Ratooning Response of Lowland Rice (*Oryza sativa L.*) var. PSB Rc22 to Production Management Practices

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Abstract

This study aimed to determine the ratooning ability of lowland rice to production management practices. It assessed the profitability of rice ratooning to the abovementioned objectives. The experiment was set out in a split-plot organized in a Randomized Complete Block Design with production management practices as the main plot and cutting heights of ratoon crop as the subplot treatment. Production management practices notably affected all agronomic characteristics, yield, and yield component parameters evaluated except the grain yield. Cutting height remarkably influenced all growth and yield parameters tested except panicle weight. Economic analysis revealed that the improved method achieved a higher gross margin (PHP21,321.60) than the farmer's practice (PHP15,419.40) because of the former's high productivity (1.64 t ha^{-1}). A cutting height of 45.0 cm under the improved method obtained the highest gross margin (PHP28,677.00). Moreso, this approach is considered a good measure in adapting to the problematic scenario relative to climate change.

Keywords: approach, gross margin, lowland rice, management, ratooning

1.0 Introduction

Rice (*Oryza sativa* L.) is the world's most useful cereal crop, and ratooning is one of the potential management technologies to increase rice production. According to Ibabao (2018) that rice ratooning is contemplated as the most primordial practice which can provide 60% productivity vis-à-vis the main crop. However, a better yield of the ratoon crop is possible by adopting appropriate management practices for the primary crop and the ratoon crop. It is essential to increase the yield of rice sustainably (Singh et al., 2021). Improving nutrient management is one of the techniques to increase the rice yield from traditional farmers' practices. The application of NPK fertilizers significantly increased rice yield at a recommended rate depending on the location. Fertilization at the rate of 90–60–60 kg ha^{-1} N, P_2O_5, and K_2O is adequate to produce higher rice yield, thereby high gross margin. Aside from the proper nutrient management to increase rice yield and productivity, ratooning allows the planted rice crop to regrow right after harvesting. Ratooning is the process of growing rice from a previous crop's leftover stubbles. It is generally considered to be an excellent strategy to increase lowland rice production. It saves time and money by eliminating two labor-intensive processes: intensive seedling raising in the seedbed and transplanting. It also improves resource use efficiency per unit of time and unit of land area (Santos et al., 2011, as cited in Baňoc & Asio, 2019). In the Philippines, a few studies concentrating on refining this technique have been conducted. Thus, this study aimed to determine the growth and yield performance of farmers' preferred lowland rice variety as influenced by production management practices of the primary and ratoon crops and the cutting height of the ratoon crop. To assess the profitability of ratooning, farmers' preferred lowland rice variety PSB Rc22.

2.0 Materials and Methods

Study site

The experiment was conducted at the farmer's field of Brgy. Marcos, Baybay City, Leyte, the Philippines, from December 18, 2020, to June 25, 2021, with farmer-partner Mr. Dante Vega. The experimental site has been characterized by experiencing type four climatic conditions, wherein it is exposed to precipitation that is evenly distributed throughout the year. The study sites' geographical coordinates possess a latitude of 10^0 41' North and a longitude of 124^0 48' East ("Eastern Visayas latitude and longitude", 2022). The geomorphology and soil type of the area were vertisols and entisols, respectively (Asio, 1996; Carating et al., 2014).

Establishment and management of the primary crop

A farmer's preferred lowland rice variety (PSB Rc22) was used to establish a field experiment during the dry season. The variety is commonly known as "Liliw," a farmer's favored lowland rice variety, and is widely grown because of its high yields, ranging from 5.0–7.2 tons ha^{-1}, and its excellent eating quality. It matures at 129 days with an average plant height of 96 cm, and intermediate resistance to brown planthopper, bacterial leaf blight, blast, and green hopper (University of the Philippines Los Baños, 2018).

