / scored 1.5 to 2.8 times more productive than conventional (0.47-0.57)(See the indigo blue dotted square in Table 4).

In addition, cultivation period of eachvariety and each cultivation management is as shown in Table 5.

4. CONCLUSION AND RECOMMENDATIONS

By using a locally popular rice cultivar “Thee Htat Yin” from 1st to 7th generations of ratoon crops were harvested with equivalent or superior to that of the main crop under the climatic conditions around the Central Dry Zone (CDZ) in Myanmar. Tropical Perennial Rice (ToPRice) farming systems (SALIBU technology) developed in West

Sumatra in Indonesia was applied to the continuous cultivation trials over generations.

Table 5. Cultivation period of each case

Variety regime	Cultivation and water management regime	Generation of rice plant		
		Main crop (Conventional practice)	1st ToPRice ratoon crop	2nd ToPRice ratoon crop
V1: Shwe Thwe Yin	SLB SLB+AWD	2017.10~2018.2	2018.2~4	2018.4~7
	Conventional		2018.2~5	2018.6~9
V2: Thee Htat Yin	SLB SLB+AWD	2017.6~10	2017.10~2018.1	2018.1~4
	Conventional		2017.10~2018.2	2018.2~6
V3: Sin Thu Kha	SLB SLB+AWD	2017.6~10	2017.10~2018.1	2018.1~4
	Conventional		2017.10~2018.3	2018.3~7

Comparative trials of water productivity under different cultivation management and cultivars demonstrate that the water productivity of ToPRice farming systems (SALIBU technology) is 2.3-2.6 times higher than that of CP (conventional practices), savings up to 60% of the amount of irrigation water used per unit yield.

It is suggested that converting CP (double cropping) to SALIBU may double the annual yield and income to farmers while reducing total irrigation water consumption by about 20% per land per annum in the CDZ.

Future research themes that should be solved include selecting suitable varieties for this farming technique, elucidating physiological mechanisms capable of obtaining a high yield, the potential of continuous cropping hazards under reduced soil conditions over the year, abnormal damage caused by pest, rat and bird attacks due to differences in growing time from ordinary rice and rejection by conservative rice farmers, who believe crops should be grown from seed remains.

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