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Response of Growth and Yield of Salibu Rice on the Stem Cutting Height of Parent Crops after Harvest

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Abstract. Salibu is the rice (*Oryza sativa* L.) cultivation derived from the stem cutting of parent crops after harvest. The remaining stems provide non-structural carbohydrate reserves to support the emergence of new shoots as salibu rice. The stem cutting height will affect the growth and yield of salibu rice. This study aims to determine the proper stem cutting height of parent crops after harvest to provide the maximum growth and yield of salibu rice. This experiment was a pot experiment and arranged in a completely randomized design (CRD) with 3 replications. Treatment of stem cutting height consisted of six levels, namely: 0, 5, 10, 15, 20, and 25 cm. Observational data were analyzed by analysis of variance at a 5% significance level. To determine the difference between treatments used Duncan's multiple distance test at a 5% significance level. The results showed that there were differences in the response of growth and yield of salibu rice to differences in stem cutting height. Stem cutting higher lead to the time of flowering and harvesting faster, tillers number and shoot dry weight higher, and leaf greenness and yields lower. Otherwise, stem cutting lower resulted in the time of flowering and harvesting slower, tillers number fewer, shoots and grain dry weight smaller. As parent crops, Cakrabuana Agritan variety through transplanting system resulted in 7.0 tons ha^{-1}. The highest grain dry weight of salibu rice was produced by stem cutting at a height of 5 cm from the soil surface with a yield of 3.8 tons ha^{-1} or 54.5% of the parent crops. The stem cutting of parent crops after harvest at a height of 5 cm is the proper treatment to get the maximum growth and yield of salibu rice. Recommendations for future research, salibu rice cultivation better uses stem cutting at a height of 5 cm from the soil surface.

Keywords: carbohydrates, salibu rice, stem cutting height, transplanting system, parent crops.

INTRODUCTION

The increasing of people number in Indonesia from time to time causes the need for food to continue to increase, especially rice. Many technologies have been developed by the Indonesian government to increase the national rice demand, one of which is the cultivation of salibu rice. Salibu rice cultivation is a modification of ratoon rice cultivation and has been developed in several areas in Indonesia. Salibu is an abbreviation from '*salin ibu*' (in Indonesian) or changes mother (in English). Salibu rice cultivation can produce grain production of about 60% of the parent crops. However, the cultivation of salibu rice has not received much attention from the farming community in Indonesia.

Salibu rice cultivation technology significantly increases land productivity per year. Salibu rice has advantages, namely a relatively shorter harvest time, less water requirement, and low production costs. Production costs could be reduced by about 45% than the transplanting system because there are no more costs for soil tillage, seeding, and planting. The salibu rice cultivation technology provides great benefits for food availability and farmers' income in Indonesia. Salibu rice cultivation technology is one of the technologies based on local wisdom that can be a solution to increase food ingredients in Indonesia, and encourage food security in Indonesia. The maximum yield of salibu depends on the stem cutting height of parent crops. No research used the Cakrabuana Agritan variety as parent crops in the salibu rice cultivation. It was not yet known how high the stem cuttings are to the parent crops using the Cakrabuana Agritan variety. Therefore, this study conduct to determine the proper stem cutting height of parent crops after harvest that can provide the maximum growth and yield of salibu rice.

Cakrabuana Agritan is a superior rice variety that is somewhat resistant to brown planthopper biotypes 1, 2, 3, and bacterial leaf blight of strain III, but susceptible to bacterial leaf blight of strains IV and VIII. Cakarabuana Agritan

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also has resistance to blast race diseases 033, and 173 and is somewhat resistant to Purwakarta Tungro inoculum disease [1]. Therefore, Cakrabuana Agritan can be used as parent crops. The use of superior rice varieties as parent crops in salibu rice cultivation technology is expected to provide early maturity and high-yielding genetic traits.

Optimal yields on the number of productive tillers, number of seeds per panicle, and rice productivity were obtained from the remaining harvest stems cuttings at a height of 3-5 cm above the soil surface and carried out at the age of 7-8 days after harvest (DAH) [2]. There were differences in yield responses of cultivated varieties on stem cutting after harvest at a height of 3-5 cm from the above soil surface. Salibu rice from the Batang Piaman variety produced 60% of the parent crops for the first generation and 62.5% for the second generation. In contrast to the Ketan Grendel variety, resulted in 70.5% for the first generation and 55% for the second generation [3].

