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Production performance of ratoon adlai (*Coix lacryma-jobi* L.) as affected by different cutting heights

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Abstract Adlai is a versatile cereal crop with its exceptional agronomic trait of regrowing from the leftover stubble after harvest. The effect of different cutting heights was recorded on Ratooned Adlai's growth and production performance during two growing seasons, specifically looking at the Guinampay variety. Results showed that the 15-30 cm cutting heights in ratooned adlai was not significantly affected the number of days from ratooning to maturity, final plant height, number of tillers, weight of 1000 grains, actual grain yield, and projected grain yield. However, taller cutting heights of 20-30 cm increased the number of grains per tiller (P=<0.01) and percent filled grains(P=<0.05). The 15–30 cm cutting range is offered farmers a useful choice that supported the productivity and flexibility of adlai ratooning.

Keywords: Cutting heights, Climate-resilient crop, Ratooned adlai, Planting system

Introduction

Adlai (*Coix lacryma-jobi* L.) is a staple cereal crop to supplement rice and corn. Adlai grain adds diversity to diets in addition to the cereals and root crops. Moreover, this crop plays an integral part in national food security in the Philippines (Gorne, 2020). Adlai is an excellent source of several essential nutrients that promote general health and wellness, such as proteins, carbs, dietary fiber, and vitamins and minerals. Adlai's nutritional makeup substantially contributes to a balanced diet by providing macro and micronutrients necessary for healthy bodily processes (Igbokwe *et al*., 2022). It is also rich in antioxidants, gluten-free, and an excellent anti-inflammatory source(Zhu, 2017).

Moreover, Adlai contains high fiber and has been utilized traditionally in medicine to support digestive health and blood sugar regulation. Additionally, this crop assists reproductive health, improves skin health, and provides anti-cancer qualities(Igbokwe *et al*., 2022). It contributes to the nation's food security

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strategy because of its nutritional advantages and versatility in growing environments(Rana-Aradilla, 2018).

The Adlai's ability to withstand adverse environments makes it promising in farming, especially in marginal land (Magallon and Cabahug, 2023). Its capacity to survive in dry conditions, tolerate flooded environments, need low resources, and be resistant to pests and diseases makes it an essential element of climate-smart agriculture technology in the locality (Azadi *et al*., 2021; Chandra *et al*., 2018; Steenwerth *et al*., 2014). With the ongoing threat of climate change on global food security, it is imperative to grow resilient crops such as adlai to maintain a sustainable and steady food supply (Aradilla, 2016).

Given the country's ongoing population growth, it is vital to develop a comprehensive strategy to ensure food availability (Badana and Andel, 2018; Gue *et al*., 2016). It will take creative solutions for resource management, food security, and agriculture to meet the needs of an increasing population. These methods must prioritize efficiency, sustainability, and equity (Fess *et al*., 2011; Gregory and George, 2011; Van Kernebeek *et al*., 2016). Alternatively, Adlai production can augment the pressing need for sustainable, healthy, and adequate food sources. These needs can be alleviated by improving the cropping index with the intensification of the ratoon system. By intensifying the ratoon system and raising the cropping index, it is possible to increase Adlai production effectively. Ratooning increases Adlai's total productivity by enabling it to generate more grain yields in the same growing season. Ratooned Adlai takes only four months to harvest as it develops from the parts of a previous harvest. Nonetheless, the recently planted Adlai requires more than six months to mature, undergoing the entire growth cycle from seed to harvest.

The ratoon system, which is frequently used in crops like rice, sugarcane, and other cereals, is a productive farming technique that maximizes cultivation and helps to produce food in a way that is both more economical and sustainable (Wang *et al*., 2020). An Adlai ratooning technique can significantly increase the grain produced annually per unit of land by allowing Adlai plants to grow again after the first harvest. Because it maximizes land utilization and minimizes the need for regular replanting, this approach is sustainable because it permits numerous harvests from a single planting. Adlai ratooning enhances total yield efficiency and helps create more sustainable food production systems by encouraging regrowth. In addition to maximizing resource use, this approach promotes agricultural output over the long term and resilience in the face of rising food demands.

In addition, adlai ratooning minimizes soil disturbance and drastically reduces the requirement for land preparation. Furthermore, ratooning lessens or eliminates the requirement for pesticide treatment because of its resistance to insects and diseases. This resistance reduces the ecological problem by lowering chemical inputs (Firouzi *et al*., 2018).

