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ORIGINAL RESEARCH PAPER in PLANT STRUCTURE

Agronomic Character of Ratoon Rice: Stem Cutting Sizes and Seprint Liquid Organic Fertilizer

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Abstract
This study aimed to identify the optimum rice stem cutting size combined with the application of Seprint liquid organic fertilizer (SLOF) to promote the growth and yield of ratoon rice. This research was conducted in a greenhouse at the Faculty of Agriculture, University of Muhammadiyah Sumatera Utara, North Sumatra Province, Indonesia, from January to August 2018. The experiment was set up as a completely randomized design factorial with four replications. The first factor consisted of the cutting sizes of the rice stem (R1 = 5 cm, R2 = 10 cm, and R3 = 15 cm) and the second factor involved the SLOF dosage (S1 = 5 mL L^{-1}, S2 = 10 mL L^{-1}, and S3 = 15 mL L^{-1}). The parameters were analyzed using analysis of variance (ANOVA), and the means were determined by Duncan's multiple range test (DMRT). The results showed that the R2 treatment significantly increased the ratoon rice height at 10 to 30 days after cutting (DAC), the number of tillers at 40 to 60 DAC, the number of productive tillers, and the yield per hectare. The S2 and S3 applications at significantly increased the yield per hill and ratoon rice height at 20 DAC. The R2S1 and R2S2 combination treatments significantly increased the number of filled grains per panicle and the ratoon rice height at 10 DAC. Cutting the stems at 10 cm combined with various dosages of SLOF resulted in greater growth and yield of ratoon rice for achieving an adequate food supply.

Keywords
dosage; growth; yield; crop model; optimization technique; ratoon technology

1. Introduction

Food is a basic human need, and adequate, nutritious, and safe food can lead to high-quality human resources. Grain (rice) is a major source of energy. According to United States Department of Agriculture (USDA) data, countries with the highest level of rice consumption worldwide from 2015 to 2019 are located in Asia, specifically in China (29.66%), India (20.39%), Indonesia (7.88%), Bangladesh (7.32%), and Vietnam (4.54%) (Ministry of Agriculture of the Republic of Indonesia, 2019). In Indonesia, rice is the main food requirement for more than 90% of the population. The consumption of rice per capita has decreased, from 107.71 kg capita^{-1} year^{-1} in 2002 to 96.33 kg capita^{-1} year^{-1} in 2018 (Ministry of Agriculture of the Republic of Indonesia, 2019). However, domestic rice yield continues to increase, although it is trending toward a slower growth rate. Indonesia's population growth increased linearly from 2005 to 2015 (226.71 to 258.16 million), and the projected population until 2035 is estimated to be up to 305.65 million (Statistics Indonesia, 2019). The total domestic consumption of Indonesian rice continues to increase, even though the per capita consumption shows a decrease.

The increased domestic consumption of rice in Indonesia must be followed by a program to increase rice yield via intensification. One of the intensification programs that can be followed is system cultivation of ratoon rice. Mengel and Wilson (1981) stated that ratoon is a technique of harvesting production from tillers from the main plant stumps to increase grain yield without increasing land area. The ratoon technique has been used to shorten the age of the rice harvest. The maturing of hybrid rice varieties is required at 105–124 days after scattering or approximately 4 months (Indonesian Center for Rice Research, 2019). Therefore, in a year, there can only be two lots of rice planting until harvesting. The ratoon system can produce three to four lots of rice harvesting. The advantages of the ratoon system are the higher efficiency of resource use per unit area of land and unit per timing (Santos et al., 2003), reduction in land preparation, cost savings on planting seeds (Zandstra & Samson, 1979), and time saving of planting because of decreased growth time (Haque & Coffman, 1980). In addition, ratoon rice is preferred by farmers because of its high quality, including cooking and flavor, short growth period, reduced water and fertilizer costs, and decreased pest control (Yazdpour et al., 2012). Alizadeh and Habibi (2016) reported that the grain thickness and amylose content of ratoon rice were higher, ranging from 1.18% to 2.25% and 2.28% to 7.69%, respectively, compared to the main crop.

System cultivation of ratoon rice has been reported. Pratama et al. (2018) stated that the time of cutting the remaining stumps on day 10 of the rice harvest was significant for obtaining the largest root diameter of 0.89 mm with a stump cutting height of 4 cm above the soil surface and could increase grain productivity by 3.39 to 3.54 tons ha^{-1}. Nuzul et al. (2018) stated that the highest yield components (e.g., the number and length of panicles, harvest age, grain number per panicle, filled grain, 1,000-grains weight, total dry weight, and harvest index), and rice yield (grain per hectare) were achieved in the cutting at harvest of a height 3 cm above the soil surface with a grain yield of 3.54 tons ha^{-1}. Susilawati et al. (2012) stated that the cutting height of ratoon rice was related to the internode of the plant, and the nodes contained lateral shoots that produced ratoon shoots. Jichao and Xiaohui (1996) showed that the number of growing shoots was determined by the cutting height stems of the main plant; however, the condition was strongly influenced by residual assimilates as reserves in the stems that could be utilized for ratoon growth, and the vigor rate of the ratoon. The stem cutting height of the main plant can also affect the number of tillers and seed yield (Harrell et al., 2009) and trigger dormant shoot growth (Mahadevappa & Yogeesha, 1988).

