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RESEARCH ARTICLE

Ratooning performance of lowland rice (*Oryza sativa L.*) var. NSIC Rc216 as influenced by cutting strategies of ratoon crop

Baňoc, D.M. [1]*, R. Sevillano [1] and V.B. Asio [2]

[1] *Department of Agronomy, Visayas State University, Visca, Baybay City, Leyte, Philippines.*
[2] *College of Agriculture and Food Science, Visayas State University, Visca, Baybay City, Leyte 6521 Philippines.*

Abstract

This study aimed to determine the ratooning response of lowland rice variety NSIC Rc216 to cutting strategies of ratoon crops. This determines the appropriate cutting strategy that produces a higher ratoon yield. It evaluates the profitability of rice ratooning following the cutting strategy adopted. The experiment was laid out in a Randomized Complete Block Design with cutting procedures as the treatments. The cutting strategy significantly affected the number of days from harvesting the primary crop to harvesting the ratoon crop, stem elongation, panicle length, and grain yield (t ha^{-1}). In contrast, it did not remarkably influence the panicle weight and percent filled grains of ratoon crops. The results revealed that shorter cutting height (7.5cm) significantly prolonged the maturity of ratoon crops (80.33 days), elongated longer stem (97.17cm), longer panicle length (28.23cm) that eventually produced higher grain yield (1.35 t ha^{-1}) compared to 30cm cutting height. The harvesting of panicles only remarkably achieved a higher grain yield (1.50 t ha^{-1}) compared to those ratoon plants with cutting heights of 30.0cm (0.67 t ha^{-1}) but comparable to ratoon plants with 60.0cm and 7.5cm cutting heights which produced higher grain yields of 1.48 t ha^{-1} and 1.35 t ha^{-1}, respectively. Economic analysis revealed that the harvesting of panicles only and cutting height of 60.0cm showed a higher gross margin of 274.09 and 267.13 US Dollars, respectively, because of higher productivity levels of said treatments. These strategies are adequate measures in solving the problems of rice self-insufficiency situation due to the climate change situation.

Keywords: Cutting height; primary crop; ratoon crop; strategy; stubble.

1. Introduction

Rice is recently considered the world's most important food crop. It is widely grown throughout the world due to its nutritional and economic value. It is commonly cultivated in all regions, and as reported by Dawe (2003), it is considered one of the most extensively grown crops in the country. However, as the country's population increases, rice production should suffice the growing population's need. It is critical to increasing rice yields sustainably (Singh *et al.*, 2021).

Rice production in the Philippines can be enhanced over time mainly because of the improved technologies and government programs envisioned to respond to the dynamic challenges and needs of the Filipinos with the primary goal of increasing the yield and income. Lowland rice production is the most common and widely practiced production in the country. However, with the effects of adverse climatic conditions, the yield of lowland rice is always affected despite the cultural mitigation practices applied. Hence, the adoption of innovative strategies for lowland rice production is needed in enhancing productivity. One of those creative strategies is ratooning. Ratooning is conventionally practiced after the harvest of the main crop when ratoon tillers arise (Torres *et al.*, 2019). However, ratoon

***Corresponding author: Dionesio M. Baňoc**
Email: dionesio.banoc@vsu.edu.ph
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yields are affected by several factors such as cultural management (cutting height, time of harvest, main crop cultural practices), light, temperature, soil moisture, and soil fertility (IRRI, 1988).

Nevertheless, if the ratoon crop is provided with better management practices like proper cutting of stubbles, the yield of the ratoon crop will be increased tremendously. This research endeavor investigates the growth and yield performance of ratoon lowland rice as influenced by different cutting strategies of ratoon crops. Examine the productivity of lowland rice as affected by different cutting strategies of ratoon crops and evaluate the profitability of ratooning lowland rice as influenced by different cutting strategies of ratoon crops.

2. Materials and Methods

2.1. Study site

The experiment was undertaken at the experimental field of the Department of Agronomy, Visayas State University (VSU), Visca, Baybay City, Leyte, the Philippines, from April 1, 2020, to June 15, 2020.