The trial was set out in a split-plot organized in a Randomized Complete Block Design (RCBD) with three replications. The aforesaid variety was used for the experiment following the production management practices. The improved method and farmer's practice served as the main plot, while the five cutting heights of the ratoon crop served as the sub-plot treatments. The improved method adopted the transplanting approach using 1 – 2 seedlings per hill and the fertilization rate of 120–60–60 kg ha^{-1} N, P_2O_5, and K_2O for the primary crop while 90 kg ha^{-1} N for the ratoon crop. However, for the farmer's practice, this option followed a transplanting method using 8 – 10 seedlings per hill and a fertilization rate of 75–15–15 kg ha^{-1} N, P_2O_5, and K_2O for the primary crop, while no fertilizer application for the ratoon crop. The fertilization rate between primary and ratoon crops varied based on the result of our previous research undertakings that the ratoon crop only needs nitrogenous inorganic fertilizer (urea) when compared to the main crop that is fertilized with complete NPK fertilizers (Baňoc, 2020). Evatt and Beachell (1960) mentioned that to attain a higher grain yield of ratoon crops, the crops were applied at a 75% level of N vis-a-vis with the maincrop. Relative to the differences in fertilization rates between production management practices, the improved method adopting 120–60–60 kg ha^{-1} N, P_2O_5, and K_2O was based on the Department of Agriculture and VSU's fertilizer recommendation while the farmers' practice was mainly based on the current rate of fertilizer application in most rice farmers in lowland farming communities in Eastern

Visayas. The treatment plot that measures 5 m × 2 m was separated by one meter and 0.5 m alleyways between replications and treatments.

The following treatments were designated as follows:

Main plot: Production management practices

- M_1: Improved method
- M_2: Farmer's practice
- S_1: Stubble height of 7.5 cm from the soil surface
- S_2: Stubble height of 15.0 cm from the soil surface
- S_3: Stubble height of 30.0 cm from the soil surface
- S_4: Stubble height of 45.0 cm from the soil surface
- S_5: Stubble height of 60.0 cm from the soil surface

The seeds of the farmer's preferred lowland rice variety PSB Rc22 were soaked for 24 hours and incubated for 48 hours before sowing in the prepared seedbed. The seedlings were raised in the seedbed for 15 days. These were pulled using bare hands before transplanting. The rice seedlings are transplanted under different production management practices adopting a planting distance of 20 cm × 20 cm. However, the improved method transplanted only 1 – 2 seedlings hill^{-1} while the farmers' practice adopted 8-10 seedlings hill^{-1}.

Rice plants were applied with inorganic fertilizers using complete fertilizer (14–14–14) and urea (46–0–0) at different application rates. For the two production management practices, the improved method followed a fertilization rate of 120–60–60 kg ha^{-1} N, P_2O_5, K_2O for the primary crop, and 90 kg ha^{-1} N for the ratoon crop. In contrast, the farmer's practice adopted a fertilization rate of 75 –15–15 kg ha^{-1} N, P_2O_5, and K_2O for the primary crop and no fertilization for the ratoon crop.

In applying complete fertilizer, 60 kg N, P_2O_5, and K_2O ha^{-1} were adopted for the improved method ten days after transplanting (14–14–14). The remaining 60 kg N ha^{-1} was applied using urea (45–0–0) at the panicle initiation (PI) stage. However, 15 kg ha^{-1} N, P_2O_5, and K_2O were applied using complete fertilizer (14–14–14) ten days after transplanting for the farmer's practice. The remaining 60 kg ha^{-1} N was also applied at the PI stage using urea (45–0–0).

Proper care and management such as proper rotary and hand weeding operations, water management, pest, and disease management were strictly followed. The different stubble heights adopted under the five subplot treatments were strictly followed at harvesting the primary crop.

Management of the ratoon crop

The same experimental layout in a split-plot is arranged in RCBD with two production management practices as the main plot and five stubble heights of ratoon crop as the subplot with three replications.

Urea (46–0–0) fertilizer was applied at the rate of 90 kg ha^{-1} N and split into two applications at 45 kg ha^{-1} at ten days after harvesting the primary crop and the other half at the panicle initiation stage of the ratoon crop.