However, in these studies, the rice cultivation system was not separated from fertilizer use to achieve the optimal yield. Islam et al. (2008) reported that fertilizer application of $N = 130$ kg ha^{-1}, $P_2O_5 = 75$ kg ha^{-1}, $K_2O = 80$ kg ha^{-1}, $S = 13$ kg ha^{-1}, and $Zn = 4$ kg ha^{-1} significantly increased the yield of Boro rice ratoon by 1.42 tons ha^{-1}. The high price of fertilizer with limited availability has resulted in the use of liquid organic fertilizer as an alternative to increase the availability and efficiency of irrigation rice nutrient uptake. The effect of liquid organic fertilizer on the growth and yield of irrigated rice has been widely reported (Ginting, 2019; Mahmoodi et al., 2020; Niis & Nik, 2017; Oh & Kim, 2013; Solihin et al., 2019); however, studies regarding the use of liquid organic fertilizer on the growth and yield of ratoon rice are limited. Thus, a special assessment of the influence of specific liquid organic fertilizers is required to increase the growth and yield of ratoon rice. The present study aimed to identify the optimum size of the rice stem cutting (ratoon) combined with the application of Seprint liquid organic fertilizer to promote growth and yield of ratoon in rice variety Inpari 30.

2. Material and Methods

2.1. Experiment I (Preliminary Research Stage)

The main plant included in the present study was the lowland rice variety Inpari 30. This variety was used because it has an average yield of up to 7.2 tons ha^{-1} (Indonesian Agency for Agricultural Research and Development, 2020), which is higher than that of the Ciherang, Situ Bagendit, and Pepe varieties (Pramono et al., 2011). In addition, the taste of this rice variety is preferred by farmers in the Cicantayan subdistrict compared to the Inpari 22, Inpari 24, and Inpari 25 varieties (Putra & Haryati, 2018) from the Assessment Institute for Agricultural Technology Pasar Miring, Pagar Merbau subdistrict, Deli Serdang District, North Sumatra Province, Indonesia. The main plant was placed in a 20-L water bucket with an upper diameter of 31 cm, a lower diameter of 22 cm, and a height of 31 cm (Figure 1A). This experiment was conducted in a greenhouse at the Faculty of Agriculture, University of Muhammadiyah Sumatera Utara, Indonesia, from January to August 2018. The bucket was filled with soil up to 5 cm from the surface. Two lowland rice seedlings were planted in the bucket and inundated with water until the vegetative phase of the main plant. The water in the bucket was then decreased to the bearing capacity for harvesting. The main plant was harvested 115 days after planting, followed by cutting the rice stem (Experiment II).

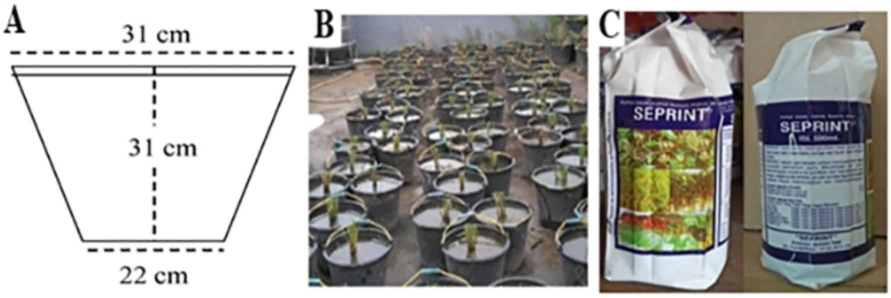

Figure 1 Size of the bucket (**A**), design of the second experiment (**B**), and Seprint liquid organic fertilizer by Bunga Tani (**C**).

2.2. Experiment II (Main Research Stage)

After the main rice was harvested, it was cut from the rice stem base, as shown in Figure 1B. Seprint liquid organic fertilizer (SLOF) was applied 1 week after cutting the rice stems by dissolving in 1 L of water and pouring onto the soil surface. The nutrient content of SLOF was 11% N, 2% K_2O, 0.17% P_2O_5, 0.49% Bioret, 8.98% boron (B), 5.35% cobalt (Co), 5.83% manganese (Mn), <0.01 ppm molybdenum (Mo), 18.16 ppm zinc (Zn), and 9.94 copper (Cu) (Figure 1C) (source: Bunga Tani). The bucket was inundated when cutting the rice stems until the end of the vegetative phase, and then the water was decreased to harvest the ratoon rice.

2.3. Research Design and Data Analysis

The present study was performed in a completely randomized design factorial with four replications. The first factor consisted of the cutting sizes of the rice stem (R1 = 5 cm, R2 = 10 cm, and R3 = 15 cm), and the second factor involved the SLOF dosage (S1 = 5 mL L^{-1}, S2 = 10 mL L^{-1}, and S3 = 15 mL L^{-1}). The distance between the treatments was 50 × 50 cm. The parameters measured included the height and growth rate of the ratoon rice; the number of tillers at 10 to 60 days after cutting (DAC); the yield component of ratoon rice including the number of productive tillers, number of grains per panicle, number of filled grains per panicle, number of empty grains per panicle, 1,000-grains weight, yield per hill, and yield per hectare. The agronomic traits of ratoon rice are transformed in the form of natural logarithms (ln) due to the different units and then analyzed with the Pearson correlation. The calculation of the growth rate and yield per hectare of the ratoon rice can be seen in Equation (1) and Equation (2):

$$\textit{Growth rate}\ (\text{cm day}^{-1}) = \frac{\textit{Average height of ratoon rice}}{\textit{Days of cutting}} \quad (1)$$

$$\textit{Yield}\ (\text{ha}^{-1}) = \textit{NP} \times \textit{NPT} \times \textit{NFGP} \times 1{,}000\ \text{GW} \quad (2)$$