2.2. Primary crop

The establishment of the primary crop was anchored on the planned implementation of the intended rice ratooning study adopting the six treatments relative to the different cutting strategies of the ratoon crop. The experimental design and field layout, seedbed and seedling preparation, transplanting, fertilizer application, and crop care and management were made based on the desired protocol of growing the primary crop to continue its growth for ratooning purposes. Thereby, the aligned activities of increasing the direct yield were strictly followed. The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications to align this plan in the actual experimental layout for ratooning. The entire area was subdivided into three divisions representing the replication. Each replication was divided into six plots, each measuring 2m × 5m. The assigned replication and treatment plots were separated by 1.0m × 0.5m alleyways, respectively, to facilitate farm operations, management, and data gathering during the implementation of ratooning experiment. Lowland rice variety (NSIC Rc216) was used since it was already known for its excellent ratooning ability under the lowland ecosystem (Baňoc *et al.,* 2022). The seeds of NSIC Rc216 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' transplant was conducted 15 days after sowing.

Transplanting was done using one to two seedlings per hill, adopting a planting distance of 20cm × 20cm. Transplanted rice plants were applied with inorganic fertilizers using complete fertilizer (14-14-14) and urea (46- 0-0) at the application rate of 120-60-60 kg ha^{-1} N, P_2O_5, K_2O was followed. In applying complete fertilizer, 60 kg N, P_2O_5, K_2O ha^{-1} was adopted 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 stage. Care and management such as proper rotary and hand weeding operations, water management, pest and disease management were followed. The different cutting strategies adopted under the five subplot treatments were strictly followed at harvesting the primary crop.

2.3. Ratoon crop

The experiment was laid out in an RCBD with three replications similar in growing the primary crop. Similarly, each replication was divided into six plots, each measuring 2m × 5m. Alleyways separated replication and treatment plots to facilitate farm operations, management, and data gathering. The different treatments adopted were designated as follows:

T_1 = cutting strategy of 7.5 cm from the soil surface

T_2 = cutting strategy of 15.0 cm from the soil surface

T_3 = cutting strategy of 30.0 cm from the soil surface
T_4 = cutting strategy of 45.0 cm from the soil surface
T_5 = cutting strategy of 60.0 cm from the soil surface
T_6 = cutting strategy of harvesting of panicles only.

Urea (46-0-0) fertilizer was applied at the 90 kg ha^{-1} N rate and split into two applications at 45 kg ha^{-1} at ten days after harvesting the primary crop. The other half was applied at the panicle initiation stage of the ratoon crop. Cultural management practices for the ratoon crop were done similarly to the primary crop except for the cutting strategy and fertilizer management. During the harvesting of the primary crop, the six cutting strategies such as cutting the height of stubbles at 7.5cm, 15cm, 30cm, 45cm, 60cm from the soil surface, and harvesting panicles only for the ratoon crops were strictly followed. The harvesting of the ratoon crops was done at maturity. It was done by using a sharp sickle at the desired cutting height during dry weather conditions. The harvested rice panicles were threshed manually, cleaned, and dried for three days before collecting data. The data gathered were collated, statistically analyzed, and interpreted based on the findings.

2.4. Data gathered

The data gathered were the number of days from harvesting of the primary crop to the harvesting of the ratoon crop, 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.

3. Results and Discussion

3.1. Soil Chemical Properties

The initial soil analysis of the experimental area revealed that the soil was strongly acidic (5.0), medium amount of organic matter (3.28) and total nitrogen (0.210), having an adequate amount of available phosphorus (10.56), and a very high amount of exchangeable potassium (1.38) (Landon, 1991). The final soil analysis showed that the soil pH (5.12) and total N (2.84) increased slightly but decreased the organic matter (2.84), available P (7.68), and exchangeable K (1.18) (Table 1). The slight increase in soil pH might be due to the decomposed rice straws of the primary crop, the transformation of organic matter by the decomposed uprooted weeds and the suspension effect of flooded soils during crop growth and development (Ratilla and Cagasan 2011). The increased total N might be attributed to the decayed plant parts that eventually provide sustainable availability of organic matter in the soil. In contrast, the slight reduction in organic matter, available P, and exchangeable K might be attributed to the rice plants' nutrients' utilization for the ratooned crop's growth and development.

Table 1. Initial and final soil analyses in the established experimental area as influenced by the cutting strategies of ratoon crop

Treatment	Soil pH (H_2O)	Organic matter	Total N (%)	Available P (mg kg^{-1})	Exchangeable (K) (me $100g^{-1}$)
Initial soil analysis	5.00	3.28	0.210	10.56	1.38
Final soil analysis	5.12	2.84	0.280	7.68	1.18

3.2. Study Site

The experiment was conducted at the Department of Agronomy, Visayas State University (VSU), Visca, Baybay City, Leyte, Philippines (Table 2). The site is experiencing a type four climate wherein precipitation is more or less evenly distributed throughout the year. According to Maplandia.com.2021, the sites' geographical coordinates possess a latitude of ten ⁰ 41' North and 124 ⁰ 48' East longitude. The geomorphology was categorized as vertisols, and soil type was entisols (Asio V. 1996, Carating *et al.*, 2014) as cited by Baňoc *et al.* (2022).

