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RESEARCH ARTICLE

Ratooning response of lowland rice (*Oryza sativa* L.) varieties to cutting height of ratoon crop

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Abstract

Rice ratooning is a vital production system nowadays for rice farming, albeit with low productivity due to climate change. However, lowland rice varieties differ in their ratooning performance even if grown in similar environments and management practices. It could be due to their environmental adaptability and biological plant responses because of tillering behavior, cutting height, fertilization, and water availability. In counteracting said constraints, a study was conducted to evaluate the effect of cutting height on the growth and yield responses of ratooned lowland rice varieties. Identify the best lowland rice variety that will produce maximum ratoon yield as affected by cutting height. Determine the profitability of ratooning lowland rice varieties as influenced by cutting height of ratoon crop. Ratooned lowland rice varieties matured earlier, produced remarkably longer stem elongation and panicle length, achieved a higher percentage of filled grains and heavier grain yield at a cutting height of 15 cm than at 45 cm. NSIC Rc216 produced the highest grain yield and most profitable among all lowland rice varieties at a cutting height of 15 cm. The study strongly recommends using NSIC Rc216 rice variety and cutting height of 15cm for the excellent ratooning performance of lowland rice, which suggests an adaptive technique in combating climate change.

Keywords: Climate change; Lowland rice; Ratoon; Stem elongation; Plant Biology

1. Introduction

Rice (*Oryza sativa* L.) is considered the global grain as it is the second-largest source of food for many people, especially in Asia (Niyaki *et al.*, 2010). It is the primary staple for more than half of the global population. The world's total estimated area under rice production is 159M ha with a production of 670M MT with an average yield of 3889 kg ha^{-1} (Harrell *et al.*, 2009). In the Philippines, this crop plays a vital role in our national food security and is a means of livelihood for most rural households. The country's population increases; thus, rice production should suffice the growing population's need.

Rice production can be increased by improving the productivity and cropping index, including the intensification of the ratoon system, i.e., the stubble of rice plants that grow back after harvest and produce new tillers and grains which can be harvested (Islam *et al.*, 2008). Rice ratooning can provide additional rice yield per season and reduce cost, labor, and tillage time (Nakano and Morita, 2007).

With the current cultivation practice called rice ratooning for rice breeding of many countries of the world like the USA, Brazil, Japan, India, Philippines, Thailand, and Taiwan have already adopted this system (Rehman *et al.*, 2013). Rice ratooning allows rice plants to regrow after harvesting. Moreover, ratoon rice

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cropping is a cultivation technology that can increase annual rice production per unit land area (Mengel and Wilson, 1981). Compared with traditional double-cropping rice systems, ratoon rice cropping can save labor, time, seed, and water and requires neither nursery supplies nor land preparation (Munda *et al.*, 2009). The labor and seed inputs for ratoon rice cropping were reduced by 29% and 52%, respectively, compared with double cropping systems (Liang *et al.*, 2016; Sen and Bond, 2017). The leading rice crop's growth duration ranges from 85-175 days in most varieties, while the ratoon crop's time only ranges from 40-90 days. Ratoon rice incurs 50-60% less labor (Chauhan *et al.*, 1985), as it does not require tillage, seeds, transplanting, and lesser cost on crop maintenance. However, ratoon performance varies because of tillering behavior, cutting height, fertilizer and water availability, pest and disease management, and environmental factors like temperature and light intensity.

This research is hypothesized that lowland rice varieties' performance to ratooning differs in response to agro-climatic conditions. Ratoon yields are affected by several factors such as cultural management, cutting height, time of harvesting, light, temperature, soil moisture, and soil fertility (IRRI, 1988). Since rice ratooning is commonly practiced in rice-growing areas in the country, there is a need to conduct a performance trial to investigate the growth and yield performance of ratooned lowland rice varieties as influenced by two cutting heights. Examine the best lowland rice variety that will produce maximum ratoon yield as affected by two cutting sizes of ratoon crop, and evaluates the profitability of ratooning lowland rice varieties as influenced by cutting height of ratoon crop. Identifying the best lowland rice variety that can produce excellent ratoon yield under the two cutting sizes. Thereby, there is a need to conduct this study to evaluate the ratooning performance of lowland rice varieties under different cutting heights to affect additional rice production in counteracting the expected low productivity due to the ill effects of climate change.