Notes:

- *NP* – number population per hectare $= \frac{\textit{Land area}\ (\text{ha}^{-1})}{\textit{Plant spacing}} = \frac{10{,}000\ \text{m}^2}{0.5\ \text{m} \times 0.5\ \text{m}} = 40{,}000$ populations;
- *NPT* – number of productive tillers;
- *NFGP* – number of filled grains per penicle;
- 1,000 GW – 1,000-grains weight (g).

The parameters were analyzed using ANOVA, and the mean was determined by DMRT at 5% significance, and correlation analysis for agronomic traits of ratoon rice using IBM SPSS statistics v.20 software.

3. Results

3.1. Height and Growth Rate of Ratoon Rice

Based on the ANOVA results, the cutting of the stems significantly increased the height of the ratoon rice at 10 to 30 DAC. In contrast, no significant increase was found at 40 and 60 DAC. SLOF application significantly increased the height of the ratoon rice at 20 DAC. In contrast, no significant increase was found at 10, 30, 40, and 60 DAC. The interaction of the cutting of the rice stems with SLOF application significantly increased the height of the ratoon rice at 10 DAC. However, no significant increase was found at 20 to 60 DAC (Table 1). The R2 treatment had the highest ratoon rice height at 10 to 60 DAC compared to the other cutting sizes, with significant increases from 10 to 30 DAC. The S3 application had the highest ratoon rice height at 10 to 40 DAC compared to the other doses, although it was significantly increased only at 20 DAC. The highest ratoon rice height was found in the S2 application at 60 DAC. The R2S2 and R2S3 combination treatments significantly increased the ratoon rice height to 27.98 cm and 25.55 cm, respectively, at 10 DAC. The highest ratoon rice heights were found in the R2S3 treatment at 20 to 60 DAC.

3.2. Number of Tillers of Ratoon Rice

Based on the ANOVA results, the cutting of the rice stems significantly increased the number of tillers of ratoon rice at 40 and 60 DAC. In contrast, no significant increase was found at 10 to 30 DAC. The SLOF application and interaction with stem cutting did not significantly increase the number of tillers of ratoon rice (Table 2). The average number of tillers of lowland rice before becoming a ratoon ranged from 9.25 to 11.75 tillers. The R2 treatment had the highest number of tillers of ratoon rice at 10 to 60 DAC compared to the other cutting sizes, with significant increases at 40 to 60 DAC. The S2 application had the highest number of tillers of ratoon rice (25.33 tillers) at 60 DAC compared to the other doses. The R2S3 combination treatment had the highest number of tillers of ratoon rice at 36.25 tillers at 60 DAC compared to the other combinations.

3.3. Yield Component of Ratoon Rice

Based on the ANOVA results, the cutting of the rice stems significantly affected the number of productive tillers. In contrast, the SLOF dosages and interactions with stem cuttings did not significantly increase the number of productive tillers of ratoon rice (Figure 2–Figure 4). The R2 treatment had the highest number of productive tillers (24.92 tillers) compared to the other rice stem cuttings.

Based on the ANOVA results, the cutting of the rice stems and SLOF dosages did not significantly affect the number of filled grains per panicle. In contrast, their interactions significantly increased the number of filled grains per panicle of ratoon

Table 1 Effect of rice stem cutting and Seprint liquid organic fertilizer (SLOF) dosages on the ratoon rice height from 10 to 60 days after cutting (DAC).

Treatment	Ratoon rice height (cm)			Average	Growth rate (cm day^{-1})
	S1	S2	S3		
	10 days after cutting				
R1	9.46 d–h	7.05 h	10.33 c–h	8.95 b	0.89
R2	7.45 gh	27.98 a	25.55 a	20.33 a	2.03
R3	13.13 b–h	8.90 fgh	9.45 e–h	10.49 b	1.05
Average	10.01 ns	14.64 ns	15.11 ns		
	20 days after cutting				
R1	15.53 ns	17.35 ns	22.93 ns	18.60 b	0.93
R2	15.25 ns	42.35ns	48.80 ns	35.47 a	1.77
R3	27.90 ns	12.73 ns	35.40 ns	25.34 ab	1.27
Average	19.56 b	24.14 ab	35.71 a		
	30 days after cutting				
R1	31.28 ns	39.95 ns	36.88 ns	36.04 b	1.20
R2	39.70 ns	58.33 ns	63.63 ns	53.89 a	1.80
R3	46.40 ns	38.13 ns	49.93 ns	44.82 ab	1.49
Average	39.13 ns	45.47 ns	50.15 ns		
	40 days after cutting				
R1	46.90 ns	52.98 ns	50.73 ns	50.20 ns	1.26
R2	61.90 ns	63.93 ns	75.23 ns	67.02 ns	1.68
R3	60.70 ns	54.28 ns	55.83 ns	56.94 ns	1.42
Average	56.50 ns	57.06 ns	60.60 ns		
	60 days after cutting				
R1	59.20 ns	65.80 ns	58.18 ns	61.06 ns	1.02
R2	67.50 ns	70.38 ns	77.53 ns	71.80 ns	1.20
R3	67.93 ns	66.28 ns	64.63 ns	66.28 ns	1.10
Average	64.88 ns	67.49 ns	66.78 ns		

