

Prospective rice varieties for high yield performance on modified ratoon salibu cultivation

LALU M. ZARWAZI^{1,2}, AHMAD JUNAEDI^{3,*}, DIDY SOPANDIE³, SUGIYANTA³, PURWONO³, JUN-ICHI SAKAGAMI⁴

¹Program of Agronomy and Horticulture, Graduate School, Institut Pertanian Bogor. Jl. Meranti, Kampus IPB Dramaga, Bogor 16680, West Java, Indonesia

²Indonesian Center for Rice Research, Indonesian Agency for Agricultural Research and Development, Ministry of Agriculture. Jl. Raya Patok Besi, Subang 41256, West Java, Indonesia

³Department of Agronomy and Horticulture, Faculty of Agriculture, Institut Pertanian Bogor. Jl. Meranti, Kampus IPB Dramaga, Bogor 16680, West Java, Indonesia. Tel. +62-251-8629354, 8629350, *email: junaediagh@gmail.com

⁴Faculty of Agriculture, Kagoshima University. Kagoshima 890-0065, Japan

Manuscript received: 29 December 2021. Revision accepted: 27 January 2022

Abstract. Zarwazi LM, Junaedi A, Sopandie D, Sugiyanta, Purwono, Sakagami J-I. 2022. Prospective rice varieties for high yield performance on modified ratoon salibu cultivation. *Biodiversitas* 23: 1065-1071. Modified Ratoon Salibu (MRS) differs from ratoon (Conventional Ratoon, CR). This research aims to investigate some rice varieties re-grown as CR and MRS after main crops are harvested. The experiment was conducted at Kuningan Experimental Station of Indonesian Center for Rice Research, using rice varieties as the main plot (Hipa 18, Hipa 19, Inpari 42, Inpari 43, IPB 3S, and Batang Piaman), and ratoon cultivation system as a sub-plot (CR and MRS), evaluated in the first (1) and second (2) generation after the main crop. The result showed that the growth character of MRS on plant height, stem diameter, blade-leaf size, root volume was significantly higher than that of CR. Furthermore, the yield component and yield were also significantly higher in MRS than CR. The CR yielded about 56.9 and 10.8 % of the main crops for R1 and CR2, respectively, whereas MRS yielded 121.0 and 93.8% of the main crops for MRS1 and MRS2, respectively. This finding could be a scientifically proven of local wisdom “Salibu” indigenous knowledge in Tanah Datar District of West Sumatra, Indonesia. Therefore, MRS could be recommended for suitable varieties and environmental conditions as the sustainable farming alternative to increase Cropping Index while still reaching high productivity.

Keywords: Cropping index, productivity, sustainable farming

Abbreviations: CR: Conventional Ratoon; DAH: days after harvest; MRS: Modified Ratoon Salibu

INTRODUCTION

Rice is one of the staple foods for the global population. Therefore, an increase in demand for rice needs to be followed by an increase in production. Strategies to increase national rice production that can be considered include extending planting areas, increasing land productivity, and increasing Cropping Index (CI) (Yuan et al. 2019). In addition, rice ratooning cultivation has become imperative to increase agricultural land productivity and CI (Lin 2019). Ratoon or *singgang* (in Javanese) or *turiang* (in Sundanese) are rice hills that re-grow after harvesting.

The ratoon rice system could increase cropping intensity due to shorter production time, and it only takes 80-90% compared to the first harvest (Yamaoka et al. 2017). The advantages of implementing the system are fast, easy, cheaper, and increased rice productivity per unit area and per unit time (Nakano et al. 2009; Shiraki et al. 2021). However, developing rice ratoon cultivation challenges are limited to suitable cultivars and low or unstable yields. Sinaga et al. (2014) reported that production from ratoon in rice varieties tested had a large variation between 20-50%

of the main crop. These variations could be caused by genetic factors and environmental conditions such as water availability, soil fertility, microclimate, and attacks by pests and diseases (Imanuddin et al. 2018). It shows that the development of superior varieties for ratoon cultivation is needed and is expected to increase national rice production.

The management practices of ratoon cultivation are an important aspect in increasing yields. Cultivating Modified Ratoon Salibu as “Salibu” (MRS) in Tanah Datar District, West Sumatra, Indonesia increased production by increasing CI. MRS is different from Conventional Ratoon (CR). CR is rice grown from part of the crop after harvest, shoots will usually appear on the top node, a steady supply of nutrients from old stems. Meanwhile, in MRS, the straw stump is cut again 7-10 days after harvest (DAH) and new buds can grow as a new tiller. At that time, the land could be irrigated like a transplanting system (Wang et al. 2021). Therefore, the photosynthetic rate of CR was lower than the main crop, which was the main cause of the low yield (Pasaribu et al. 2018). In addition, there are some reports that the yield of ratoon plants is influenced by morphological characters of varieties such as stem diameter (He et al. 2019), blade leaves (Dong et al. 2017), plant

biomass (Jiang et al. 2021), number and length of roots (Chen et al. 2019), panicle length (Faruq et al. 2014) as well as the height of cutting the main plants (Daliri et al. 2009; He et al. 2019). Therefore, the development of management practices in MRS cultivation is required with several approaches such as selecting varieties and methods of cutting the main crop.