2. Materials and Methods

The experiment was conducted at the experimental field of the Department of Agronomy, Visayas State University, Visca, Baybay City, Leyte, the Philippines, from January 1, 2020, to June 30, 2020. However, the proper methodology on crop establishment of the main crop is presented to thoroughly understand the main crop establishment's accurate picture.

2.1. Establishment of the main crop

The experiment adopted a split-plot arranged in a Randomized Complete Block Design (RCBD) with three replications. The two cutting heights (15cm and 45cm) were used as the main plot, while the six lowland rice varieties such as PSB Rc18, NSIC Rc128, NSIC Rc214, NSIC Rc216, NSIC Rc218, and NSIC Rc222 were used as the subplot. Each treatment plot that measures 5m × 2m was separated by 1 meter and 0.5 m alleyways between replications and treatments, respectively. As a protocol for crop establishment, rice seeds of the lowland mentioned above rice varieties were soaked for 24 hours, incubated for 48 hours, and sown in the prepared seedbed for 15 days before uprooting and transplanting into the rice field. Actual transplanting of the rice seedlings was done when the seedling reached 15 days after sowing, adopting a planting distance of 20cm × 20cm. The rice plants were applied with inorganic fertilizers using complete (14-14-14) and urea (46-0-0) at the rate of 90 - 60 - 60 kg ha^{-1} N, P_2O_5, K_2O, wherein 60 kg N ha^{-1} was applied at ten days after transplanting using complete (14-14-14). The remaining 30 kg N ha^{-1} was applied using urea at the panicle initiation stage. Necessary care and management, such as proper rotary and hand weeding operations, water management, pest and disease management, etc., were strictly followed. Then, at harvesting the main crop, the two prescribed cutting heights were followed.

2.2. Establishment of the ratoon crop

The same experimental layout was arranged in a split-plot adopting RCBD with two cutting heights as the main-plot while six lowland rice varieties as the sub-plot, with three replications, were followed. At harvesting, the main crop (HMC), cutting heights of 15cm and 45cm were adopted. Complete fertilizer (14-14-14) and urea (46-0-0) fertilizers were applied at the rate of 45-30-30 kg ha^{-1} N, P_2O_5, and K_2O ten days after harvesting the main crop. Complete fertilizer (14-14-14) was applied basally at the rate of 30-30-30 kg ha^{-1} of N, P_2O_5, K_2O ten days after harvesting the main crop. The remaining 30 kg ha^{-1} N was complied by applying urea (46-0-0), top-dressed 20 days after harvesting the main crop. The main crop's proper cultural management practices were also done similarly for the ratoon crop except for the cutting height and fertilizer management. The data on agronomic and yield components were gathered only for the ratoon crop since this experiment focused on the response of six lowland rice varieties to the two cutting heights of the ratoon crop. Ratoon crops were reached until maturity, similar to the main crop.

2.3. Data Gathered

The data were gathered were the number of days from harvesting of the main crop to 50% heading, and until the harvesting of the ratoon crop (days), stem elongation (cm), panicle length (cm), panicle weight (g), % filled and unfilled grains, and grain yield (t ha^{-1}). However, the formula in obtaining grain yield was expressed in tons per hectare using the formula:

$$Grain\ yield\ (t\ ha^{-1}) = \frac{Yield\ (kg\ plot^{-1})\ x\ 10{,}000 m^2\ ha^{-1}}{Harvestable\ area\ (m^2)\ x\ 1000\ kg\ ton^{-1}}$$

3. Results and Discussion

3.1. Soil Chemical Properties

Table 1 shows that the initial soil analysis indicated that the experimental area was very strongly acidic, with a medium amount of organic carbon and total nitrogen, a high amount of both available phosphorus and exchangeable potassium (Landon, 1991). For final soil analysis, results showed that the organic carbon, available phosphorus, and exchangeable potassium decreased. However, soil pH and the total N (%) increased slightly. The slight reduction in the organic carbon, available P, and exchangeable K might be attributed to the rice plants' utilization of the nutrients above. The slight increase in soil pH might be due to the decomposed rice stubbles of the main crop, the uprooted weeds, and the suspension effect of flooded soils during the growth and development of the crop (Ratilla and Cagasan, 2011). The increased total N could be due to the decayed plant parts, which contributed to the soil's additional amount of organic materials.