The study in the Ciherang variety showed that the highest yield was achieved by the stem cutting at a height of 3 cm above the soil surface with a grain yield of 3.54 tons ha^{-1}. The highest growth and yield components of ratoon rice were achieved by the stem cutting after harvest with a height of 3 cm above the soil surface [4]. However, the highest grain yield was at stem cutting at a height of 30 cm and yielded dry grain of 1,95 tons ha^{-1} on ratoon rice [5].

The salibu rice cultivation system allowed the rice harvest 3-4 times per year. The benefits of salibu rice cultivation were even greater because it could shorten the harvest period of plants, save various resources such as water, labor, nurseries, and land preparation as well as a short crop growth period [6]. Stem cutting time at physiological harvest gave the best shoots of salibu rice [7]. The salibu rice yield was proportional to the new tillers number produced. Delay in stem cutting could affect the new tillers number (Oda et al. 2019). Stem cutting height affects plant height, empty seeds number, and filled seeds.

Harvesting of the parent crops was carried out at a stem cutting height of 5 cm from the soil surface [9]. Carbohydrates were required to maintain metabolic activity during the early growth stages. The remaining rice stem provided energy for the growth of new shoots after the stems were cut, then immediately grows into new shoots [10]. The highest yield of salibu rice from the Ciherang variety was achieved at harvest with a stem cutting height of 3 cm above the soil surface [4]. Stem cutting at a height of 2-3 cm from the soil surface caused new shoots to germinate to form the next new sapling. Variation in tiller genotype after harvest was related to carbohydrate content remaining in the stem after harvest [11]. Salibu rice was a rice crop that grows from the rest of the basal stem after harvest. Shoots emerge from nodes near the soil surface. The new sapling roots' function absorbed nutrients from the surroundings so that the supply of nutrients was no longer dependent on the stem of parent crops. New tillers immediately formed the next tillers like parent crops [12].

Based on the literature search above, there have not many studies related to salibu rice cultivation technology. Previous research was more related to ratoon rice cultivation. No research aims to know the response of growth and yield of salibu rice to differences in stem cutting height after harvest. Therefore, this study aims to determine the proper stem cutting height of parent crops after harvest to provide the maximum growth and yield of salibu rice.

MATERIALS AND METHODS

Study site

The research was carried out from March to May 2021 and located in the greenhouse facility of the Department of Agrotechnology, Faculty of Agriculture, Universitas PGRI Yogyakarta, Bantul Regency, Special Territory of Yogyakarta, Indonesia. The altitude of this place was 118 m above sea level. The average air temperature and relative humidity in the greenhouse during the research were 38.3°C and 44.6%, respectively and were measured by Corona Thermo-Hygrometer.

Research preparation

Latosol soil was taken from the topsoil layer at a depth of 0-20 cm. The soil was taken from Minggir District, Sleman Regency, Special territory of Yogyakarta. Place of planting media made from Sengon wooden boxes in size of 50 × 80 cm. This study used the Cakrabuana Agritan variety as parent crops in salibu rice cultivation. Silver black plastic mulch was used to line the inner edges of the wooden box to prevent water and soil from leaking out.

Research design

This experiment was a pot experiment arranged in a completely randomized design (CRD) and 3 replications. The treatment of stem cutting after harvest consisted of six levels, namely: 0, 5, 10, 15, 20, and 25 cm from the above soil surface. Overall, this study required 6 × 3 = 18 treatment plots or wooden boxes.

Research procedures

This research was conducted in two stages. The first stage was planting rice through the transplanting system to function as parent crops. The second stage was carried out for the salibu rice cultivation. The first stage of the study began with the preparation of planting media. Latosol soil was dried and crushed into uniform granules. Then the soil was put into wooden boxes that have been coated with silver black plastic. A wooden box was placed on the desk in the greenhouse.