Table 2. Site characteristics of the experimental area planted to lowland rice (*Oryza sativa* L.) var NSIC Rc216 as influenced by cutting strategies of the ratoon crop

Site	Coordinates	Geomorphology	Soil type	Climate type
VSU, Baybay City, Leyte, Philippines	10º 41' N & 124 º48' E	Vertisols	Entisols	Type 4

3.3. Agronomic characteristics, yield and yield component parameters

The study results revealed that the cutting strategy of ratoon in NSIC Rc216 significantly affected the number of days from harvesting the primary crop to harvesting the ratoon crop, stem elongation, length of panicles, and grain yield. But it did not influence the weight of panicles and percent filled grains of the ratoon crops (Table 3). The shorter stubble height of 7.5cm above the soil surface achieved a significantly more extended period of maturity (80.33 days) than all other treatments, most especially stubble heights of 60cm and those ratoon plants that were manipulated by harvesting of panicles only with 42.33 and 40.67 days, respectively.

The result construed with Rahman *et al.*'s (2007) findings that the shorter the cutting height, this prolonged the maturity of ratoon grains. Bahar and De Datta (1977) claimed that reducing the cutting size of ratoon crop from 15 to 5 cm extended the growing period from 73 to 86 days, thereby delaying harvesting operation. The number of days harvesting the ratoon follows a corresponding trend wherein the shorter cutting height has a more extended maturity period. It follows a decreasing trend as the cutting height increases its size (Table 3). It connotes that the taller the cutting height, the earlier its maturity as conformed by Mareza *et al.* (2016) that the higher the cutting height has, the shorter time in its vegetative growth phase. Thus, the ratooned plants with taller cutting heights have a quicker vegetative stage since ratoon shoots in the higher nodes grow faster than those produced by, the lower nodes.

For stem elongation, the shortest stubble height (7.5cm) obtained the most extended length of protruding stem or culm with 97.17cm than those of all other stubble heights except stubble height of 15cm (T_2) an elongated stem of 85.83cm. On the other hand, the harvesting of the panicle only (T_0) emanated the shortest stem elongation of 21.28cm remarkably compared to all different cutting strategies adopted. The result of the study conformed to the findings of Mareza *et al.* (2016) who stipulated that the more extended cutting height also connotes shorter stem elongation. In this study, the higher cutting height, particularly 60.0cm, and harvesting panicles, only have shorter stem elongation of 34.43cm and 21.28cm, respectively.

Relative to panicle length (cm), the stubble height of 7.5cm significantly achieved the most extended panicle length of 28.23cm than those of other cutting strategies except a cutting height of 15.0cm with a comparable panicle length of 27.63cm. In contrast, a cutting height of 30.0cm achieved the shortest panicle length (19.82cm) compared to shorter cutting heights of 7.5 and 15.0cm but comparable to those ratooned plants with more extended cutting heights of 45.0cm and 60.0cm with panicle lengths of 20.55cm and 20.99cm, respectively. Besides, it was also similar to those ratoon plants with a cutting strategy of harvesting panicles only with a panicle length of 21.28cm.

For the grain of the ratoon crop, the higher grain yield (1.50 t ha^{-1}) was significantly achieved in ratoon plants adopting a cutting strategy of harvesting panicles only (T_6) when compared in those ratoon plants with cutting heights of 30.0cm (T_3). Those ratoon plants followed it with stubble height of 60.0cm (T_5), 7.5cm (T_1), 15.0cm (T_2), 45.0cm (T_4), and the minuscule grain yield was obtained in ratoon plants at a stubble height of 30.0cm (T_3) of 0.67 t ha^{-1}. The remarkable higher grain yield of ratoon in T_6, T_5, and T_1 ratoon plants might be due to the combined development of a higher percentage filled grains, panicle length, and panicle weight of such treatments compared to other stubble height treatments in general.