Evaluation of varieties that are potential for ratoon cultivation and have higher yields in the MRS system have not been widely carried out. Meanwhile, some information about the system mentioned that rice cultivation with ratoon requires cheap, easy inputs and is profitable. Proper and good management of ratoon cultivation could increase production up to 72-129% higher annual grain yield (Santos et al. 2003; Yuan et al. 2019). Furthermore, cutting the ratoon by 40 cm significantly increased the yield of rice varieties on the main ratoon crop compared to 10 cm (He et al. 2019). Therefore, the results of this evaluation are expected to contribute to the development of MRS cultivation technology.

Research on ratoons in hybrid, inbred, and new types of rice had been published. Several reports mentioned that the productivity of ratoon rice is still low at only 3.84-4.90 t ha⁻¹ in hybrid rice (Chen et al. 2019), 1.5-1.6 t ha⁻¹ in tidal swamp rice (Sinaga et al. 2014; Mareza et al. 2016), and 52% in lowland rice of the main crop productivity (Pasaribu et al. 2018). However, the MRS system developed in the Tanah Datar, West Sumatra, yielded higher than CR. Information about MRS is still limited, mainly related to academic evidence of cultivation techniques and recommended varieties. Farmers in Tanah Datar District, West Sumatra Province, experienced using Batang Piaman local variety for a modified ratoon called the "Salibu" technique. This research would like to investigate how the difference of this MRS compared to CR for several release varieties. This research will give scientific proof on how different MRS compared to CR.

MATERIALS AND METHODS

The research was conducted at the Kuningan Experimental Station of the Indonesian Center for Rice Research (BB Padi) West Java, Indonesia, 6°58'47.8"S 108°27'59.0"E, from October 2018 to August 2019. The study used a split-plot design. The main plot consisted of the following varieties: Hipa 18, Hipa 19, Inpari 42, Inpari 43, IPB 3S, and Batang Piaman. The sub-plot was a ratoon system with two levels: Conventional Ratoon (CR) and Modified Ratoon Salibu (MRS). The treatment combination was repeated in 4 replications. Therefore, there were 48 experimental units or sub-plots. The experimental plot was a plot with a size of 3 m x 5 m. Replications were bordered with a ridge with a width of 50 cm.

Rice was planted with the transplanting system at the age of 25 days after sowing (DAS), using the 2:1 double row system (25-12.5-50 cm) with two seedlings per hill. Fertilization was adjusted to the recommended dose for the Cigugur District, namely 300 kg ha⁻¹ Urea, 100 kg ha⁻¹

SP36, and 100 kg ha⁻¹ KCl. Application time of Urea fertilizer was three times, namely 1/3 as base fertilizer after transplanting, 1/3 when the plant was 14 days after planting (DAP), and when the plant was 28 DAP, and SP36 and KCl fertilizer were given together with Urea in the first application. Following maintenance standards, rice plants were maintained from weeds and diseases (Windarsih and Utami 2017; Estiati 2019). Harvesting was conducted when the grains were physiologically ripe, indicated by the color of the grains turning yellow by 85%.

Rice plants growing from transplanting were called the main crop. In the conventional ratoon system, the straw stem of the main crop was cut as high as 20 cm from the ground and maintained until harvest. While in the modified ratoon salibu system, after the straw was cut at harvest time to a height of 20 cm, it was cut again at 7 DAH with a straw height of about 5 cm from the ground surface using a sickle. The dose of ratoon plant fertilizer was the same as the main crop fertilizer dose, applied at 3, 21, and 42 DAH. Likewise, after harvesting the first generation of conventional ratoon and modified ratoon salibu (CR1 and MRS1), the straw stump of the first-generation plant was cut to be maintained as the second generation (CR2 and MRS2).

The variables observed in the main crop, conventional ratoon 1 and 2, and modified ratoon salibu 1 and 2 were growth variables and yield and yield components. The growth variables observed consisted of plant height, stem diameter, blade-leaf length, and root volume. Yield and yield component variables observed consisted of harvest age, the number of productive tillers, panicle length and the number of grains per panicle, grain weight per hill, percentage of filled grain per hill, the weight of 1000 seeds, and yield of 2.25 m to 3.0 m for projected to ha⁻¹. The data obtained were analyzed for variance with the F test, then with the honest significant difference (HSD) or Tukey test with a level of 5% significance level.