The seedling was carried out in germination plastic tubs in a size of 25 cm × 30 cm. The planting medium was made of soil and manure in a ratio of 1:1. Rice seeds were spread in soil media in germination plastic and covered with a small amount of soil to maintain moisture. Seedlings were ready to be planted at the age of 18 days after sowing. The plant spacing used in rice cultivation is 25 cm × 25 cm. The planting was done with one seed per planting hole. Each wooden box consisted of 6 planting holes. Watering was done every two days until the soil remains waterlogged or as needed.

The dose of fertilizer was used 300 kg ha^{-1} urea and 200 kg ha^{-1} NPK Phonska. The application of urea and NPK fertilizers was carried out in two stages. The first stage was given 40% of each dose and given at the age of 2 weeks after planting (WAP). The second stage was applied at 60% of each dose at 5 WAP. Weeding was done one day before fertilization. Pest and disease control were carried out as needed. Harvesting was carried out at the age of 104 days after planting (DAP) when the grain in the panicle was physiologically ripe (or 95% had turned yellow).

In the second stage of research, there were no soil preparation, seeding, and planting. The stems of the parent crops after harvest were immediately cut at a height according to the treatment. The shoots that emerge from the stem nodes of the parent crops are retained. Plant maintenance included watering, fertilizing, and controlling pests, diseases, and weeds the same transplanting system in the first stage of research above. The dose of fertilizer was used the same as for the transplanting system, namely 300 kg ha^{-1} urea and 200 kg ha^{-1} NPK Phonska. Fertilizer application was carried out in two stages, namely 40% of each dose for the first stage at the age of 2 weeks after stem cutting (WASC). The second fertilization was 60% of each dose at the age of 4 WASC. Salibu rice harvest was carried out at the age of 80 days after stem cutting (DASC).

Observational variable

Plant height was measured from the neck of the stem near the soil surface to the tip of the highest leaf using a ruler. The tiller's number was calculated manually by counting the number of the stem of rice plants in one plant clump. The leaf greenness was calculated using the chlorophyll meter or Soil Plant Analysis Development (SPAD) by measuring leaf samples from the bottom, middle, and top at the age of 6 WASC. Flowering time was determined by counting 50% of the rice tillers in one clump that has been flowered. Harvest time was carried out after the grain in panicles had physiologically matured 90% in one clump of rice. The shoot dry weight and grain dry weight were measured using an Ohaus PA214 Pioneer Analytical Balance digital scale. The rice population (clump ha^{-1}) was calculated based on the land area of 1 ha (10,000 m^{-2}) divided by the plant spacing (0.25 × 0.25 m^{-2}) was 160,000 clumps ha^{-1}. The weight of 1 ton was identical to the weight of 1,000,000 g. The shoot dry weight (tons ha^{-1}) was calculated by Eq. 1, while the grain dry weight (tons ha^{-1}) was calculated by Eq. 2.

$$= \frac{Shoots\ dry\ weight\ (g\ clump^{-1}) \times rice\ population\ (clumps\ ha^{-1})}{1{,}000{,}000\ (g\ ton^{-1})} \tag{1}$$

$$= \frac{Grain\ dry\ weight\ (g\ clump^{-1}) \times rice\ population\ (clumps\ ha^{-1})}{1{,}000{,}000\ (g\ ton^{-1})} \tag{2}$$

Statistical analysis

Observational data were analyzed by analysis of variance at 5% significance levels. To determine the difference between treatments used Duncan's multiple distance test (DMRT) at 5% significance levels [13].

RESULTS AND DISCUSSION

Growth components of salibu rice

The stem cutting of parent crops had a significant effect on plant height, tillers number, leaf greenness, and shoot dry weight. The results of the DMRT on growth components could be seen in Table 1.

TABLE 1. Response of growth components on the stem cutting height of parent crops after harvest

Stem cutting height (cm)	Growth components			
	Plant height (cm)	Tillers number (stem)	Leaf greenness (unit)	Shoot dry weight (tons ha^{-1})
0	121.3 a	13.8 c	26.4 a	2.5 c
5	122.8 a	15.2 c	27.7 a	4.1 b
10	115.3 a	16.3 bc	26.8 a	4.2 ab
15	108.1 b	20.2 ab	27.1 a	4.4 ab
20	109.2 b	20.8 ab	28.0 a	5.1 a
25	114.0 ab	21.5 a	20.8 b	5.3 a

Remarks: The mean followed by the same letter in the column showed that there is no significant difference between treatments based on the DMRT at a 5% significance level.