Note: Data followed by different letters in the same column and row are significantly different according to the DMRT at 5% significance. Size cutting of rice stems (R1 = 5 cm, R2 = 10 cm, and R3 = 15 cm). SLOF dosages (S1 = 5 mL L^{-1}, S2 = 10 mL L^{-1}, and S3 = 15 mL L^{-1}). ns = not significant.

rice (Figure 2–Figure 4). The R2S1 combination treatment significantly increased the highest number of filled grains per panicle to 114.30 grains compared to the other combinations. The R2 treatment had the highest number of filled grains per panicle (97.58 grains) compared to the other cutting sizes. The S2 application had the highest number of filled grains per panicle (91.53 grains) compared to the other doses.

Based on the ANOVA results, the SLOF dosages significantly increased the yield per hill of ratoon rice. In contrast, the cutting of the rice stems and their interactions did not significantly increase the yield per hill of ratoon rice (Figure 2–Figure 4). The S2 application significantly had the highest yield per hill of ratoon rice of 54.32 g compared to the other doses. The R2 treatment had the highest yield per hill of ratoon rice of 46.56 g compared to the other cutting sizes. The R2S2 combination treatment had the highest yield per hill of ratoon rice of 60.63 g compared to the other combinations.

Based on the ANOVA results, the cutting of rice stems significantly increased the yield per hectare of ratoon rice. In contrast, the SLOF dosages and their interactions did not significantly increase the yield per hectare of ratoon rice (Figure 5). The R2 treatment had the highest yield per hectare of ratoon rice of 3.58 tons ha^{-1} compared to the other cutting sizes. The S2 application had the highest yield per hectare of ratoon rice of 3.12 tons ha^{-1} compared to the other dosages, whereas the R2S3 combination treatment had the highest yield per hectare of ratoon rice of 3.88 tons ha^{-1} compared to the other combinations.

Table 2 Number of tillers of ratoon rice after cutting the stems and Seprint liquid organic fertilizer (SLOF) dosages from 10 to 60 days after cutting (DAC).

Treatment	Number of tillers of ratoon rice			Average
	S1	S2	S3	
	10 days after cutting			
R1	6.75 ns	2.00 ns	3.75 ns	4.17 ns
R2	7.00 ns	7.00 ns	6.00 ns	6.67 ns
R3	8.00 ns	5.00 ns	4.50 ns	5.83 ns
Average	7.25 ns	4.67 ns	4.75 ns	
	20 days after cutting			
R1	8.75 ns	4.25 ns	5.00 ns	6.00 ns
R2	8.25 ns	14.50 ns	15.25 ns	12.67 ns
R3	15.00 ns	9.00 ns	8.75 ns	10.92 ns
Average	10.67 ns	9.25 ns	9.67 ns	
	30 days after cutting			
R1	9.00 ns	7.25 ns	8.00 ns	8.08 ns
R2	9.25 ns	19.25 ns	24.00 ns	17.50 ns
R3	20.00 ns	12.75 ns	15.00 ns	15.92 ns
Average	12.75 ns	13.08 ns	15.67 ns	
	40 days after cutting			
R1	10.75 ns	12.00 ns	10.50 ns	11.08 b
R2	10.50 ns	33.25 ns	33.00 ns	25.58 a
R3	22.75 ns	23.00 ns	19.50 ns	21.75 ab
Average	14.67 ns	22.75 ns	21.00 ns	
	60 days after cutting			
R1	13.00 ns	13.25 ns	13.25 ns	13.17 b
R2	16.00 ns	35.00 ns	36.25 ns	29.08 a
R3	24.00 ns	27.75 ns	23.50 ns	25.08 a
Average	17.67 ns	25.33 ns	24.33 ns	

Note: Data followed by different letters in the same column and row are significantly different according to the DMRT at 5%. Size cutting of rice stems (R1 = 5 cm, R2 = 10 cm, and R3 = 15 cm). SLOF dosages (S1 = 5 mL L^{-1}, S2 = 10 mL L^{-1}, and S3 = 15 mL L^{-1}). ns = not significant.

Based on the ANOVA results, the rice stem cutting sizes, SLOF dosages, and their interactions were insignificant on the yield components of ratoon rice (number of grains per panicle, number of empty grains per panicle, and 1,000-grains weight; Figure 2–Figure 4). The R2 treatment had the highest number of grains per panicle and 1,000-grains weight of 116.77 grains and 25.91 g, respectively, compared to the other cutting sizes. The R3 treatment had the highest number of empty grains per panicle (20.29 grains) compared to the other cutting sizes. The S1 application had the highest number of grains per panicle and number of empty grains per panicle of 113.59 and 22.69 grains, respectively, compared to the other doses. The S2 application had the highest 1,000-grains weight of 25.92 g compared to the other doses. The R2S1 combination treatment had the highest number of grains per panicle of 139.85 grains compared to the other combinations. The R3S1 and R3S2 combination treatments had the highest number of empty grains per panicle and 1,000-grains weight of 25.90 grains and 26.78 g, respectively, compared to the other combinations.