RESULTS AND DISCUSSIONS

Ratoon system response to rice plant growth

The analysis of variance in the first ratoon generation on growth variables showed significant differences in plant height, stem diameter, blade-leaf length, and root volume. The means of plant height in CR1 and CR2 was shorter than that of MRS1 and MRS2 (Figure 1). The stem diameter of CR1 and CR2 decreased by 9.4% from the main crop, whereas MRS1 and MRS2 were 17.1% higher than that of CR1 and CR2 (Figure 2). The blade-leaf length on MRS was higher by 107.9% than the main crop and CR1 and CR2. The blade-leaf length means of CR1 were lower than the main crop. While the blade-leaf length on MRS1 and MRS2 is higher than CR1 and CR2 (Figure 3). Root volume variables in MRS1 and MRS2 increased by 14.1% compared to the main crop. Root volume in CR1 and CR2 decreased by 17.3% compared to the main crop and 27.5% compared to MRS1 and MRS2 (Figure 4). All this information reflects the morphological difference of MRS compared to CR. The plant height, stem diameter,

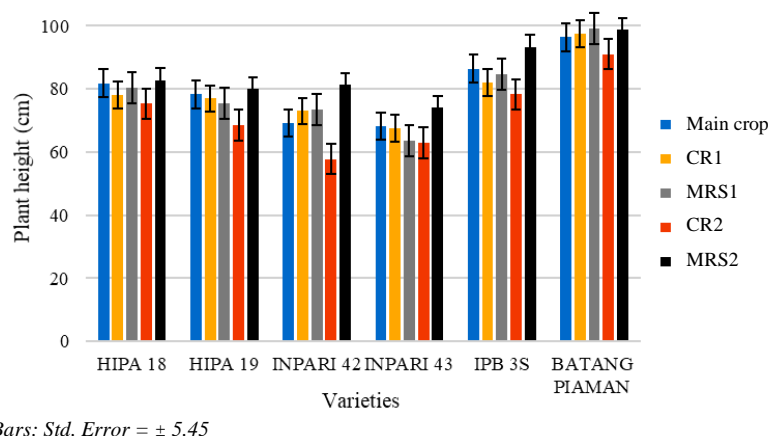
and leaf blade size of MRS performed more likely as the main crop's. This will imply that the growth and development of MRS are better than that of CR and may perform the same as the main crops.

Batang Piaman variety was the tallest variety for the main crop, R, and MRS. The stem diameter of the IPB 3S and Batang Piaman was significantly different from the other varieties (Figure 2). The stem diameter of CR1 and CR2 was lower than MRS1 and MRS2, or the average stem diameter of the main crop. Negalur et al. (2017) mentioned that new types of rice varieties have stems with a larger diameter than other lowland rice. Varieties with larger stem diameters have better ratooning abilities than varieties with smaller stem diameters (Sinaga et al. 2014). The diameter of the stem is one of the determinants of the ratooning ability of the plant. He et al. (2019) reported that the diameter of the rice plant greatly determines the ability to regrow the ratoon. Higher the stem diameter produced higher the weight of the panicle.

Hipa 18 blade-leaf length was significantly different from other varieties except for IPB 3S and Batang Piaman

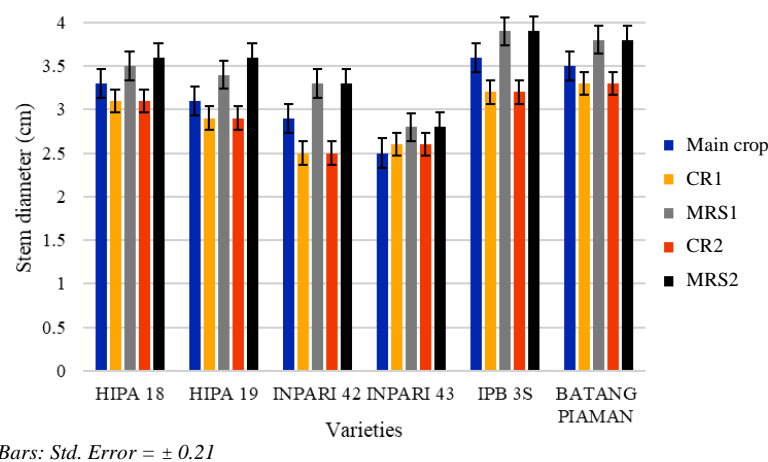
varieties. The significant effect of CR and MRS treatment on the length of the blade-leaf variable can be seen in Figure 3. The figure showed that MRS has a better morphological agronomical growth performance than the CR. It proves that the MRS experienced a better vegetative growth phase. It is in line with Zhang et al. (2017) and Lin (2019) that the growth ability of rice production organs is strongly affected by the environment and cultivation system.