Table 1. Initial and final soil analysis of the experimental area planted to lowland rice (*Oryza sativa* L.) varieties as influenced by cutting height of ratoon crop

	Soil pH (H_2O)	Organic carbon (%)	Total N (%)	Available P (mg kg^{-1})	Exchangeable (K) (me $100g^{-1}$)
Initial Soil Analysis	5.04	3.43	0.204	12.86	1.41
Final Soil Analysis	5.16	3.42	0.266	8.07	1.35

3.2. Study Site

The study was conducted at the Visayas State University (VSU), Visca, Baybay City, Leyte, the Philippines, as reflected in Table 2. The experimental site is experiencing type four climatic conditions. The characteristics of this area exposed to rain which more or less evenly distributed throughout the year. However, the study sites' geographical coordinates possessed latitude 10 ^{0} 41' North and 124 ^{0} 48' East (Maplandia.com. 2021). However, the geomorphology and soil type of the study site were vertisols and entisols, respectively (Asio, 1996; Carating *et al.*, 2014).

Table 2. Site characteristics of the experimental area planted to lowland rice (*Oryza sativa* L.) varieties as influenced by cutting height of ratoon crop

Site	Coordinates	Geomorphology	Soil Type	Climate Type
VSU, Baybay City, Leyte, Philippines	10^{0} 41' N & 124 ^{0} 48' E	Vertisols	Entisols	Type 4

3.3. Agronomic characteristics

Statistical analysis showed that all agronomic characteristics of lowland rice varieties to ratooning were significantly (p = 0.01 – 0.05) affected by cutting height except plant height (Table 3). However, all gathered agronomic parameters were significantly (p = 0.01 – 0.05) affected by the different lowland rice varieties tested.

Table 3. Agronomic characteristics of lowland rice (*Oryza sativa* L.) varieties as influenced by cutting height of ratoon crop

Treatment	Number of days from harvesting of the main crop to 50% heading of ratoon crop	Number of days from harvesting of the main crop to harvesting of ratoon crop	Stem elongation (cm)	Plant height (cm)
Cutting height (a)				
C_1= 15.00 cm	43.94a	75.72a	91.27a	106.27
C_2= 45.00 cm	22.44b	49.22b	50.09b	95.09
F value	339.61**	1,763.79**	202.31**	14.91 ^{ns}
Variety (b)				
V_1= PSB Rc18	34.83ab	64.67a	72.63a	102.63a
V_2= NSIC Rc128	27.50d	58.17c	63.00b	93.00b
V_3= NSIC Rc214	36.00a	64.50a	71.77a	101.77a
V_4= NSIC Rc216	30.67c	61.67b	71.60a	101.60a
V_5= NSIC Rc218	32.67bc	61.67b	69.00ab	99.00ab
V_6= NSIC Rc222	37.50a	64.17a	76.07a	106.07a
F value	27.38**	124.24**	7.27**	7.27**
CV (a) %	10.54	3.03	12.29	8.63
CV (b) %	5.21	0.88	5.65	3.97

Means with the same letter and without letter designations in a column are not significantly different at 5% significance level, Tukey's Studentized Range (HSD) Test.