Cultural management practices for the primary crop were done similarly for the ratoon crop except for the stubble height and fertilizer management. At harvesting, the primary crop, the five heights of 7.5 cm, 15 cm, 30 cm, 45 cm, and 60 cm for the ratoon crop, was followed.

The data on agronomic and yield components were collected only for the ratoon crop since this experiment focuses only on the ratooning ability of farmers' preferred lowland rice variety to production management practices of the primary and ratoon crops and different cutting heights of the ratoon crop. The ratoon crop also attained maturity similar to the primary crop.

Data Collection

The data gathered were the number of days from harvesting of the primary crop to the harvesting of the ratoon crop, plant height (cm), stem elongation (cm), panicle length (cm), panicle weight (g), % filled grains, and grain yield (t ha^{-1}). The grain yield (t ha^{-1}) was obtained by weighing the harvested grains from the harvestable area at maturity. The parameter was expressed in tons per hectare using the formula:

$$\text{Grain yield (t ha}^{-1}) = \frac{\text{Yield (kg plot}^{-1}) \times 10{,}000 \text{ m2 ha}^{-1}}{\text{Harvestable area (m2)} \times 1{,}000 \text{ kg ton}^{-1}}$$

3.0 Results and Discussion

Soil chemical properties

The initial soil analysis revealed that the experimental area was strongly acidic (4.79), medium amount of both organic carbon (5.0%) and total nitrogen (0.37%), a meager amount of obtainable phosphorus (3.38 mg/kg), and a high amount of exchangeable potassium (1.31 me/100g) (Landon 1991). For the final soil analysis relative to the experimental plot under the farmer's practice, results showed that the organic carbon (4.77%), total N (0.36%), obtainable phosphorus (2.53 mg/kg), and convertible potassium (0.79 me/100g) decreased slightly but maintained on its pH level at 4.79 (Table 1). For the experimental plot under the improved method, organic carbon (4.92%) and convertible potassium (0.83 me/100g) were reduced when compared to the initial soil analysis while slightly increasing their soil pH (5.01), total N (0.39%), and obtainable phosphorus at 4.01 mg/kg.

The slight reduction in the organic carbon, total N, obtainable P, and convertible K in the experimental plots under the farmer's practice might be attributed to the rice plants' utilization of the nutrients above. Similarly, under the improved method, the reduction in organic carbon and convertible potassium was also due to the utilization of the ratooned crop for their growth and development. The slight increase in soil pH might be attributed to the decomposed rice stubbles of the primary crop, the transformation of organic matter by the decomposed uprooted weeds, and the suspension effect of flooded soils during the period of its crop growth and development (Ratilla & Cagasan, 2011). The increased total N and obtainable phosphorus might be due to the decayed plant parts, which contributed to sustaining the amount of organic matter in the soil.

Table 1. *Initial and final soil analyses under the improved method and farmer's practice as influenced by production management practices of the primary and ratoon crops and the stubble height of the ratoon crop*

Treatment	Soil pH (H_2O)	Organic carbon	Total N (%)	Obtainable P (mg kg^{-1})	Convertible (K) (me $100g^{-1}$)
Initial soil analysis	4.79	5.00	0.37	3.38	1.31
Final soil analysis					
Farmer's practice	4.79	4.77	0.36	2.53	0.79
Improved method	5.01	4.92	0.39	4.01	0.83
Mean (Final analysis)	**4.90**	**4.84**	**0.38**	**3.27**	**0.81**

Agronomic characteristics, yield, and yield component parameters

Statistical analysis revealed that the ratoon lowland rice variety (PSB Rc22) responded appreciably to adopting production management practices in all agronomic and yield and yield component parameters gathered except the grain yield (Tables 2 & 3). Ratoon lowland rice elongated longer stem or culm, produced longer and heavier panicles, and developed higher-filled grains. There was a remarkable increase in the parameters mentioned above of ratoon lowland rice variety PSB Rc22 in the improved method compared to farmer's practice; however, it did not markedly affect ratoon grain yield compared to the latter approach. Although the improved method had a slightly higher ratoon grain yield of 1.63 t ha^{-1} than the farmer's practice with only 1.01 t ha^{-1}.