Like other plants, these methods prolong the harvesting season, resulting in a longer and more consistent crop supply, lessening the need for labor in replanting (Yu *et al*., 2021). Successful ratooning requires management practices like pruning to stimulate new growth, nutrient management, and monitoring potential pests and diseases that could affect the regrowth (Nassiri *et al*., 2011; Setiawan *et al*., 2014). More in-depth study is needed to determine the best management strategies for Adlai ratooning, emphasizing cutting heights. The crucial part cutting heights plays in the productivity and success of Adlai Ratooning has yet to be fully covered. Research is needed to understand better how varied cutting heights affect grain production and regrowth in Adlai, which will lead to more productive agricultural strategies, the optimization of yield efficiency, and the development of sustainable agriculture techniques (Gloria *et al*., 2015; Mercado Jr *et al*., 2014; Tumapon *et al*., 2012). With an emphasis on the Guinampay variety, this study is substantially contributed to understand the effects of different cutting heights on the growth and productivity of ratooned Adlai. The study is provided a baseline for future research on other Adlai cultivars and their tolerance to varying planting seasons by highlighting the critical significance of cutting heights. This research is particularly significant done to Zamboanga Peninsula, Philippines for understanding these practices which leaded to more sustainable and effective farming methods to be adapted to the local farmers.

Materials and methods

The study was conducted at the School of Agriculture, Forestry and Environmental Studies experimental site, Dapiwak, Dumingag, Zamboanga del Sur, with a latitude of 8°11'18.61"N longitude of 123°17'32.60"E. The experiment covered two growing seasons (rainy and dry seasons) during ratooning from July-October 2021 and January-April 2023 within the same experimental site.

The experimental area was laid out with four treatments replicated four times and arranged in a Randomized Complete Block Design (RCBD). Each plot measured 4.5 meters with six rows per plot and ten hills in each row. Plots were separated by a 0.5 alleyway between plots and replications to facilitate farm operations, management, and data gathering. The treatments were the different cutting heights above the ground: Treatment 1: 15 cm; Treatment 2: 20cm; Treatment 3: 25 cm; and Treatment 4: 30 cm.

The Adlai plants were ratooned by cutting them to predetermined heights above the ground following the treatment specifications after they were harvested. The Inorganic fertilizer was applied using a side-dressed method after ratooning at 60-60-60 kg of N-P2O5-K2O per hectare. Weeding operations were done twice throughout the growing period. Harvesting was done when all of the grains in the panicles ripened. All sample plants in the harvestable area were harvested, excluding two border rows on each side and the end hills of each row. The panicles were cut at the panicle base by a sharp bolo, sun-dried before threshing, and winnowed before all the necessary data were gathered.

Observed variables

The following data were observed:

Number of days from ratooning to maturity. This was recorded when 50% of the panicles in each treatment plot exserted from the flag leaf sheath.

Final plant height before harvesting was done by measuring the height of the ten sample hills in each treatment plot from ground level up to the tip of the tallest plant part a day before harvest.

Number of tillers before harvest was done by counting the number of tillers from ten sample hills in each treatment plot a day before harvest.

Number of grains/tillers was determined by counting the filled and unfilled grains/tiller from the ten (10) sample panicles in each treatment plot.

Percentage of filled grains/panicles was computed using the formula.

% of filled spikelets: [Total number of filled spikelets/Total number of spikelets] x 100

Weight (g) of 1,000 grains was obtained by weighing 1,000 filled grains taken from each treatment plot.

Harvest index was calculated using the formula.

Harvest index: [Economic yield/Biological yield] x 100

Actual economic grain yield (kg) per plot was done by weighing the total harvested grains obtained from the harvestable area in each treatment plot. The grains were cleaned and sun-dried at approximately 14% moisture content before weighing.

Projected adlai grain yield (t/ha) was done by converting the actual grain yield per treatment into hectare yield. The data were in tons per hectare using the formula.

Grain yield (t/ha): [(Plot yield (kg)/Harvestable area (18 m^2) x 10,000 m^2 per ha/1,000kg/t]

Statistical process

Analysis of variance was used in the computation of data in Randomized Complete Block Design (RCBD). The data were analyzed using the Statistical tool for Agricultural Research software. The mean comparison was done using Least Significance Difference (LSD).

Results

The laboratory analysis of soil samples is shown in Table 1. The soil at the experimental site was strongly acidic (5.57 pH) and low in organic matter (2.58%), nitrogen (0.129%), and available phosphorus (7.10%). However, there was a high amount of exchangeable potassium at 749 ppm. Growing adlai can tolerate acidic soil conditions.