The shorter stubble height (15cm) remarkably extended its 50% heading of ratoon crop (21.5 days) and maturity by 26.5 days than a stubble height of 45cm. This result construed with the findings of Calendacion *et al.* (1991) that lower cutting height of ratoon crop extended its growth period than that of higher cutting height. The stem elongation emanated significantly longer at 91.27cm for 15cm stubble height than only 50.09cm for 45cm stubble height (Table 3). It conformed with Bond *et al.* (2009) that the lower cutting height of ratoon crops produces excellent agronomic characteristics than those ratoon crops at higher cutting height. Relative to the variety used, NSIC Rc222 significantly extended more extended number of days (37.5 days) from harvesting of the main crop to 50% heading of the ratoon crop when compared to all lowland rice varieties tested except NSIC Rc214 (36.0 days) and PSB Rc18 (34.83 days) with the comparable growing period. For the number of days from harvesting of the main crop to the harvesting of ratoon crop, PSB Rc18 remarkably grew more extended period (64.67 days) when compared to NSIC Rc128 (58.17 days), NSIC Rc216 (61.67 days), and NSIC Rc218 (61.67 days) but comparable to NSIC Rc214 (64.50 days) and NSIC Rc222 with 64.17 days. NSIC Rc128 significantly (p=0.01) had the shortest growth period of ratoon crop at maturity (58.17 days) compared to all lowland rice varieties used with growth periods ranged from 61.67 to 64.67 days. The longer days to achieve at 50% heading and until maturity of NSIC Rc222, NSIC Rc214, and PSB Rc18 compared to NSIC Rc128, NSIC Rc216, and NSIC Rc218 were all the manifestations of genetic characters of such varieties under the aforementioned environmental conditions.

Relative to stem elongation, NSIC Rc222 significantly **(**p = 0.01) elongated longer stem or culm (76.07cm) than NSIC Rc128 with only 63.00 cm, but comparable to PSB Rc18, NSIC Rc214, Rc216, and Rc218 with the elongated stems of 72.63, 71.77, 71.60, and 69.00cm, respectively. Similarly, NSIC Rc222 remarkably elongated longer plant height (106.07cm) than that of NSIC Rc128 (93.0cm) but comparable to all other lowland rice varieties such as PSB Rc18, NSIC Rc214, NSIC Rc216, and NSIC Rc218 with plant heights of 102.63, 101.77, 101.60, and 99.0cm), respectively. This result had similar findings with Ruales (2018) that NSIC Rc222 had notably elongated higher plant height when compared to other lowland rice varieties tested under VSU conditions.

3.4. Yield and Yield Component Parameters

Statistical analysis revealed that all yield and yield component parameters were remarkably affected by cutting height except the number of productive tillers and panicle weight (g) (Table 4). About the variety used, all yield and yield components were remarkably affected except panicle length and grain yield (t ha^{-1}). However, no interaction effects were noted on all its yield and yield components based on statistical analysis.

The panicle length remarkably (p = 0.01) developed longer at 27.66cm for 15cm while only 21.44cm for 45cm stubble height (Table 4, Fig 1A). Relative to percent filled grains, the 15cm stubble height produced significantly (p = 0.01) more abundant filled grains with 83.0 percent than at 45cm cutting height with only 73.63 percent (Table 4, Fig. 1C). In terms of percent unfilled grains, 15cm cutting height notably (p = 0.01) developed a higher percentage of unfilled grains (26.37%) than that of 45cm cutting height with only 17.0 percent (Table 4). The ratoon's grain yield remarkably (p = 0.05) attained a higher grain yield of 2.95 t ha^{-1} for 15cm stubble height than 1.72 t ha^{-1} for a stubble height of 45cm (Table 4, Fig. 1D).

Based on the result of the study, the higher grain yield of ratoon in 15cm stubble height was mainly attributed to the remarkable growth and development of stem or culm, produced longer panicles, favored more production of filled grains, and the extended growth period especially in the translocation of photo-assimilates for better grain production during the reproductive phase. Nakano *et al.* (2020) stated that when rice ratooning is practiced, the grain yield of the ratoon crop is affected by the time of harvest and cutting height of the main crop. The data shows that a cutting height of 15cm was harvested late compared to 45cm. However, a cutting height of 15cm has been demonstrated to have more extended stem elongation and panicle length.

Table 4. Yield and yield components of lowland rice (*Oryza sativa* L.) varieties as influenced by cutting height of ratoon crop