Based on the crop production management practice adopted, ratooned plants under the improved method substantially elongated a taller plant height (88.67 cm) than the farmer's approach with a plant height of 78.38 cm (Table 2). It signifies more nutrients were provided to the crop resulting in taller plants. This result is corroborated by the findings of Baňoc (2020) who reported that ratoon plants supplied with available nutrients remarkably influenced increased growth and development that led to enhance the productivity of tillers, longer and heavier panicles, excellent development of grains, and higher productivity of grains. Ratoon plants under the improved method extended a remarkably long period of maturity (58.87 days) than those ratoon plants grown under the farmers' practice with only 56.80 days (Table 2). The result explained further that more nutrients provided by both primary and ratoon crops eventually extended the vegetative growth phase of ratooned and favored productive tillers due to healthy regrowth and a sufficient number of productive tillers during the primary crop growth. According to Ye et al. (2019), increasing the application of fertilizers, especially N nutrients, prolonged the vegetative phase and delayed the flowering duration of rice.

Table 2. *Plant height and the number of days from harvesting the primary crop to harvesting the ratoon crop of lowland rice (Oryza sativa* L.*) var. PSB Rc22 as influenced by production management practices of the primary and ratoon crops and the stubble height of the ratoon crop*

Treatment	Plant height (cm)	Days from harvesting of the main crop to harvesting of ratoon crop
Management practice (a)		
Improved method	88.67a	58.87a
Farmer's practice	78.38b	56.80b
Mean	83.52	57.83
Stubble height - cm (b)		
S_1 = 7.5 cm	82.44	72.67a
S_2 = 15.0 cm	83.27	67.00b
S_3 = 30.0 cm	79.33	51.00c
S_4 = 45.0 cm	86.16	50.00d
S_5 = 60.0 cm	86.00	48.50e
Mean	83.44	57.83
CV (a) %	2.45	0.83
CV (b) %	5.17	0.89

Means within a column and treatment with the same letter and those without letter designations are not significantly different at a 5% significance level based on Tukey's Honestly Significant Difference (HSD) test.

Ratoon plants at stubble height of 7.5 cm (S1) notably extended their growth as indicated by its highest number of days (72.67 days) from harvesting the primary crop to harvesting the ratoon crop compared to all stubble heights being compared. These were followed by ratoon plants with stubble height of 15.0 cm (67.0 days), 30.0 cm (51.0 days), and 45.0 cm (50.0 days), and the shortest period of maturity was remarkably achieved in ratoon plants with stubble height of 60.0 cm with only 48.50 days. The trend shows that with the increasing stubble heights, there was also a corresponding reduction in the number of days from harvesting the primary crop to harvesting the ratoon crop. Thereby, taller stubble heights have a short vegetative stage since ratoon shoots of the higher nodes grow faster than those produced by the lower nodes, thus the ratoon plants are harvested earlier. This is confirmed by the findings of Mareza et al. (2016), the higher the cutting above the soil surface the shorter time in the vegetative growth phase of the ratoon crop. The longer the stubble height, the quicker its time in the vegetative phase (Mareza et al., 2016), so the stubbles with a height of 60 cm did not need much time in the stem elongation. In effect, the cutting height of 60 cm achieved the shortest elongation of the stem. The results coincide with *Rice ratooning: A technology to increase production* (2007) findings that the decline of cutting height causes a delay in the maturity of the ratoon grains. This is because the shorter stubble height will take a longer time in regrowing the culm or in the elongation of the stem.