Daliri et al. (2009) and He et al. (2019) stated that when cutting straw stump lower than 10 cm, the ratoon of rice plants will have a longer leaf length, especially blade leaf, compared to cutting above 10 cm. This technique impacts differences in the longer vegetative growth phase before entering the reproductive stage. The average harvesting age of the ratoon in this study (47-65 days after cutting) compared to the MRS (88-115 days after cutting) indicates that the CR growing period of rice crop would reach generative stage faster than that of MRS. This will imply the source capacity that may affect to yield achievement.



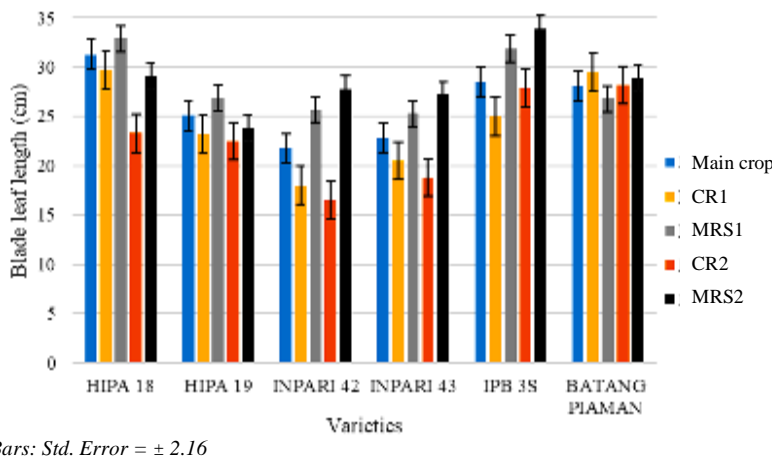
Bars: Std. Error = ± 5.45

Figure 1. Plant height approaching harvest time on the main crop, conventional ratoon (CR1, CR2) and modified ratoon (MRS1, MRS2)



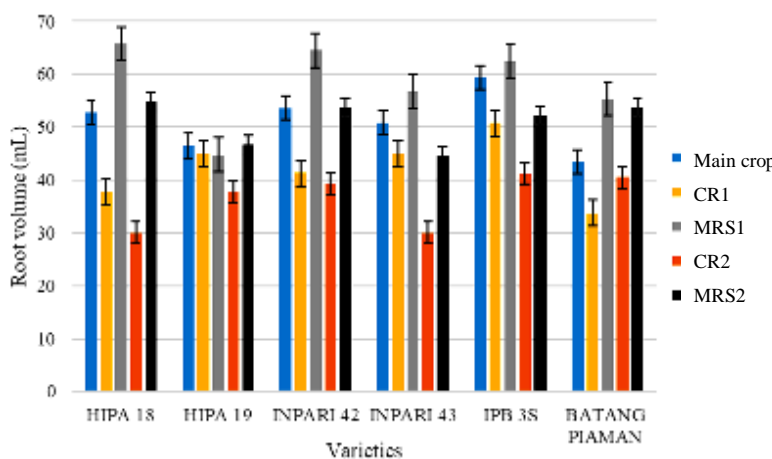
Bars: Std. Error = ± 0.21

Figure 2. Stem diameter of the main crop, conventional ratoon (CR1, CR2) and modified ratoon salibu (MRS1, MRS2)



Bars: Std. Error = ± 2.16

Figure 3. Blade leaf length (cm) on the main crop, conventional ratoon (CR1, CR2) and modified ratoon salibu (MRS1, MRS2)



Bars: Std. Error = ± 4.74

Figure 4. Root volume (ml) on main crop, conventional ratoon (CR1, CR2) and modified ratoon salibu (MRS1, MRS2)

Data in Table 4 and 5 showed this phenomenon that a shorter growing period would have a lower grain index and yield. Dong et al. (2017) stated that the number of leaves to blade leaves increased vegetative growth. CR1 and CR2 of rice plants have blade leaf lengths that are shorter than MRS1 and MRS2. The length of the blade leaf affects the photosynthesis process for the production of plant assimilate. The limited assimilate production because of the low leaf area and blade leaf length in conventional ratoon (CR1, CR2) caused a lower amount of grain produced than the main crop and MRS1 and MRS2 (Table 2 and Table 3). R plants showed harvest time faster than MRS. Jiang et al. (2021) stated that the volume and biomass of plants greatly determine the duration of the vegetative stage of plants, which impacts the ability to produce better than plants that are lower in weight or biomass volume, including root volume. Chen et al. (2019) reported that the development of the number of roots and root length significantly affects the root volume and the length of the reproductive phase of rice plants.