3.4. Correlations of Agronomic Traits of Ratoon Rice

The agronomic traits of ratoon rice include the plant height, number of tillers, number of productive tillers, number of grains per panicle, number of filled grains per panicle, 1,000-grains weight, and yield per hill significantly increase the yield per hectare of ratoon rice with the highest contribution was found in the number of

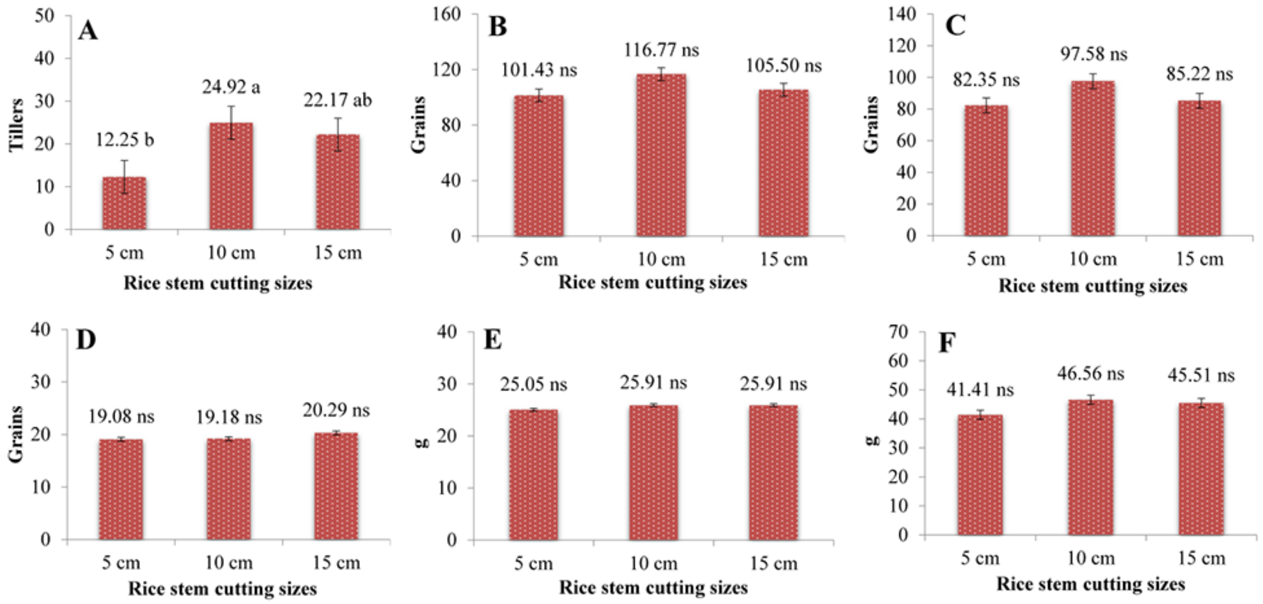

Figure 2 Effect of rice stem cutting sizes on the yield component of ratoon rice: (**A**) number of productive tillers; (**B**) number of grains per panicle; (**C**) number of filled grains per panicle; (**D**) number of empty grains per panicle; (**E**) 1,000-grains weight; (**F**) yield per hill. Data followed by different letters on the same graph are significantly different according to DMRT at 5% ± standard error (*SE*).