Treatment	Number of productive tillers	Panicle length (cm)	Panicle weight (g)	% filled grains	% Unfilled grains	Grain yield of ratoon crop (t ha^{-1})
Cutting height (a)						
C_1= 15.00 cm	18.44	27.66a	3.12	83.00a	26.37a	2.95a
C_2= 45.00 cm	16.15	21.44b	2.92	73.63b	17.00b	1.72b
F value	8.29^{ns}	261.55**	1.86^{ns}	2932.85**	2932.85**	46.72*
Variety (b)						
V_1= PSB Rc18	15.63b	23.89	2.77ab	80.11ab	19.89ab	2.22
V_2= NSIC Rc128	16.47ab	23.86	2.94ab	78.42ab	21.59ab	2.28
V_3= NSIC Rc214	20.13a	23.96	2.53b	69.74b	30.26a	2.16
V_4= NSIC Rc216	18.83ab	25.55	3.44a	83.66a	16.34b	2.74
V_5= NSIC Rc218	16.93ab	24.71	3.02ab	82.12a	17.88b	2.31
V_6= NSIC Rc222	15.80b	25.32	3.41a	75.86ab	24.13ab	2.28
F value	3.97*	2.85^{ns}	5.35**	3.67*	3.67*	1.17^{ns}
CV (a) %	13.78	4.69	14.00	0.66	2.39	23.04
CV (b) %	12.81	4.49	12.48	8.19	29.58	20.07

Means with the same letter and without letter designations in a column are not significantly different at 5% significance level, Tukey's Studentized Range (HSD) Test.

It has also observed heavier weight and a higher percentage of filled grains. Therefore, the cutting height of 15cm notably produces a greater grain yield than the cutting height of 45cm. The results coincide with Calendacion *et al.* (1991) findings that a lower cutting height increases grain yield with prolonged maturity. Szokolay (1956) also found that plants cut at 15cm gave a higher yield than plants cut at ground level. Bahar and De Datta (1977) and Pirdashit *et al.* (2006) have the same findings that 15cm is the optimum cutting height for rice ratooning where greater ratoon yield was produced. Alternatively, Bond *et al.* (2009) reported that the appropriate cutting height positively affects ratoon yield. Hence, the cutting height of 15cm is more productive and has more beneficial effects on the parameters tested than 45cm.

On the other hand, Nakano *et al.* (2020) stipulated that ratooned rice plants grown at higher cutting height produced higher grain yield than those plants grown at lower cutting height. Furthermore, the increased grain yield at higher cutting height was due to the abundant spikelet number m^{-2} and excellent grain filling as mainly attributed by more fantastic LAI and higher nonstructural carbohydrate in the stubble that contribute great carbohydrates during the growing period. However, Jones (1993) suggested that an appropriate main crop harvesting cutting height can elevate ratoon yields but selecting a cultivar with inherent ratooning ability is also essential to successful ratooning. Several researchers, namely: (Harrell *et al.*, 2009; Mareza *et al.*, 2016; Shahri *et al.*, 2012) also reported the results of grain yield in rice ratooning in response to cutting height. They suggested that the effect might be significantly influenced by the environment, as mainly contributed by climate and soil fertility, and variety.