In contrast, ratoon plants under the farmer's practice only used a limited amount of inorganic fertilizers (75–15–15 kg ha^{-1} N, P_2O_5, and K_2O) for the primary crop. However, there was no fertilizer applied for the ratoon crop. Thus, the improved method significantly increases PSB Rc22 since it provided an adequate amount of nutrients needed by the ratoon plants compared to the plants under the farmer's practice, which only applies a minimum amount of inorganic fertilizer during primary crop growth and development. Hence, it has a shorter ratooned plant height under the farmer's method than the improved approach. Besides, applying inorganic fertilizer, especially N, helps enhance the development of flowers at the heading stage of the ratoon crop than those plants under the farmer's practice. According to Oad et al. (2002), N fertilizer application is considered essential nutrient management for elevating the growth and yield of the ratoon crop. Wasli and Mansi (2019) reported that fertilizer is one of the most critical factors and primary input in rice production, wherein excellent fertilizer management accelerates rice yield. Slaton et al. (2001) reported that fertilizers are needed to provide the plant's nutrient requirements and attain high performance in producing grain yield. Ye et al. (2019) said that yield components were increased when applying high rates of NPK fertilizers.

Statistical analysis revealed that crop production management practices outstandingly affected stem elongation, panicle length, panicle weight, and % filled grains but not the grain yield of the ratoon crop (Table 3). Stubble height contributed a significant effect to all parameters above except panicle weight (g). However, no interaction effect was noted in all parameters evaluated.

Results showed that the improved method substantially promoted the elongation of the stem (56.83 cm) of ratoon plants than those under the farmer's practice with stem elongation of 46.89 cm. Relative to panicle length (cm), the improved approach notably elongated longer panicles (22.11 cm) of ratooned when compared to those panicles under the farmer's practice with only 19.37 cm. For the panicle weight, however, the improved method produced a remarkably heavier panicle (3.14g) vis-à-vis with farmer's practice with 2.21g. Ratoon plants under the improved way had importantly higher % filled grains (77.0 %) than that of farmer's practice with only 65.31 percent. This result agrees with the findings of Javier et al. (2002) stipulated that the effective and efficient utilization of nutrients for the rapid growth and development of plant parts responded mainly to achieving a heavier weight of panicles and longer panicle length, and more abundant filled grains.

Ratoon plants are grown with a cutting height of 7.5 cm (S_1) notably achieved longer stem elongation (74.94 cm) than those ratoon plants grown at different cutting heights; 15.0 cm, 30.0 cm, 45.0 cm, and 60.0 cm with stem elongation of 67.44 cm, 49.73 cm, 41.17 cm, and 26.00 cm, respectively (Table 3). Results showed that in the shorter cutting heights of ratooned, there were also corresponding increases in the stem elongations as indicated. In contrast, the higher stubble height, especially at 60.0 cm, has the shortest stem elongation (26.0 cm). The longer the stubble height, the faster its time in the vegetative growth phase (Mareza et al., 2016). The stubble height of 7.5 cm (S_1) remarkably elongated longer panicle length (23.60 cm) when compared to all subplot treatments adopted except ratoon plants with stubble height of 15.0 cm (S_2) with a comparable panicle length of 22.32 cm. Although ratoon plants with stubble height of 60.0 cm seriously reduced their panicle length (19.03 cm) as construed with the shortest stem elongation (Table 3). Relative to percent filled grains of the ratoon crop, the longer stubble height, especially at 60.0 cm (S_5), notably enhanced its % filled grains (83.28%) when compared to those ratoon plants with a stubble height of 15.0 cm (S_2) and 7.5 cm (S_1) with % filled grains of 57.15% and 54.45%, respectively. However, S5 plants did not crucially differ with stubble heights of 45.0 cm (S_4) and 30.0 cm (S_3), which achieved % filled grains of 82.84% and 78.05%, respectively.

Table 3. *Grain yield (t ha-1) and other component parameters of ratoon lowland rice (Oryza sativa* L.*) var. PSB Rc22 as influenced by production management practices of the primary and ratoon crops and the stubble height of the ratoon crop*