According to Santos et al. (2003) the ratoon crop generally yields 40 to 60% vis-a-vis the primary crop depending on management practices. Harrel *et al.* (2009) mentioned that the appropriate cutting height of ratoon lowland rice positively affects ratoon grain yield. Pirdashti *et al.* (2006) mentioned that the utmost yield of ratoon was achieved at 15cm cutting height. However, Turner (2007) stated that in enhancing the productivity of ratooned lowland rice, the cutting height must be 0-50 cm from the soil surface. In contrast, Mengel and Wilson (1981) claimed that higher cutting heights decreased ratoon yields. Saran and Prasad (1952) proved that cutting the primary crop harvest at ground level resulted in lower productivity than cutting it at 50% of its plant height. In another concrete report, cutting size does not remarkably affect ratooning ability, reproductive tillers, and ratoon yield. Although Negalur *et al.* (2017) pointed out that the performance of ratoon depends on the combined effects of cutting size, tillering behavior, duration of the main crop, plant height, cultural practices, etc., including external factors like temperature and light intensity.

Table 3. Grain yield and other component parameters of ratoon lowland rice (*Oryza sativa* L.) var. NSIC Rc216 as influenced by cutting strategies of ratoon crop

Treatment	No. of days to the harvesting of ratoon	Stem elongation (cm)	Panicle length (cm)	Panicle weight (g)	% filled grains	Grain yield (t ha^{-1}) (ratoon)
Cutting strategy						
T_1 = 7.5 cm from soil surface	80.33a	97.17a	28.23a	2.70	76.38	1.35a
T_2 = 15.0 cm from soil surface	74.33b	85.83a	27.63a	2.41	74.97	1.13ab
T_3 = 30.0 cm from soil surface	59.67c	55.53b	19.82b	2.20	70.86	0.67b
T_4 = 45.0 cm from soil surface	44.33d	43.17c	20.55b	2.61	81.69	0.90ab
T_5 = 60.0 cm from soil surface	42.33de	34.43c	20.99b	2.67	85.03	1.48a
T_6 = harvesting of panicles only	40.67e	21.28d	21.28b	2.97	88.36	1.50a
Mean	56.94	56.24	23.08	2.59	79.55	1.19
F value Significance	0.0001^{**}	0.0001^{**}	0.0001^{**}	0.74^{ns}	0.08^{ns}	0.005^{*}
C.V. (%)	1.35	7.64	4.11	10.43	8.69	16.16

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.

Based on the results of this study, these conformed to the findings of Daliri *et al.* (2009), Dunand and Dilly (2005) and Nassiri *et al.* (2011) that the cutting height of ≥ 40cm produced higher productivity. Similarly, the higher the cutting height of ratooned crops also implies abundant production of nodes and internodes. The number of nodes is essential for increasing productivity since nodes produced more lateral buds that transformed into productive tillers. Then, the productive tillers reflect grains' development with higher grain yield (Daliri *et al.*, 2009; Harrel *et al.*, 2009; Nassiri *et al.*, 2011). Therefore, the result agrees with Daliri *et al.* (2009) that the higher cutting height of ratoon crop precisely 40cm from the soil surface efficiently produces a higher grain yield.

3.4. Comparative analysis on grain yields of primary and ratoon crops

Comparative analysis between the grain yield of the primary and the ratoon crops as influenced by the different cutting strategies of the ratoon crop is presented in Table 4. The result shows that cutting height of 60.0cm from the soil surface achieved the highest percent difference (34.02%) between the primary and ratoon crops compared to all other treatments tested. It was followed by ratoon plants with a cutting strategy of harvesting the panicles only (33.86%) then cutting height of 7.5cm with a percent difference of 32.22 percent. In contrast, a 30.0cm cutting height achieved the lowest percent difference between the primary and ratoon crops of 14.56%. Within its cutting strategy, a cutting height of 45.0cm (T_4) gained a lower percent difference value (18.60%) then followed by stubble height of 15.0cm (T_2) with a percent difference value of 23.79%.

The result of comparative difference analysis signifies that a cutting strategy of 60.0cm cutting height generally contributed to higher productivity of ratooned plants when compared to the primary crop (Table 4). The result conformed to Mareza *et al.*'s (2016) findings that higher cutting height encourages more nodes that develop into ratoon tillers. They produced several nodes that are vital for ratoon productivity since the aforesaid nodes will emerge corresponding lateral buds that are eventually produced into ratoon tillers. Thereby, the produced number of nodes will directly influence the development of ratoon tillers (Daliri *et al.*, 2009; Harrel *et al.*, 2009; Nassiri *et al.*, 2011). The more nodes developed, the high tendency to produce ratoon tillers led to higher grain productivity of ratoon crop.