Table 1. Chemical properties of the soil before planting

Treatment	pH	Organic Matter (%)	Nitro-gen (%)	Avail-able P (%)	Exchang-able K (ppm)	CEC (meg/100)	Ca (meg/100)
Soil Analysis	5.57	2.58	0.129	7.10	749.0	19.34	2.20
Interpre-tation	Strongly Acidic	Very Low	Low	Low	Very High		

The effects of the cutting heights of Adlai ratooning in terms of the number of days from ratooning to maturity, final plant height, and the number of tillers before harvest for the first and second trials are shown in Table 2. The study's findings showed that as the cutting height increases, the number of days from ratooning to maturity decreased. It was evident from the first and second trials with the decreasing means of treatment 1 (145.50 and 144.00 days) to treatment 4 (135.50 and 141.25 days). However, statistically, the treatments were not significantly differed in the number of days from ratooning to maturity. In both trials, there was slightly differed in average height across the treatments regarding plant height and the average number of tillers before harvest. Regardless of treatments, the maximum height of adlai during ratooning recorded from 180 cm to 198.48 cm with a 6-10 average number of tillers. However, statistically, there were not significantly differences among treatment means. This implies that, despite numerical differed, the average plant height and number of tillers before harvest of the Guinampay cultivars of Adlai, as the plant's physiological response, were not significantly varied among the cutting height treatments.

Table 2. The number of days from ratooning to maturity, final plant height, and number of tillers before harvest

Treatment	Number of days from ratooning to maturity		Average plant height (cm)		Average number of tillers before harvest	
	1st	2nd	1st	2nd	1st	2nd
T1- 15 cm	145.50	144.00	192.55	184.15	8.83	7.65
T2- 20 cm	144.75	144.00	198.48	180.00	9.60	6.25
T3- 25 cm	140.50	140.00	195.80	187.88	8.88	7.28
T4- 30 cm	135.50	141.25	196.08	183.13	9.90	8.03
F-Test	ns	ns	ns	ns	ns	ns
C.V. %	3.87	3.72	4.99	1.85	10.66	1.24

[1]/ns- no significant differences among treatment means.
[2]/[a]1st -first trial; [3]/[a]2nd -Second trial

The number of grains per tiller, the percentage of filled grains, and the weight of 1000 grains of the first and second trials are presented in Table 3. Treatments 4 (30 cm) and 2 (20 cm) showed the highest number of grains per tiller, with 101.60 and 99.30, respectively. The same trend was observed in the second trial, in which Treatments 2, 3, and 4 obtained the highest number of grains per tiller. The lowest values obtained by treatment 1 (15 cm) were 78.58 and 117.83. Statistical analysis revealed highly significant differences in all treatments, such as treatments 2, 3, and 4 significantly different. Regarding the percent filled grains, data showed a slightly variations among treatment means in the first trial but not significant differences in the second. The filled grains mean value from 86.20 to 96.30 percent. The weight of 1000 grains was observed to be the same trend. Treatments 2 and 4 showed the highest weight at 78.82g and 77.42g, respectively. Treatments 1 and 3 showed the lower means. In addition, in the second trial, treatments 4, 3, and 2 got the highest treatment mean at 86.37, 86.06, and 85.08, respectively. However, statistically, no significant differences were observed. Therefore, the weight of 1000 grains was not affected by the different cutting heights studied.

The harvest index, actual grain yield, and projected grain yield per hectare of the first and second trials of different cutting heights are shown in Table 4. The harvest index showed that the mean value decreased as cutting heights increased. Specifically, treatment 1 (15cm) was the highest harvest index at 39.93 percent, followed by treatment 2 (20cm) at 33.10 percent, treatment 3 (25cm) at 29.37 percent, and treatment 4 (30cm) which showed the lowest harvest index, with 25.72 percent. During the second trial, the same trend was observed; however, there were not significantly differed among treatment means. Notably, the 15-20 cm (T1 and T2) cutting height had the highest percentage of harvest index.