Treatment	Stem elongation (cm)	Panicle length (cm)	Panicle weight (g)	% filled grains	Grain yield (t ha^{-1})
Management practice (a)					
Improved method	56.83a	22.11a	3.14a	77.00a	1.64
Farmer's practice	46.89b	19.37b	2.21b	65.31b	1.01
Mean	51.86	20.74	2.67	71.15	1.33
Stubble height from the soil surface (cm) (b)					
S_1 = 7.5 cm	74.94a	23.60a	2.43	54.45b	1.30ab
S_2 = 15.0 cm	67.44b	22.32ab	2.61	57.15b	1.47a
S_3 = 30.0 cm	49.73c	19.87bc	2.71	78.05a	0.87b
S_4 = 45.0 cm	41.17d	18.90c	2.85	82.84a	1.51a
S_5 = 60.0 cm	26.00e	19.03c	2.77	83.28a	1.48a
Mean	51.86	20.74	2.67	71.15	1.33
CV (a) %	2.50	9.03	6.82	5.01	35.93
CV (b) %	8.04	12.62	17.49	11.61	27.38

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

Relative to grain yield, ratoon plants with a stubble height of 45.0 cm (S4) markedly produced a higher grain yield (1.51 t ha^{-1}) when compared to ratoon plants grown under the stubble height of 30.0 cm (S3) with a grain yield of 0.87 t ha^{-1}. The grain yield of S4 plants was comparable to those of ratoon plants grown with stubble heights of 60.0 cm (1.48 t ha^{-1}), 15.0 cm (1.47 t ha^{-1}), and 7.5 cm (1.30 t ha^{-1}). Even though the ratoon plants with stubble height of 45.0 cm have the shortest panicle length (18.90 cm) and only achieved 82.84% filled grains but still managed to produce the highest grain yield (1.51 t ha^{-1}) among the stubble height treatments. The results are similar to Daliri et al. (2009); Dunand and Dilly (2005) and Nassiri et al. (2011) that which the cutting height of ≥ 40 cm produced a higher grain yield. The higher the cutting height, it implies more presence of nodes and internodes in a ratooned crop. The number of nodes is vital for crop productivity since lateral buds emerged into the nodes and transformed into ratoon tillers. The number of nodes influences the number of ratoon tillers, and tillers reflect the formation of grains, thus producing higher grain yield (Daliri et al., 2009; Harrel et al., 2009; Nassiri et al., 2011). This result agrees with Daliri et al. (2009) that the 40 cm stubble cutting height of the ratoon is enough to produce a higher grain yield. Saran and Prasad (1952) discovered that cutting the main crop at ground level resulted in lower ratoon yields than cutting it at 50% of its height. Cutting the plants 35 cm above ground level (50 percent of the main crop height) resulted in the highest yield of 566 kg ha^{-1}, compared to 68 kg ha^{-1} for plants cut near the ground. Palchamy and Soundrapandian (1988) stipulated that longer stubble height is vital in maintaining better ratoon growth because the presence of sufficient buds is necessary on stem or crown tissue for the production of fast-growing tillers. Wilson (2001) suggested a better yield of ratoon crops; it is possible to adopt appropriate management practices for both the main and ratoon crops. Santos et al. (2011) noted that a better yield of ratoon crops is possible by adopting appropriate management practices for both the main and ratoon crops. However, the grain yields of both the main and ratoon crops were strongly correlated with the number of tillers $plant^{-1}$, several productive tillers $plant^{-1}$, grain $panicle^{-1}$, fertile grain $panicle^{-1}$, and 1,000-grain weight (Faruq et al., 2014). They further stipulated that this inquiry supports rice breeders and producers to contemplate rice ratooning as a salient practice in sustaining rice production in the tropics.