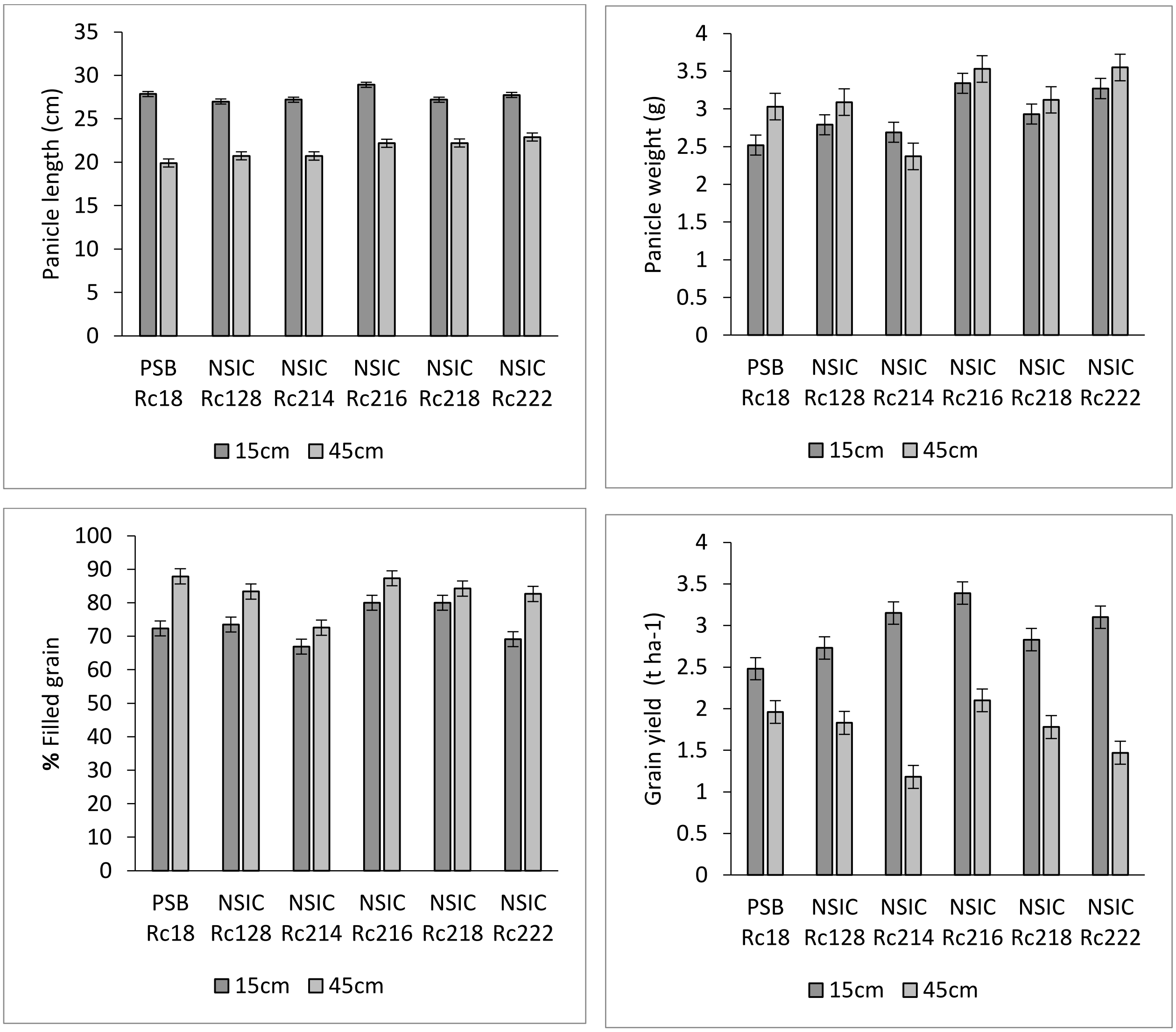

Figure 1. The panicle length (cm) (Fig. 1A), panicle weight (g) (Fig. 1B), percent filled grains (Fig. 1C), and grain yield (t ha^{-1}) (Fig. 1D) of lowland rice (*Oryza sativa* L.) varieties as influenced by cutting heights (15cm & 45cm) of ratooned crop under type four climatic conditions