The response of plant height, tillers number, and leaf greenness at the age of 2, 4, 6, 8, and 10 WASC and shoot dry weight at 10 WASC on various stem cutting heights were presented in Figure 1.

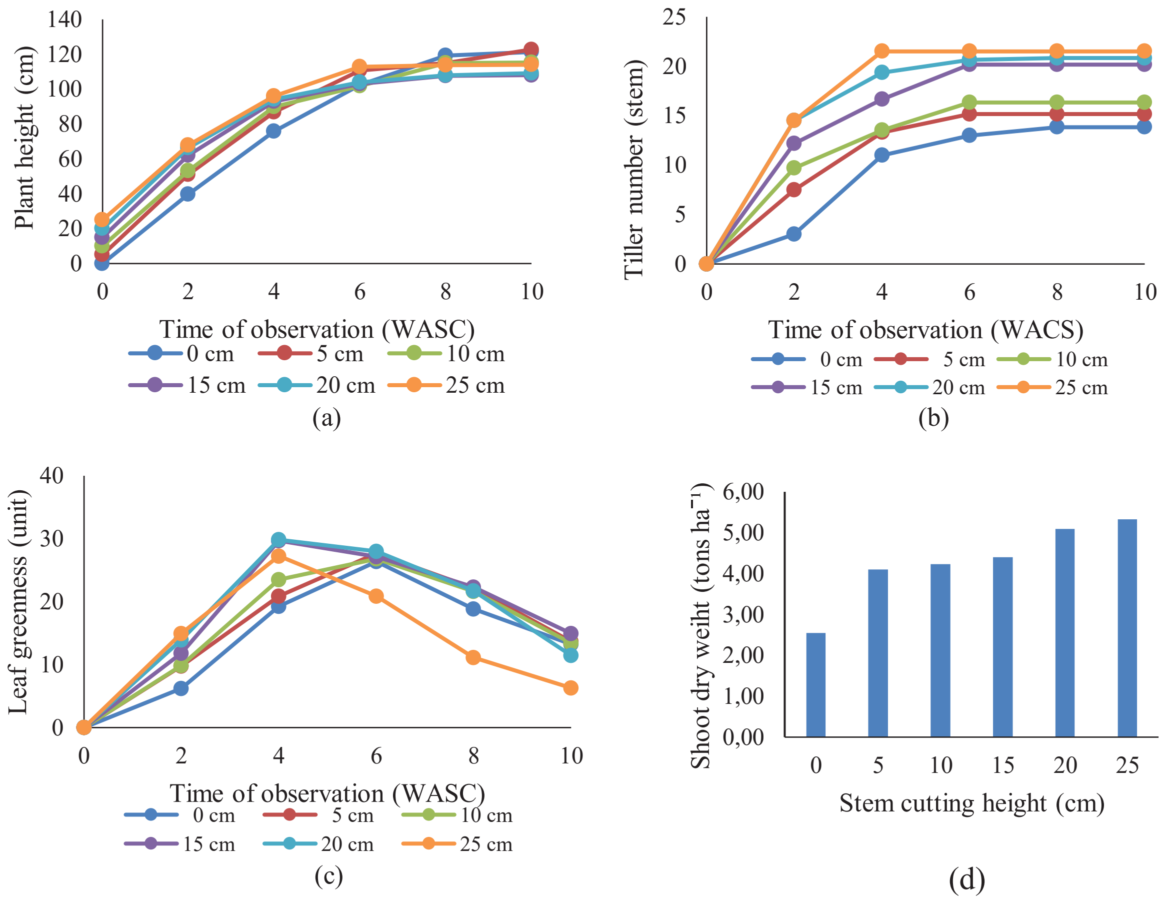

Fig.1. Response of plant height (a), tiller number (b), leaf greenness (c), and shoot dry weight (d) on the stem cutting height of parent crops

The height of the stem cutting of the parent crops after the harvest had a significant effect on plant height. Plant height showed that stem cutting of 0, 5, and 10 cm produced plant heights higher than 15 and 20 cm, but not significantly different from stem cutting at a height of 25 cm. Stems cutting shorter resulted in plant height higher than stem cutting taller, then it could support the vegetative growth longer. Stem cutting higher caused the plant to flower quickly because the sufficient carbohydrate content in the remaining stems of parent crops moved to generative growth.