The study's significant result relative to grain yield of ratoon crop was mainly attributed to the considerably higher percentage of filled grains developed in more extended cutting height, especially at 45 cm and 60 cm. Oad et al. (2002) pointed out variations in the physiological parameters between the primary and ratoon crops. For instance, the panicle development and heading are more uneven in the ratoon than in the main crop. Mareza et al. (2016) reported that rice ratoon responses to main crops cutting height at harvest depend on location, varieties, and cultivation. According to an article "Rice ratooning: A technology to increase production" (2007), a better yield of ratoon crops is possible by adopting appropriate management practices for the main crop and the ratoon crop. These management practices include the application of an adequate rate of fertilizers and proper height of cutting. This result agrees with the study of Javier et al. (2002) that readily available macronutrients (NPK) provided by the inorganic fertilizer enhanced the growth and development of rice plants leading to the production of longer panicles, more filled grains, heavier grains, and, consequently, higher grain yield. These management practices include land preparation, adequate plant density, and spacing, use of proper cultivars, water management, a reasonable rate of fertilizers, the appropriate height of cutting, and control of diseases, insects, and weeds. Based on the result of the study, the higher grain yield of ratoon crops in 45 cm cutting size from the soil surface was mainly favored by more filled grains in the translocation of photoassimilates for better grain yield production during the reproductive phase. The relatively higher yields of ratoon crops in all treatments adopted were mainly attributed to the non-presence of insect pests and diseases damaging the ratoon crops. Besides, attacking rodents and birds (Maya & Gorion) did not also hamper the production and development of grains, as this coincides with the mating and/or nurturing of the aforesaid rodents and birds for their multiplication and existence (based on farmers' interviews).

Comparative performance between improved method and farmer's practice

Table 4 presents the comparative percentage difference between the grain yield of the primary and the ratoon crops adopting two crop production management practices and the different stubble heights were noted. Results showed that the improved method generally appeared with higher % difference values when compared to the farmer's approach adopted, with stubble height of 45.0 cm (S_4) as the highest value (21.51%), followed by stubble height of 60.0 cm (S_5) with 17.32 %, then stubble heights of 15.0 cm (S_2), 7.5 cm (S_1), and 30.0 cm (S_3) with 16.87 %, 14.6%, and 10.40%, respectively. In contrast, the farmer's practice generally resulted in lower % difference values when compared to the improved method. Still, within its practice, a cutting height of 60.0 cm (S_5) achieved the highest % difference value (12.11%) then followed by stubble heights of 15.0 cm (S_2), 7.5 cm (S_1), 45.0 cm (S_4), and 30.0 cm (S_3) with % difference values of 11.76%, 11.53%, 9.85%, and 6.41%, respectively.

Based on the comparative difference analysis formulated, this signifies that the improved method generally contributed to higher productivity of ratoon plants vis-à-vis the primary crop, mainly when grown at a stubble height of 45.0 cm (Table 4). This result confirmed the findings of Mareza et al. (2016) that the higher the stubble height, the more abundant nodes, and internodes developed in the said undertaking, as sufficient production of nodes also produced more productive tillers. The more nodes developed, the more possibility of ratoon tillers emerging, leading to higher productivity of the ratooned crop. However, the overall mean % difference was obtained in the improved method with 16.00% compared to farmers' practices with 10.26%. Thus, this comparative analysis entails a significant difference between the main crop's two management practices and the ratoon crop's stubble height.

Cost and return analysis

Cost and return analysis revealed that the improved method produced higher ratoon grain yield (1.64 t ha^{-1}) that contributed mainly to a higher gross income (PHP 32,800.00) and gross margin of PHP 21,321.60 when compared to farmer's practice with gross income and gross margin of PHP 20,200.00 and PHP 15,419.40, respectively. Comparing the two methods evaluated, adequate differences in grain yield (0.63 t ha^{-1}), gross income (PHP 12,600.00), and gross margin (PHP 6,697.80) were determined (Table 5).

Relative to the cutting height of the ratoon crop, a stubble height of 45 cm (S_4) under the improved method obtained the highest gross income (PHP 41,000.00) and gross margin of PHP 28,677.00 due to the higher grain yield of the ratoon crop. It was followed by ratoon plants with stubble height of 60.0 cm (S_5) and 15.0 cm (S_2) with gross margins of PHP 24,550.00 and PHP 23,474.40, respectively. For the farmer's practice, a stubble height of 15.0 cm (S_2) was achieved higher than the traditional practice adopted with a gross income (PHP 23,400.00) and gross margin of PHP 18,289.80. On the other hand, the lowest ratoon grain yield in cutting height of 30.0 cm obtained in both improved method and farmer's practice consequently achieved the lowest gross margins of PHP 11,454.60 and PHP 8,781.60, respectively.