Rice plant response to ratoon system on yield and yield components

The number of productive tillers in R plants decreased by 32.8% to 47.5% of the main crop, while MRS had a higher number of productive tillers than R (26.3-45.2%). Hipa 18 and Inpari 43 varieties tended to have a higher number of productive tillers, followed by Batang Piaman and Inpari 42 varieties compared to others (Table 1). The number of productive tillers will determine the grain's yield, number, and weight. Table 3 regarding grain weight hill^{-1} in CR1 and CR2 showed a decrease in grain weight of 21.7% when the number of productive tillers decreased (Table 1). On the other hand, the number of productive tillers in MRS1 and MRS2 showed higher, on average, than that of CR1 and CR2. The performance of productive tillers in MRS1 and MRS2 showed that cutting the straw stump as high as $\pm 5\text{cm}$ from the ground encouraged the growth of more productive tillers due to pressing. The cutting height of the main plant stems can affect the number of tillers and seed yields (Harrel et al. 2009).

The panicle length of MRS2 was 27.2% higher than that of CR2 (Table 2). It indicates that the ratoon system has decreasing ability to produce panicle length resulting in a decrease in the average number of grains (Table 2). Panicle length is closely related to the amount of grain that can be supported in one panicle. The IPB 3S variety tends to have a higher panicle length than other varieties. Panicle length of ratoon plants affects other yield components (Faruq et al. 2014).

IPB 3S produced the highest weight of grain which was significantly different from all varieties. While in CR2 and MRS2 plants, there was an interaction between varieties and the ratoon system. The ability of the rice ratoon to produce grain is highly dependent on the genotype, cultivation system, and environmental support (Dong et al. 2017).

The main crop's highest grain weight per hill was produced by Inpari 43 variety followed by Batang Piaman,

Hipa 19, Inpari 42, IPB 3S, and Hipa 18 (Table 3), respectively. Inpari 42 variety in the percentage of unfilled grain was significantly different from other varieties (Table 3). Table 3 show that the weight of grain per hill in the CR1 and CR2 was significantly different from the MRS1 and MRS2. Harrell et al. (2009) stated that the genotypes of ratoon rice that can produce a high weight of grain or equivalent to the main crop had a high percentage of grain content, as reflected in each Salibu treatment (MRS1 and MRS2). On the other hand, CR1 and CR2 produced the number of grains per hill lower than the main crop. It also resulted in a lower percentage of filled grain (Table 3), showing that the average empty grain weight was above 50%. These data indicated that the productivity limiting factor in seed filling of ratoon plants was similar to the limiting factor for seed filling in the main crop.

Table 1. Number of productive tillers on the main crop, conventional ratoon (CR1, CR2) and modified ratoon salibu (MRS1, MRS2)

Varieties	Main crop	CR1	MRS1	CR2	MRS2
Hipa 18	23.6	13.3	17.2	10.5	18.8
Hipa 19	16.3	12.7	16.4	11.5	18.3
Inpari 42	18.3	13.1	18.6	10.8	13.5
Inpari 43	23.0	15.8	19.2	10.8	16.5
IPB 3S	16.8	11.4	13.2	9.8	12.3
Batang Piaman	20.7	12.8	16.3	9.0	11.0
Means	19.8	13.3B	16.8A	10.4E	15.1D

Note: On the same column, there was no significant difference based on the HSD test at the level of 5%. Numbers followed by the same letter in the Means row show no significant difference based on the HSD test at the level of 5% among the same generation.

Table 2. Panicle length and number of grain per panicle in the main crop, conventional ratoon (CR1, CR2) and modified ratoon salibu (MRS1, MRS2)

Varieties	Main crop	Panicle length (cm)				Number of grains panicle ⁻¹ (grain)				
		CR1	MRS1	CR2	MRS2	Main crop	CR1	MRS1	CR2	MRS2
Hipa 18	25.3ab	25.4	25.1	18.4	23.4	122.8cd	97.7a	116.8a	95.2	116.9
Hipa 19	23.0b	23.3	22.9	15.9	23.3	131.3c	107.9a	117.3a	87.5	132.3
Inpari 42	24.9ab	22.2	22.7	18.1	24.3	169.8b	85.5b	148.5a	83.9	158.5
Inpari 43	21.8b	21.1	22.3	18.9	23.7	116.3cd	88.9a	109.9a	100.8	127.4
IPB 3S	30.6a	28.8	33.6	17.1	25.8	211.4a	135.9b	192.2a	116.8	188.9
Batang Piaman	23.6b	23.5	24.2	17.9	25.1	94.5d	95.5a	113.3a	89.9	109.9
Means	24.8	24.0	25.1	17.7B	24.3A	141.0	101.9E	133.0D	95.6G	138.9F

Note: On the same column, there was no significant difference based on the HSD test at the level of 5%. Numbers followed by the same letter in the Means row show no significant difference based on the HSD test at the level of 5% among the same generation.