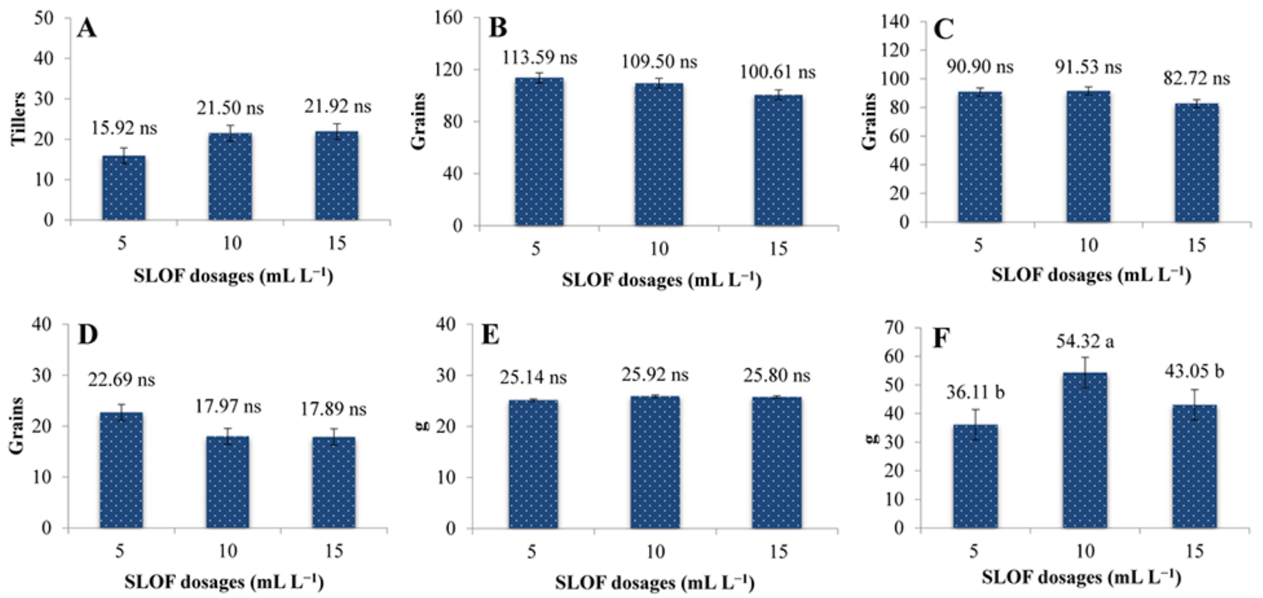

Figure 3 Effect of Seprint liquid organic fertilizer (SLOF) dosages on the yield component of ratoon rice: (**A**) number of productive tillers; (**B**) number of grains per panicle; (**C**) number of filled grains per panicle; (**D**) number of empty grains per panicle; (**E**) 1,000-grains weight; (**F**) yield per hill. Data followed by different letters on the same graph are significantly different according to DMRT at 5% ± standard error (*SE*).

productive tillers (correlation coefficient value of 0.885) (Table 3). The present study confirmed that an increase the yield per hectare of ratoon rice along with an increase in the number of productive tillers in the combination treatment of stem cutting with SLOF dosages.

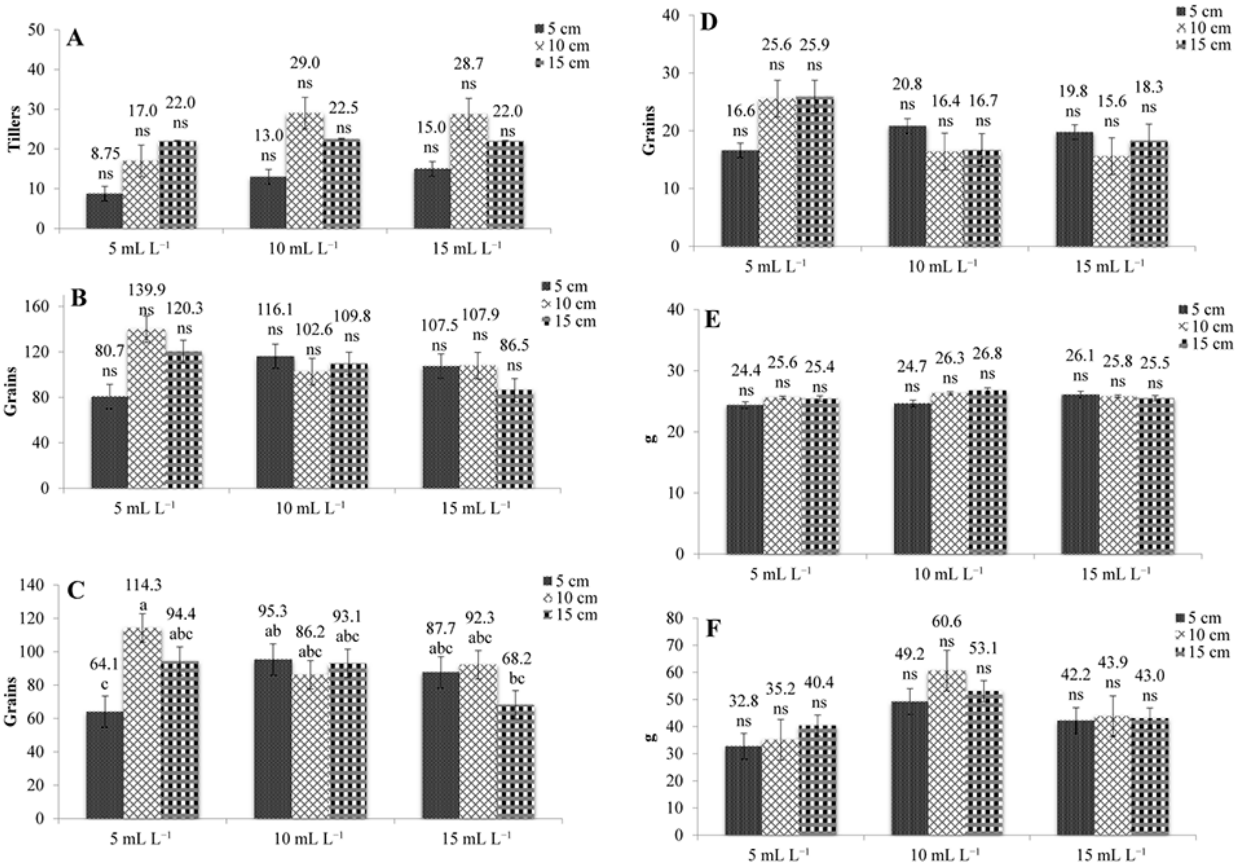

Figure 4 Combinations of stem cutting sizes and Seprint liquid organic fertilizer (SLOF) dosages on the yield component of ratoon rice: (**A**) number of productive tillers; (**B**) number of grains per panicle; (**C**) number of filled grains per panicle; (**D**) number of empty grains per panicle; (**E**) 1,000-grains weight; (**F**) yield per hill. Data followed by different letters on the same graph are significantly different according to DMRT at 5% ± standard error (*SE*).