Regarding conceptual economic analysis on stubble height for the improved method and farmer's practice, the former process is generally inclined to produce higher and more profitable at higher stubble heights (45.0 cm and 60.0 cm) than those of lower stubble heights, particularly at 7.5 cm. In the later practice (farmer's practice), this option is generally inclined to benefit at lower stubble heights (7.5 cm and 15.0 cm) compared to a higher stubble height of 45.0 cm

Table 4. *The comparative difference in grain yield (t ha-1) of lowland rice (Oryza sativa* L.*) var. PSB Rc22 between main and ratoon crops as influenced by production management practices of the primary and ratoon crops and the stubble height of the ratoon crop*

Stubble height from the soil surface (cm)	Improved method			Farmer's practice		
	Main crop	Ratoon crop	% Difference	Main crop	Ratoon crop	% Difference
S_1 = 7.5 cm	10.31	1.47	14.26	9.89	1.14	11.53
S_2 = 15.0 cm	10.43	1.76	16.87	9.95	1.17	11.76
S_3 = 30.0 cm	10.48	1.09	10.40	9.98	0.64	6.41
S_4 = 45.0 cm	9.53	2.05	21.51	9.95	0.98	9.85
S_5 = 60.0 cm	10.51	1.82	17.32	9.41	1.14	12.11
Mean	10.25	1.64	16.00	9.84	1.01	10.26

Table 5. *Cost and return analysis of ratoon lowland rice (Oryza sativa* L.*) var. PSB Rc22 as influenced by production management practices of the primary and ratoon crops and the stubble height of the ratoon crop*

Treatment	Grain yield (t ha^{-1})	Gross income (PHP)	Total variable cost (PHP)	Gross margin (PHP)
Management practice (a)				
Improved method	1.64	32,800	11,478.40	21,321.60
Farmer's practice	1.01	20,200	4,780.60	15,419.40
Difference	0.64	12,600	6,697.80	5,902.20
Stubble height from the soil surface (cm) (b)				
Improved method				
S_1 = 7.5 cm	1.47	29,400	11,128.20	18,271.80
S_2 = 15.0 cm	1.76	35,200	11,725.60	23,474.40
S_3 = 30.0 cm	1.09	21,800	10,345.40	11,454.60
S_4 = 45.0 cm	2.05	41,000	12,323.00	28,677.00
S_5 = 60.0 cm	1.82	36,400	11,849.20	24,550.80
Farmer's practice				
S_1 = 7.5 cm	1.14	22,800	5,048.40	17,751.60
S_2 = 15.0 cm	1.17	23,400	5,110.20	18,289.80
S_3 = 30.0 cm	0.64	12,800	4,018.40	8,781.60
S_4 = 45.0 cm	0.98	19,600	4,718.80	14,881.20
S_5 = 60.0 cm	1.14	22,800	5,048.40	17,751.60

4.0 Conclusion

Improved practice produced taller plants than the farmer's practice but took a longer maturity period for the ratoon crop. It has appreciably more days to harvesting ratooned, longer panicle length, heavier weight per panicle, and greater % filled grains than the farmer's practice.

Based on the results obtained, the ratoon lowland rice has good growth and greater yield under the improved method with a stubble height of 45 cm. A notable profit is achieved by rice ratooning of lowland rice under the improved technique and with a stubble height of 45 cm since these two options have greater ratoon yield than the farmer's practice with the other stubble heights tested. Generally, the improved method of ratooning produced a higher grain yield than those plants under the farmer's existing rule. Thereby, this is considered a more profitable investment to adapt and adjust to the problematic situation brought by mild and worst-case scenarios of climate change.

Recommendations

This study firmly recommends using PSB Rc22 adopting the improved method and a stubble height of 45 cm for the rice ratooning during the dry season to gain higher productivity and increased profit. The said management practice is hypothesized as one of the best strategies in adapting to the harmful effects of climate change by cultivating lowland rice in the tropics. Thus, this approach is considered a good measure of adapting to problematic conditions relative to the mild and worst-case scenarios of climate change.

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