Table 3. Grain weight per hill and percentage of filled grain per hill of the main crop, conventional ratoon (CR1, CR2) and modified ratoon salibu (MRS1, MRS2)

Varieties	Main crop	Grain Weight Hill ⁻¹ (g)				Percentage of Grain Filled Hill ⁻¹ (%)				
		CR1	MRS1	CR2	MRS2	Main crop	CR1	MRS1	CR2	MRS2
Hipa 18	46.1	38.2	51.2	46.2	56.2	62.1b	43.6	47.2	39.4	45.7
Hipa 19	49.9	39.6	50.7	42.9	52.9	61.3b	39.6	48.7	37.6	52.3
Inpari 42	48.3	38.3	54.5	45.5	49.9	76.8a	47.5	74.0	43.3	70.8
Inpari 43	51.7	40.1	50.2	47.8	51.4	61.6b	48.6	54.8	38.8	59.0
IPB 3S	48.2	42.6	53.9	48.3	52.8	63.8b	43.0	65.6	35.3	66.5
Batang Piaman	51.0	43.5	71.4	47.4	56.1	56.9b	47.5	53.0	37.1	56.3
Average	49.2	40.4B	55.3A	46.4D	53.2C	63.75	44.9F	57.2E	34.5H	58.4G

Note: On the same column, there was no significant difference based on the HSD test at the level of 5%. Numbers followed by the same letter in the Means row show no significant difference based on the HSD test at the level of 5% among the same generation

The weight of 1000 grains of the IPB 3S variety was significantly different from other varieties (Table 4). CR2 and MRS2 were significantly different in this variable. This difference indicated that each variety had a different ability to collect assimilate. The ability of plants to produce grain and overall production could be determined by genetic and environmental traits, such as water availability, soil fertility, sunlight, temperature, and the state of plant pests and diseases (Sinaga et al. 2014; Imanuddin et al. 2018). Application of MRS after main crops would be suitable for recommended certain rice varieties in the suitable climate for optimum rice growing (temperature, sunshine, and moisture). Although we planted rice in the tropical area in this experiment, that's no weather limitation for rice growing. Water supply is also available by irrigated facilities to not depend on natural precipitation. Pest and disease may be the factor that needs to anticipate. We considered recommending MRS in a large enough area to prevent yield loss by bird attack and endemic pest and disease.

The average grain yield of each variety of the main crop was 6.5 tons⁻¹. IPB 3S varieties and Inpari 42 produced the highest production. The yield increase in the Salibu system was around 84.7-164.4% than the main crop. On the other hand, CR1 and CR2 increased their results from 4.7-79.7%. The difference in yield increase between R and MRS proved that MRS could increase the production and yield of ratoon, which has never been reported better than the main crop. Yamaoka et al. 2017 stated that Salibu could give the same or higher yield than R plants and even higher than the main crop production.

The MRS in the first and second generations showed a significantly better plant height growth, blade-leaf size, and

root volume than the ratoon system. The MRS, both in the first and second generations, also showed better yield components than the ratoon system in panicle number, panicle length and the number of grain⁻¹, grain weight, and percentage of grain content in hill⁻¹, as well as the weight of 1000 seeds in the second generation. The average grain yield of varieties was 3.7 tons ha⁻¹ and 0.7 tons ha⁻¹ for CR1 and CR2, respectively, equivalent to 56.9% and 10.8% of the main crop yield. Whereas the yield of MRS1 and MRS2 were 7.9 tons ha⁻¹ and 6.1 tons ha⁻¹, respectively, equivalent to 121.0% and 93.8% of the yield of the main plant. All varieties tested showed MRS yield was equal to or better than the main plant in the first generation. In the second generation, the Batang Piaman and Inpari 43 varieties produced the same or higher MRS production than the main crop, while the Hipa 18, Hipa 19, Inpari 42, and IPB 3S varieties had productivity ranging from 84.7-92.2% of the main crop. This finding could be a scientifically proven of local wisdom "Salibu" indigenous knowledge of the farmers in Tanah Datar District of West Sumatra. According to this research, Batang Piaman and Inpari 43 are superior to reach high yield in 1st and 2nd generation of MRS while Hipa 18, Hipa 19, Inpari 42, and IPB 3S showed high yield in 1st generation and quite lower for 2nd generation compared to its main crop. High yield of MRS relates with superior characters on plant growth (plant height, stem diameter, leaf area, root growth), and superior yield component (productive tiller number, grain number per panicle, filled grain percentage, and grain index). All varieties tested in this experiment are lowland rice types. This MRS may apply for irrigated lowland or paddy fields that have no limitation of water supply.