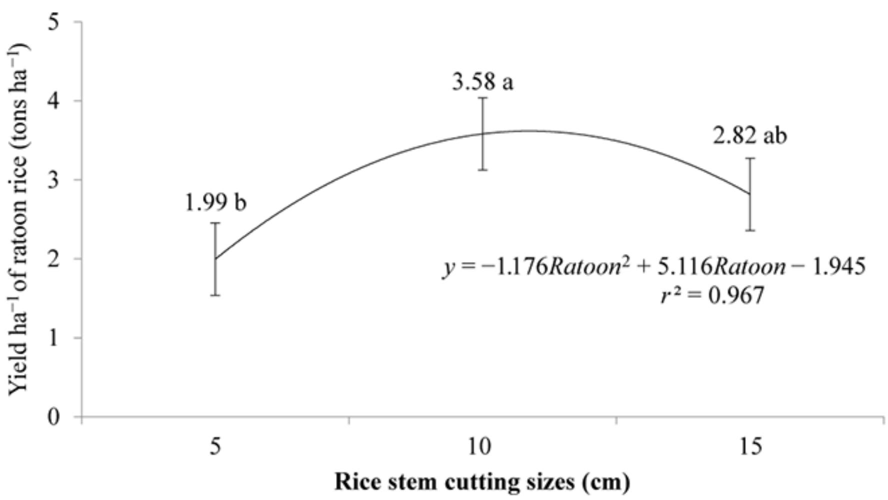

Figure 5 Effect of rice stem cutting sizes on the yield per hectare of ratoon rice. Data followed by different letters on the same line are significantly different according to DMRT at 5% ± standard error (*SE*).

Table 3 Correlations of agronomic traits of ratoon rice in the treatment of stems cutting and Seprint liquid organic fertilizer (SLOF) dosages.

Agronomic traits of ratoon rice	PH	NT	NPT	NGP	NFGP	NEGP	1,000 GW	YH	Y
PH	1								
NT	0.500**	1							
NPT	0.683**	0.612**	1						
NGP	−0.043	−0.143	0.157	1					
NFGP	0.104	−0.051	0.217	0.927**	1				
NEGP	−0.264	−0.207	0.055	0.693**	0.387*	1			
1,000 GW	0.167	0.243	0.271	−0.085	0.090	−0.311	1		
YH	0.208	0.241	0.222	0.071	0.258	−0.310	0.329*	1	
Y	0.582**	0.500**	0.885**	0.488**	0.600**	0.137	0.396*	0.360*	1

Note: Correlation is significant at the * 0.05 and ** 0.01 level (two-tailed). Agronomic traits: PH – plant height; NT – number of tillers; NPT – number of productive tillers; NGP – number of grains per panicle; NFGP – number of filled grains per panicle; NEGP – number of empty grains per panicle; 1,000 GW – 1,000-grains weight; YH – yield per hill; Y – yield per hectare.

4. Discussion

Cutting 10 cm of the rice stem (R2 treatment) significantly increased the height of ratoon rice at 10 to 30 DAC and significantly increased the number of tillers of ratoon rice at 40 to 60 DAC and the number of productive tillers. The results were similar for the growth rate of ratoon rice, with the R2 treatment higher by 1.20 to 2.03 cm day^{-1} compared to the R1 and R3 treatments that ranged from 0.89 to 1.26 cm day^{-1} and 1.05 to 1.49 cm day^{-1}, respectively. This was caused by an optimal carbohydrate supply from the emergence of the ratoon shoots that resulted in higher vegetative growth and was supported by the plant height, number of tillers, growth rate, and number of productive tillers on the R2 treatment being higher than the other cutting sizes (Table 1, Table 2 and Figure 2–Figure 4). The optimal cutting size of rice stems supports the growth and yield of ratoon rice. Santos et al. (2003) showed a decrease in yield ranging from 12% to 37% in <5 cm rice stem cuttings, whereas cuttings >20 cm of the rice stem produced tillers faster, and the number of grains was less than the optimal cutting size. Harrell et al. (2009) found that height cutting of the main plant stems affected the number of tillers and seed yield. Susilawati et al. (2012) stated that the height and number of productive tillers for ratoon rice in genotype IPB106-F-8-1 at a 10 cm cutting was higher than that at 20 cm and 30 cm cuttings. Mareza et al. (2016) stated that cutting 40 to 50 cm of the main rice stem was significant for the number of productive tillers, with the highest found at the 40 cm cutting (6.55 tillers) compared to the other cutting sizes.

The R2 treatment significantly increased the yield per hectare of ratoon rice to 3.58 tons ha^{-1} compared to the other cutting sizes (Figure 5). The yield per hectare of ratoon rice in the study was smaller than that of the main plants (rice variety Inpari 30) where the initial planting was 5.08 tons ha^{-1} and the yield decreased by 29.53% compared to the main plant. This resulted in a growth pattern (height and number of tillers) of ratoon rice that was higher in the R2 treatment compared to the other cutting sizes because photosynthesis caused the formation of assimilates and the production of filled grains. The number of productive tillers, number of filled grains per panicle, and 1,000-grains weight for the R2 treatment were also higher than the other cutting sizes (Figure 2–Figure 4). According to Harrell et al. (2009), the height of the cutting stems of the main plant affects the number of tillers and grains. Susilawati et al. (2012) showed that the yield per hectare of ratoon rice in genotype IPB106-F-8-1 for the 10 cm cutting was greater (2.1 tons ha^{-1}) than that for the 20 and 30 cm cuttings (1.6 and 1.1 tons ha^{-1}, respectively). Nuzul et al. (2018) found that the yield of ratoon rice decreased by 58.72% from that of the main plants.