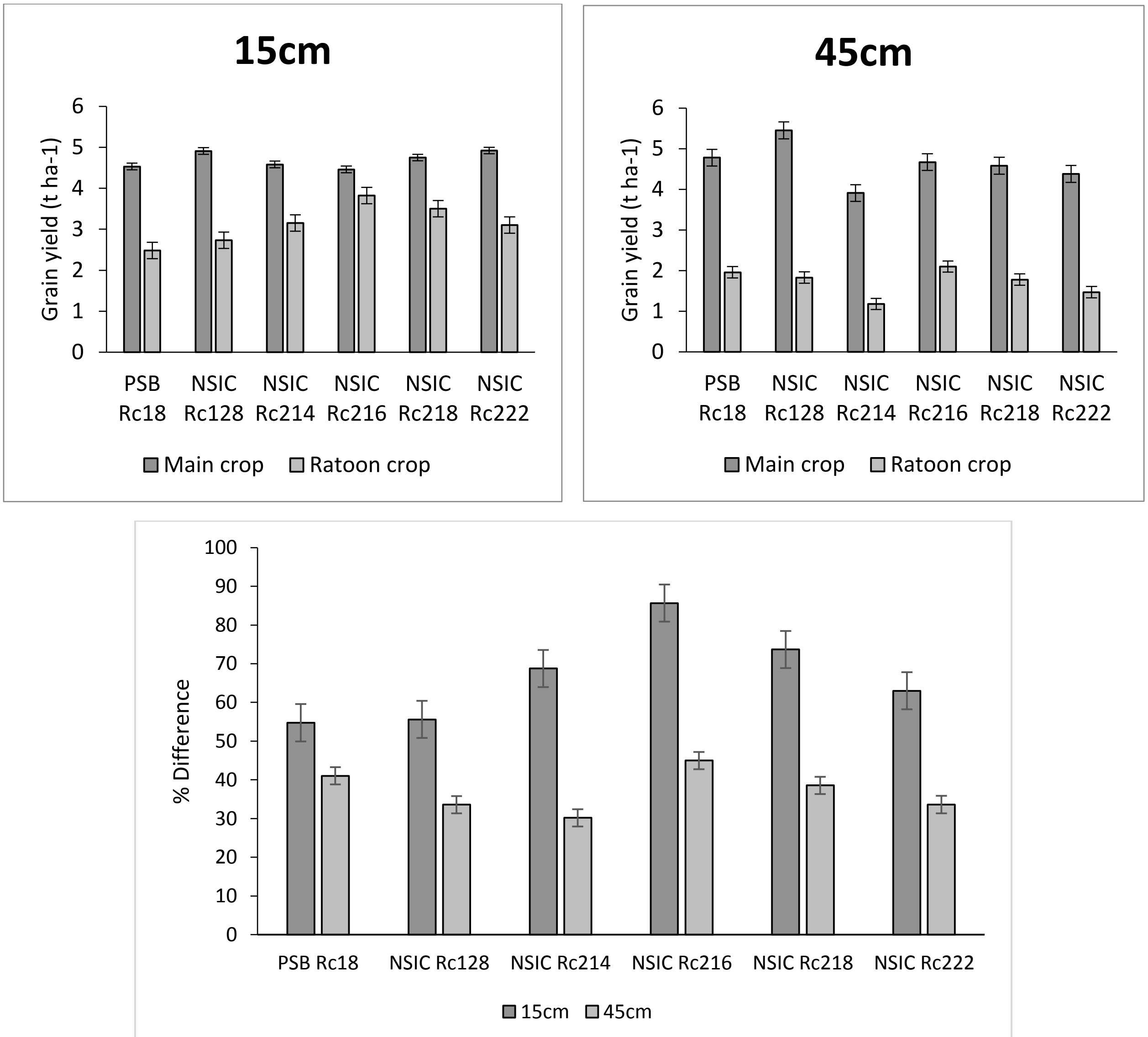

Figure 2. Grain yield (t ha^{-1}) of lowland rice varieties (*Oryza sativa* L.) to ratooning when compared to the main crop as influenced by cutting height at 15cm (Fig. 2A) and 45cm (Fig. 2B) with corresponding percentage difference (Fig. 2C) under irrigated lowland conditions.

For panicle weight and percent filled grains, however, NSIC Rc216 remarkably (p = 0.01 to 0.05) developed heavier weight of panicles (3.44g) and produced a higher percentage of filled grains (83.66%) when compared to NSIC Rc214 with panicle weight (2.53g) and % filled grains of 69.74%, although comparable to all other lowland rice varieties evaluated. In terms of percent unfilled grains, NSIC Rc216 notably (p = 0.05) produced a lower percentage of unfilled grains than that of NSIC Rc214 that produces (p = 0.05) abundant percentage of unfilled grains (30.26%) significantly, but comparable to all other lowland rice varieties tested most especially NSIC Rc218 with percent unfilled grains of 17.88%. Relative to grain yield (t ha^{-1}), the higher grain yield of ratoon crop (2.74 t ha^{-1}) in NSIC Rc216 was mainly attributed to an excellent development of panicles, produced a higher percentage of filled grains, and also developed remarkably lesser percentage of unfilled grains. But it did not contribute to a remarkable difference between all other lowland rice varieties used. With almost similar grain yield of ratoons in this study, we can justify that all six lowland rice varieties are responsive to ratooning when grown under irrigated lowland conditions.

Rice variety selection is one of the significant decisions made by a rice farmer before planting the crop. The different rice varieties differ in their ratooning ability. NSIC Rc216 has consistent results by having the heavier panicle weight, the highest percentage of filled grains, and the lowest percentage of unfilled grains. These three parameters regarding panicle weight, percent filled, and unfilled grains were considered prominent yield components. Thus, it connotes that NSIC Rc216 produces maximum ratoon yield among all the rice varieties tested. A similar result was obtained with Gajete *et al.* (2018) study that the lowland rice variety, NSIC Rc216, was brought to have better performance and high grain yield under ratooning technology management.