Table 4. Weight of 1000 grains (g) of the main crop, conventional ratoon (CR1, CR2) and modified ratoon salibu (MRS1, MRS2)

Varieties	Main crop	CR1	MRS1	CR2	MRS2
Hipa 18	25.4c	23.8	23.6	23.1 a	22.8 a
Hipa 19	22.7d	20.7	20.6	22.2 a	21.7 a
Inpari 42	24.7c	22.1	22.1	22.5 a	22.9 a
Inpari 43	23.2d	20.3	21.1	20.9 b	22.2 a
IPB 3S	30.3a	26.2	27.1	22.5 b	27.5 a
Batang Piaman	29.2b	26.3	26.4	26.9 b	28.4 a
Average	25.9	23.2	23.7	23.0B	24.3A

Note: On the same column, there was no significant difference based on the HSD test at the level of 5%. Numbers followed by the same letter in the Means row show no significant difference based on the HSD test at the level of 5% among the same generation

Table 5. The yield of dry milled grain (t ha⁻¹) of the main crop, conventional ratoon (CR1, CR2) and modified ratoon salibu (MRS1, MRS2)

Varieties	Result of dry milled grain (t ha ⁻¹)				
	Main crop	CR1	MRS1	CR2	MRS2
Hipa 18	6.4ab (100)	3.2 (50.0)	6.4 (100.0)	0.3 (4.7)	5.9 (92.2)
Hipa 19	5.9b (100)	3.3 (58.9)	6.9 (116.9)	0.4 (6.8)	5.0 (84.7)
Inpari 42	6.9a (100)	2.9 (42.0)	7.5 (108.7)	0.5 (7.2)	5.2 (88.1)
Inpari 43	6.8ab (100)	3.7 (54.4)	8.4 (123.5)	0.8 (11.8)	6.9 (101.5)
IPB 3S	6.9a (100)	4.2 (60.9)	8.4 (121.7)	0.9 (13.0)	6.0 (86.9)
Batang Piaman	5.9b (100)	4.7 (79.7)	9.7 (164.4)	1.5 (25.4)	7.7 (130.5)
Average	6.5 (100)	3.7B (56.9)	7.9A (121.0)	0.7 (10.8)	6.1 (93.8)

Note: On the same column, there was no significant difference based on the HSD test at the level of 5%. Numbers followed by the same letter in the Means row show no significant difference based on the HSD test at the level of 5% among the same generation

In conclusion, the cultivation of MRS for the appropriate varieties can be applied to the appropriate growing environment. The maintenance of the MRS plant needs attention to meet the needs of nutrients, water, and control of plant-disturbing organisms. MRS could be recommended for suitable varieties and environmental conditions as the sustainable farming alternative to increase CI while still reaching high productivity. The MRS cultivation technique would be recommended to the farmers with no obstacles in water supply and loss potential by pest and disease during ratooning period. The prospective of MRS could be more investigated to see the benefit of elite rice varieties, including hybrid rice. MRS could be more explored to see the benefit of speed reduction, labor reduction and efficiency as well as growing period efficiency, and soil tillage cost efficiency.

ACKNOWLEDGEMENTS

We would like to thank you for the research and publication support to the Indonesian Agency for Agricultural Research and Development (IAARD), Ministry of Agriculture, Republic of Indonesia. The author thanks IAARD for the education finance support for the first author.