The S3 treatment significantly increased the height of ratoon rice at 20 DAC (Table 1). SLOF has a main nutrient content of 11% N, which is higher than that of

K (2%). Therefore, a SLOF dose of 15 mL L^{-1} could support the photosynthesis level and increase the vegetative phase of the ratoon rice. According to Surtinah (2009), liquid organic fertilizers are very efficient because plants easily absorb such fertilizers. Parman (2007) stated that liquid organic fertilizers improved soil physical, chemical, and biological properties, and increased the yield and quality of plants. Niis and Nik (2017) showed that the application of liquid organic fertilizer at a dose of 6 L ha^{-1} significantly increased the highest number of seeds per panicle and the dry seed weight of rice by 107.38 seeds and 29.65 g, respectively, compared to doses of 2 and 4 L ha^{-1}.

The S2 application significantly increased the yield per hill of ratoon rice by 54.32 g. SLOF contains 11% N and 2% K, which played an important role in improving the nutrient uptake and soil organic matter and increasing the availability of macro- and micronutrients for ratoon rice. Liquid organic fertilizers can play a role in cell division and increase assimilation, leading to increased biomass and yield of ratoon rice. According to Vidigal et al. (2002), the growth of onions increased progressively with an increased application of K fertilizer. El-Bassiony (2006) also stated that the application of K fertilizer incresased the dry weight of onions. Martínez-Alcántara et al. (2016) stated that liquid organic fertilizers increased the uptake of macro- and micronutrients, and organic matter in soil compared to chemical fertilizers. Phibunwatthanawong and Riddech (2019) showed that liquid organic fertilizers contained micro- and supplementing nutrients, beneficial microorganisms such as plant growth-promoting rhizobacteria, and hormone indole acetic acid, which are not found in chemical fertilizers.

The R2S2 combination treatment significantly increased the ratoon rice height to 27.98 cm at 10 DAC. The R2S2 and R2S3 combination treatments had the highest ratoon rice height compared to the other combinations. This was caused by the main nutrients N and K in the S2 and S3 applications promoting the photosynthesis rate to form assimilates to stimulate ratoon rice growth, including the plant height, number of tillers, and number of productive tillers (Table 1, Table 2 and Figure 2–Figure 4). According to Nurhayati (2009), liquid organic fertilizer can promote metabolism in plants via the nutrient solubility process, and nutrient transport will occur from the roots to all parts of the plant. Hamzah (2014) stated that liquid organic fertilizer could increase plant height, and the number of branches and soybean pods.

The R2S1 combination treatment significantly increased the number of filled grains per panicle by 114.30 grains. This was because SLOF stimulated the metabolic process with the growth rate of ratoon rice, and photosynthesis formed assimilates and led to grain panicle production. According to Susilawati et al. (2012), the cutting of 10 cm of rice stem in genotype IPB106-F-8-1 significantly increased the number of grain per panicle. which was 108.0 grains higher than the 20 cm and 30 cm cuttings (78.5 and 71.1 grains, respectively). Mareza et al. (2016) stated that cutting 10 cm of the rice stems significantly improved the panicle length and the number of grains per panicle of ratoon rice by 14.93 cm and 47.05 grains, respectively, compared to the cuttings of 20 to 50 cm.

The correlations result confirmed that the number of productive tillers had a positive linear correlation (0.885) and was classified as very strong in increasing the yield per hectare of ratoon rice compared to another agronomic traits (Table 3). Similar results were reported by Sadeghi (2011); Ranawake et al. (2013) the number of productive tillers and the number of grains per panicle had a significant effect on grain yield per plant. Faruq et al. (2014) also reported that the number of productive tillers per hill has a correlated positively and significant increase the grain yield per plant of ratoon rice.

The application of ratoon rice technology combined with SLOF greatly encouraged rice yield to improve adequate food supply because a year of rice cultivation (main plants and ratoon technology) can produce an average yield of 8.66 tons ha^{-1}. Thus, farmers will receive a double benefit by applying ratoon technology during a cycle of irrigated rice.

5. Conclusions

The R2 treatment significantly increased the ratoon rice height from 20.33 to 53.89 cm at 10 to 30 DAC, the number of tillers from 25.58 to 29.08 tillers at 40 to 60 DAC, the number of productive tillers to 24.92 tillers, and the yield per hectare of ratoon rice to 3.58 tons ha^{-1}. The S3 application significantly increased the ratoon rice height to 35.71 cm at 20 DAC, and the S2 application significantly increased the yield per hill of ratoon rice to 54.32 g. The R2S2 combination treatment significantly increased the ratoon rice height to 27.98 cm at 10 DAC and the R2S1 combination treatment also significantly increased the number of filled grains per panicles of ratoon rice to 114.30 grains. The R2 treatment combined with various dosages of SLOF resulted in higher growth and yield of ratoon rice compared to the other cutting sizes.

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