The highest tillers number was produced by treatment with tall stem cutting, then decreased by short stem cutting. The tillers number at the stem cutting at heights of 10, 15, 20, and 25 cm had more nodes number than the stem cutting at heights of 0 and 5 cm. Shoots appear from each segment of the scion down so that the new shoots number was more. On stem cutting of 0 and 5 cm indicated that most of the shoots emerged from the base of the stem and subsequently formed new tillers. According to Souza et al. [14], carbohydrate content in stems mainly affected root growth. He et al. [15], stated that the ratoon rice yield depends on the panicle growing from the stem of the parent crops. Regeneration ability is an index used to assess the number of shoot germination. The opinion to Alridiwirsah [16], stem cutting at a height of 15 cm produced more tillers than cutting 5 and 10 cm in ratoon rice.

Our study shows the carbohydrates reserves in the remaining stems can supply energy for the formation of new tillers. Stem cutting at a height of 0 cm caused the least tillers number due to the low carbohydrate reserved to support the formation of new shoots. In addition, the nodes number where new shoots appear was less. The first shoots emerge from the dormant buds at the base of the remaining stems. Furthermore, the first tiller came from the axil of the second leaf on the stem of the first shoot. The second tiller came from the leaf axillary buds. This only occurred at stem cutting at heights of 0 and 5 cm and did not occur at heights of 10, 15, 20, and 25 cm.

The leaf greenness was highest at the age of 6 WASC, in which the vegetative phase transitioned to the generative phase. Based on the results of the study, there was no difference in the leaf greenness from stem cutting at a height of 0 to 20 cm, but the five treatments were significantly different with stem cutting at a height of 25 cm. The stem cutting shorter provided an opportunity for the rice plant to extend its vegetative phase. The photosynthesis process that occurred in leaf chlorophyll could last longer than the cutting higher. Leaf greenness was one of the determinants of N leaf status. The N content higher in the leaves caused the absorption of sunlight to run better to support the photosynthesis process. Carbohydrates produced from the photosynthesis process were used as an energy source for vegetative and generative growth. According to Krasavina et al. [17], the accumulation of carbohydrates in the leaves affected plant survival. The decrease in the entry of source into the sink results in inhibition of growth and generative development.

The highest shoot dry weight occurred at stem cutting at heights of 15, 20, and 25 cm, then decreased at cutting at heights of 5, and 10 cm and the lowest was at stem cutting of 0 cm from the soil surface. Stem cutting at heights of 15, 20, and 25 cm produced stem residues containing sufficient non-structural carbohydrates to support the emergence of new shoots than stem cutting at heights of 0, 5, and 10 cm. Shoot dry weight higher on stem cutting resulted in the total shoot dry weight higher too. The remaining stem cutting higher and the addition of new shoot growth resulted in the shoot dry weight higher at stem cutting at heights of 20 and 25 cm. It is different from the opinion of Dong et al. [18], the non-structural carbohydrate content (rice straw) decreases with increasing height of stem cutting.

Yield components of salibu rice

The stem cutting of parent crops significantly affected flowering time, harvesting time, panicle length, and grain dry weight. The results of the DMRT on yield components could be seen in Table 2.

TABLE 2. Responses of flowering time, harvesting time, panicle length, and grain dry weight on the stem cutting height of parent crops after harvest

Stem cutting height (cm)	Yield components			
	Flowering time (DASC)	**Harvesting time (DASC)**	**Panicle length (cm)**	**Grain dry weight (tons ha^{-1})**
0	43.3 a	79.0 a	27.8 a	2.9 c
5	41.5 a	78.5 a	28.0 a	3.8 a
10	37.7 b	77.3 ab	26.0 ab	3.5 a
15	32.5 c	75.0 bc	24.8 bc	3.3 ab
20	29.8 cd	74.5 bc	24.2 bc	3.3 abc
25	27.8 d	72.7 c	23.8 c	3.2 bc

Remarks: The mean followed by the same letter in the column shows that there is no significant difference between treatments based on the DMRT at a 5% significance level.