REFERENCES

- Chen Q, He A, Wang W, Peng S, Huang J, Cui K, Nie L. 2019. Comparisons of regeneration rate and yields performance between inbred and hybrid rice cultivars in a direct seeding rice-ratoon rice system in Central China. *J Field Crops Res* 223: 164-170. DOI: 10.1016/j.fcr.2018.04.010.
- Daliri MS, Eftekhari A, Mobbasser HARI, Tari DB, Polkahor H. 2009. Effect of cutting time and cutting height on yield and yield components of ratoon rice (Tarom Langrodi Variety). *Asian J Plant Sci* 8: 89-91. DOI: 10.3923/ajps.2009.89.91.
- Dong H, Chen Q, Wang W, Peng S, Huang J, Cui K, Nie L. 2017. The growth and yield of a wet-seeded rice-ratoon rice system in Central China. *J Field Crops Res* 208: 55-59. DOI: 10.1016/j.fcr.2017.04.003.
- Estiati A. 2019. Rice momilactones, potential allelochemical for weeds suppression. *Asian J Agric* 3: 6-15. DOI: 10.13057/asianjagric/g030102.
- Faruq G, Taha RM, Prodhon ZH. 2014. Rice ratoon crop: A sustainable rice production system for tropical hill agriculture. *J Sustain* (6): 5785-5800. DOI: 10.3390/su6095785.
- Harrell DL, Bond JA, Blanche S. 2009. Evaluation of main-crop stubble height on ratoon rice growth and development. *J Field Crops Res* 114: 396-403. DOI: 10.1016/j.fcr.2009.09.011.
- He A, Wanga W, Jianga G, Suna H, Jianga M, Mana J, Cuia K, Huang J, Penga S, Nie L. 2019. Source-sink regulation and its effects on the regeneration ability of ratoon rice. *J Field Crops Res* 236: 155-164. DOI: 10.1016/j.fcr.2019.04.001.
- Imanuddin MS, Bakri, Jelita R. 2018. Ratoon systems in tidal lowland: Study of groundwater dynamics and the change of nutrient status on rice growth. *J Soil Sci Agroclim* 15 (2): 93-103. DOI: 10.15608/stjssa.v15i2.18928.
- Jiang P, Xu F, Zhang L, Liu M, Xiong H, Guo X, Zhu Y, Zhou X. 2021. Impact of tillage and crop establishment methods on rice yields in a rice-ratoon rice cropping system in Southwest China. *Sci Rep* 11: 18421. DOI: 10.1038/s41598-021-98057-x.
- Lin WX. 2019. Developmental status and problems of rice rationing. *J Integr Agric* 18 (1): 246-247. DOI: 10.1016/S2095-3119(19)62568-2.
- Mareza E, Djafar ZR, Suwignyo RA, Wijaya A. 2016. Rice ratoon yield response to main crops cutting height in tidal swamp using direct seeding system. *J Agrivita* 38 (2): 126-132. DOI: 10.17503/agrivita.v38i2.502.
- Nakano H, Hattori I, Sato K, Morita S. 2009. Effects of double harvesting on estimated total digestible nutrient yield of forage rice. *J Field Crops Res* 114: 386-395. DOI: 10.1016/j.fcr.2009.09.008.
- Negalur RB, Yadahalli GS, Chittapur BM, Guruprasad GS, Narappa G. 2017. Ratoon rice: A climate and resource smart technology. *Intl J Curr Microbiol Appl Sci* 6 (5): 1638-1653. DOI: 10.20546/ijcmas.2017.605.179.
- Pasaribu PO, Tiadiati, Anas I. 2018. Rice ratooning using the salibu system and the system of rice intensification method influenced by physiological trait. *Pertanika J Trop Agric Sci* (41) 2: 637-654.
- Santos AB, Fageria NK, Prabhu AS. 2003. Rice ratooning management practices for higher yields. *Commun Soil Sci Plant Anal* 34: 881-918. DOI: 10.1081/CSS-120018981.
- Shiraki S, Cho TM, Matsuno Y, Shinogi Y. 2021. Evapotranspiration and crop coefficient of ratoon rice crop determined by water depth observation and bayesian inference. *J Agron* (11): 1573. DOI: 10.3390/agronomy11081573.
- Sinaga PH, Trikoesoemaningtyas, Sopandie D, Aswidinnoor H. 2014. Screening of rice genotypes and evaluation of their ratooning ability in tidal swamp area. *Asian J Agric Res* 8 (5): 218-233. DOI: 10.3923/ajar.2014.218.233.
- Wang YC, Li XF, Lee T, Peng SB, Dou FG. 2021. Effects of nitrogen management on the ratoon crop yield and head rice yield in South USA. *J Integr Agric* 20 (6): 1457-1464. DOI: 10.1016/S2095-3119(20)63452-9.
- Windarsih G, Utami DW. 2017. Evaluation of neck blast resistance and agronomical performances on double haploid rice population in greenhouse and endemic field. *Nusantara Biosci* 9: 371-377. DOI: 10.13057/nusbiosci/n090406.
- Yamaoka Y, Mar Htay K, Erdiman, Fitri R. 2017. Increasing water productivity through applying tropical perennial rice cropping system (*salibu* technology) in CdZ, Myanmar. 23rd International Congress on Irrigation and Drainage. Mexico, 8-14 October 2017.
- Yuan S, Kenneth G. Cassman, Huang J, Peng S, Grassini P. 2019. Can ratoon cropping improve resource use efficiencies and profitability of rice in central China? *J Field Crops Res* 234: 66-72. DOI: 10.1016/j.fcr.2019.02.004.
- Zhang S, Hub J, Yang C, Liu H, Yang F, Zhou J, Ben K. Samson, Boulaphanhf C, Huang L, Huang G, Zhang J, Huang W, Tao D, Harnpichitvitaya D, Wade LJ, Hu F. 2017. Genotype by environment interactions for grain yield of perennial rice derivatives (*Oryza sativa* L./*Oryza longistaminata*) in Southern China and Laos. *J Field Crops Res* 207: 62-70. DOI: 10.1016/j.fcr.2017.03.007.