Figure 2 presents the grain yield (t ha^{-1}) of lowland rice varieties (*Oryza sativa* L.) to ratooning compared to the main crop as influenced by two cutting heights. Results revealed that NSIC Rc216 is the most outstanding variety under rice ratooning. It produces the highest grain yield and higher differences relative to the main crop among all other rice varieties tested. However, it was noted that at 15cm cutting height, it produced a higher grain yield compared to the cutting height of 45cm. Gajete *et al.* (2018) reported that NSIC Rc216 showed better performance when ratooned and can be ratooned both in irrigated and rainfed conditions. The lowland rice varieties such NSIC Rc214, NSIC Rc218, and NSIC Rc222 obtained better yields under ratooning at 15cm cutting height. The study results are similar to the findings of Ruales (2018) that NSIC Rc216, NSIC Rc214, NSIC Rc218, and NSIC Rc222 acquired better ratoon yield under similar agro-ecological conditions.

3.5. Cost and return analysis

Cost and return analysis revealed that the cutting height of ratoon crop at 15 cm obtained a higher gross income (USD 1,180.00) and gross margin (USD 896.60) than that of 45cm cutting height with gross income and gross margin of USD 688.00 and USD 468.56, respectively (Table 5). The higher gross income and gross margin of 15cm cutting height were mainly due to the higher grain yield of such endeavor.

Relative to the different lowland rice varieties tested, the NSIC Rc216 remarkably achieved the highest gross income (USD 1,096.00) and gross margin with USD 823.52 due to higher grain yield, followed by NSIC Rc218 with gross income and gross margin of USD 924.00 and USD 673.88, respectively. Based on the results obtained, a cutting height of 45cm, obtained a lower gross margin (USD 468.56), is not highly recommended for rice ratooning if the main purpose is to attain higher productivity. But suppose the objective is to produce ratoon grain yield for a shorter growth period. In that case, the cutting height of 45cm is also one of the best strategies in obtaining yield under the urgent need of rice production, albeit climate change situation.

Table 5. Cost and return analysis of lowland rice (*Oryza sativa* L.) varieties as influenced by cutting height of ratoon crop

Treatment	Grain yield ($t\ ha^{-1}$)	Gross income (USD)	Total variable cost (USD)	Gross margin (USD)
Cutting height (a)				
C_1= 15.00 cm	2.95	1,180.00	283.40	896.60
C_2= 45.00 cm	1.72	688.00	219.44	468.56
Mean	2.33	934.00	251.42	682.58
V_1= PSB Rc18	2.22	888.00	245.44	642.56
V_2= NSIC Rc128	2.28	912.00	248.56	663.44
V_3= NSIC Rc214	2.16	864.00	242.32	621.68
V_4= NSIC Rc216	2.74	1,096.00	272.48	823.52
V_5= NSIC Rc218	2.31	924.00	250.12	673.88
V_6= NSIC Rc222	2.28	912.00	248.56	663.44
Mean	2.33	934.00	251.42	682.58

4. Conclusion

Cutting height significantly influenced the number of days from harvesting the primary crop to 50% heading until harvesting the ratoon crop. In as much as the stem elongation, panicle length, percent filled grains, and grain yield of ratooned lowland rice varieties, especially when ratooned at 15 cm cutting height was also remarkably affected. NSIC Rc216 produced a high grain yield (2.74 t ha^{-1}) and achieved a higher gross margin (USD 823.52) due to the higher grain yield of the ratooned crop.

Recommendations

The study strongly recommends using NSIC Rc216 rice variety and a cutting height of 15cm for excellent ratooning performance. The lowland rice varieties such as NSIC Rc214, NSIC Rc218, and NSIC Rc222 are also recommended for rice ratooning under similar soil and agro-ecological conditions. Thereby, the results of this study are recommended for quick adoption by rice farmers in alleviating their rice production and income, albeit in the worst scenario of climate change.

Declaration of Competing Interest

All authors declare no competing interest.

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