The response of flowering and harvesting time, panicle length, and grain dry weight in various stem cutting heights were presented in Figure 2.

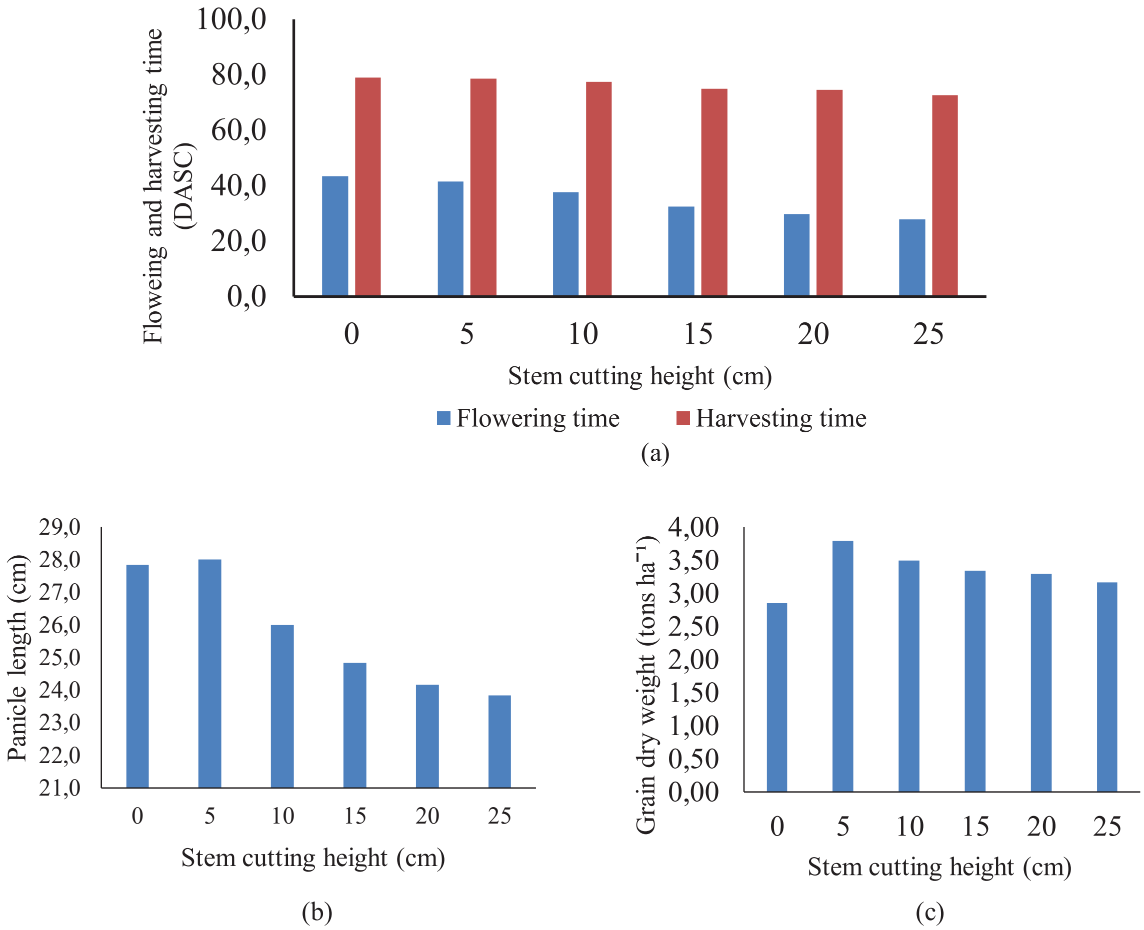

Fig.2. Response of flowering time and harvesting time (a), panicle length (b), and grain dry weight (c) in various stem cutting heights of parent crops

The stem cutting of parent crops higher caused the plants to flower and harvest faster. This could be seen in the treatment of stem cutting at a height of 25 cm which was significantly different from stem cutting height of 15, 10, 5, and 0 cm. The stem cutting lower, the salibu rice would be flowering and harvesting lower. It was related to the carbohydrate content that is still left in the stem. In the opinion of Harrell et al. [19], shorter stem cutting cause ratoon growth to changes in the vegetative growth stage longer and delay the seed filling period. According to El-Lithy et al. [20], carbohydrate content has a positive relationship with flowering rice.