Relative to the grain yield of the primary crop, rice plants intended for 45.0cm cutting height produced higher grain yield (4.84 t ha^{-1}) than those of other primary crops tested but generally, the grain yields of all primary crops were ranged from 4.19 to 4.84 t ha^{-1} with cutting height of 7.5cm garnered the lowest grain yield of 4.19 t ha^{-1} (Table 4). Based on the result of the study, the higher percent difference of 60cm cutting height from the soil surface (34.02%) was mainly attributed to more favorable development of filled grains in support of the higher productivity during the reproductive growth. This result conformed to the findings of Daliri *et al.* (2009), stipulated that a higher yield was obtained from the more extended cutting height of stubbles.

Table 4. Comparative analysis on grain yield (t ha^{-1}) of primary and ratoon crops of lowland rice (*Oryza sativa* L.) var. NSIC Rc216 as influenced by cutting strategies of ratoon crop

Cutting strategy	Grain yield (t ha^{-1})		
	Primary crop	Ratoon crop	% Difference
T_1 = 7.5 cm from soil surface	4.19	1.35	32.22
T_2 = 15.0 cm from soil surface	4.75	1.13	23.79
T_3 = 30.0 cm from soil surface	4.60	0.67	14.56
T_4 = 45.0 cm from soil surface	4.84	0.90	18.60
T_5 = 60.0 cm from soil surface	4.35	1.48	34.02
T_6 = harvesting of panicles only	4.43	1.50	33.86
Mean	4.53	1.17	26.18

3.5. Cost and return analysis

Profitability analysis revealed that the cutting strategy of harvesting panicles only achieved a higher gross income (600.00 US Dollars) and gross margins of (274.09 US Dollars) due to a higher grain yield of 1.50 t ha^{-1} (Table 5). It was closely followed by ratoon plants with a cutting height of 60.0cm with gross income (592.00 US Dollars) and a gross margin of 267.13 US Dollars. In contrast, a cutting height of 30.0cm from the soil surface of ratoon plants obtained the lowest gross income and gross margin of 268.00

US Dollars and negative 15.83 US Dollars, respectively.

Relative to the conceptual economic analysis of the study, harvesting of panicles only and cutting heights of 60.0cm from the soil surface are generally inclined to produce more and profitable than those of lower cutting heights (15.0cm, 30.0cm & 45.0cm) except cutting the size of 7.5 with a higher gross margin of 221.89 US Dollars. Thus, rice ratooning is beneficial since it could provide remarkable economic benefits to resource-poor farmers in the rice farming community, as mentioned by Torres et al., 2019. Still, it is a potential alternative to planting a third rice crop annually because it requires minimal water input and grows quicker than the primary crop. Thereby, for enhancing productivity without increasing the land area, ratooning has been emphasized as a valuable method of increasing productivity while reducing per-unit production costs in rice farming.

Table 5. Cost and return analysis of lowland rice (*Oryza sativa* L.) var. NSIC Rc216 as influenced by cutting strategies of ratoon crop

Treatment	Grain yield (t ha^{-1})	Gross income (US Dollar)	Total variable cost (US Dollar)	Gross margin (US Dollar)
Cutting strategy				
T_1 = 7.5cm	1.35	540.00	318.11	221.89
T_2 = 15.ocm	1.13	452.00	306.67	145.33
T_3 = 30.0cm	0.67	268.00	283.83	(15.83)
T_4 = 45.0cm	0.90	360.00	294.71	65.29
T_5 = 60.0cm	1.48	592.00	324.87	267.13
T_6 = panicles only	1.50	600.00	325.91	274.09

Price of palay = US Dollar 0.40 kg^{-1} at PHP 50.00 per 1 US Dollar

4. Conclusion and Recommendation

Determine the other option best for rice ratooning by cutting only the panicles of the primary crop at harvest through increasing productivity. Ratoon lowland rice at cutting heights of 60cm, 7.5cm, and cutting off panicles only during harvesting of the primary crop enhanced the grain yields of the ratoon crops. To shorten the maturity of ratoon lowland rice in areas with unpredictable weather conditions, cutting panicles only during harvesting the primary crop is an excellent practice to escape the ratoon crop in any destructive maladies (typhoons, drought, etc.) brought by climate change. A similar study should be conducted under different climatic conditions to verify further the effect of varying cutting strategies of the ratoon crop under the unpredictable weather conditions brought by the ill effects of climate change.

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