The flowering and harvesting faster was due to the carbohydrate content in the remaining stems of parent crops to support the vegetative growth of new shoots and immediately move to the generative phase. Stem cutting at heights of 20 and 25 cm showed early flowering at 29.8 and 27.8 DASC, while stem cutting at 0 and 5 cm showed flowering at 41.5 and 43.3 DASC. Similarly, observations of harvest time showed the same trend. The stem cutting taller caused rice crops to grow and flower more quickly because new shoots could take advantage of the carbohydrate reserves left in the stem of parent crops. In contrast to the stem cutting shorter, where new shoots grew to form new tillers, and so on so that the vegetative growth phase lasts longer.

High carbohydrate content in spare organs caused greater production [21]. Stem cutting with heights of 0 and 5 cm resulted in a panicle length longer than stem cutting at heights of 15, 20, and 25 cm. Stem cutting at heights of 0, and 5 cm caused rice crops to form new tillers on the soil surface. The shoots that emerged had time to form new tillers so that the vegetative growth phase was longer. The yield of photosynthesis is higher and can be used to support the elongated growth of the panicle. Panicle length correlated with the grain dry weight. Longer panicles resulted in higher grain dry weight.

Stem cutting at a height of 5 cm resulted in the grain dry weight higher than stem cutting at heights of 0, and 25 cm although not significantly different from a height of 10, 15, and 20 cm. As parent crops, Cakrabuana Agritan variety through transplanting system resulted in the grain dry weight of 7.0 tons ha^{-1}. Based on the rice yield in this study showed that the grain dry weight was lower than the transplanting system, namely 40.8; 54.2; 49.9; 47.7; 47.0, and 45.3% at stem cutting at heights of 0, 5, 10, 15, 20, and 25 cm, respectively. The stem cutting at a height of 5 cm resulted in a grain dry weight of 3.8 tons ha^{-1} or 54.2% of the parent crops, greater than other stem cutting heights.

Reducing the stem cutting height of the parent crops caused the harvesting to be lower than the traditional system and can alter growth and increase the yield of ratoon rice [19]. Stem cutting at a height of 5 cm from the soil surface was the best treatment for salibu rice cultivation. The stem cutting higher did not result in the grain dry weight higher. The results of this study by the opinion of Mareza et al. [22], stated that the effect of stem cutting on the yield of salibu rice depends on the photosynthetic conditions and the number of segments remaining on the stem of the parent crops as a place for the emergence of new shoots.

CONCLUSION

The findings of this study were expected to greatly contribute to the development of proper salibu rice cultivation in Indonesia. These results should be viewed as a first attempt to determine the response of growth and yield of salibu rice at various stem cutting heights of parent crops after harvest. The results showed that there were differences in the response of growth and yield of salibu rice to differences in stem cutting height. The stem cutting higher after harvest caused the flowering and harvesting time faster, tiller number and shoot dry weight higher, and leaf greenness and yield lower. Otherwise, stem cutting lower resulted in the flowering and harvesting slower, tillers number fewer, shoot, and grain dry weight smaller. As parent crops, Cakrabuana Agritan variety through transplanting system resulted in the grain dry weight of 7.0 tons ha^{-1}. The highest grain dry weight of salibu rice was found at stem cutting at a height of 5 cm with a yield of 3.8 tons ha^{-1} or 54.5% of the parent crops. The stem cutting of parent crops after harvest at a height of 5 cm is the proper treatment to get the maximum growth and yield of salibu rice. Recommendations for future research, salibu rice cultivation better uses stem cutting at a height of 5 cm from the soil surface.

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