Table 3. Number of grains per tiller, percent of filled grains, and weight of 1000 grains

Treatment	Number of grains/tillers		Percent filled grains		Weight of 1000 grains (g)	
	1st	2nd	1st	2nd	1st	2nd
T1- 15 cm	78.58[b]	117.83[b]	7.49[ab]	95.45	76.07	79.26
T2- 20 cm	99.30[a]	150.80[ab]	90.65[a]	96.18	78.82	85.08
T3- 25 cm	84.80[b]	173.37[a]	86.20[b]	96.36	73.07	86.06
T4- 30 cm	101.60[a]	169.81[a]	90.77[a]	96.43	77.42	86.37
F-Test	**	*	*	ns	ns	ns
C.V. %	27.74	13.96	2.33	1.24	6.11	6.55

[1]/ [a]Means having the same letter are not significantly different from each other. [b]**-significant at a 1% level of significance. [c]* significant at a 5% level of significance. ns- no significant difference
[2]/[a]1st -first trial; [3]/[a]2nd -Second trial

Table 4. Harvest index, actual grain yield, and projected grain yield of the first and second trials

Treatment	Harvest Index (%)		Actual Grain Yield (kg)		Projected grain yield (t/ha)	
	1st	2nd	1st	2nd	1st	2nd
T1- 15 cm	39.93[a]	73.64	2.98	1.94	2.66	1.08
T2- 20 cm	33.10[ab]	56.11	3.35	2.01	2.98	1.12
T3- 25 cm	29.37[b]	61.60	3.89	2.14	3.46	1.19
T4- 30 cm	25.72[b]	56.70	4.12	2.23	3.66	1.25
F-Test	*	ns	ns	ns	ns	ns
C.V. %	15.75	26.86	15.76	37.81	18.67	37.22

[1]/[a]Means having the same letter are not significantly different from each other. [b]*-significant at a 5% level of significance. [c]ns- no significant difference
[2]/[a]1st -first trial; [3]/[a]2nd -Second trial

Conversely, 25-30 cm (T3-T4) had the lowest harvest index. The results indicated that the lower cutting heights encourage a more efficient biomass allocation to grain production due to reduce competition for nutrients and lights. Furthermore, treatment 1 obtained the highest mean value in the second trial, followed by treatment 3 (25cm) at 73.64 and 61.60, respectively. The lowest value was observed in treatments 2 and 4, with 56.11 and 56.70, respectively. However, there was not significantly differed among treatment means. A slight disparity of grain yield was observed for the actual grain yield that shows 30 cm cutting heights (T4) in both trials obtained the highest grain yield, 4.12kg, and 2.23 kg, followed by 25 cm (T3), 3.89kg and 2.14kg, and 10 cm 20cm (T2) 3.35kg and 2.01, respectively.

Moreover, the lowest yield was recorded at 15cm (T1), with 2.98kg and 1.94kg. Higher grain yield is associated with higher cutting heights during the ratooning. Although, there were not significantly varied among treatment means.

The projected grain yield (t/ha) showed the same pattern. According to the data, treatment 4 (30 cm) can yield 3.66 t/ha, followed by treatment 3 (25 cm) with 3.46 t/ha, treatment 2 (20 cm) with 2.98 t/ha, and treatment 1 (15 cm) with 2.66 t/ha, which had the lowest anticipated yield. The same pattern was observed in the second trial. The analysis of variance, however, revealed no significant differences between the treatments in the two trials. This is suggested that the estimated grain yield was unaffected by the cutting heights used in the study.

Discussion

Adlai ratooning production performance using different cutting heights in two growing seasons. The 15-30 cm cutting heights in ratooned adlai did not significantly affect the number of days from ratooning to maturity, plant height, number of tillers, the weight of 1000 grains, actual grain yield, and projected yield. Adlai takes 6-7 months to mature after planting (Rana-Aradilla, 2018). Nevertheless, when ratooning, the time for maturation is shortened to only 4-5 months, leading to considerable time savings while producing significant yield. Regardless of the cutting height used in adlai, ratooning data shows no significant differences. However, the findings of Yu *et al*. (2018), who reported similar outcomes with other cereal crops, showed that taller cutting heights lead to fewer days for the plants to mature. The connection is explained by De Datta and Bernasor (1988) and Vergara *et al*. (1988), maintaining photosynthetically active tissues and nutrient reserves at higher cutting levels, improving the plant's regenerative ability. Higher cutting heights allow the plant to recover more quickly and grow faster, thus reducing the time it takes to mature by leaving more of its structure undisturbed. Previous studies of Al-Taweel *et al*. (2020) found that cutting heights significantly influenced the agronomic traits of sorghum. Mareza *et al*. (2015) found that 50 cm cutting heights of rice can enhance plant height, tiller count, and productive tiller number, as well as speed up the flowering process in rice ratoon. Moreover, Suhartanto *et al*. (2020) revealed that the plant's maturity plays a role in sorghum's ability to produce ratoons with certain agronomic traits. These contrasting findings imply that adlai ratooning is different from other cereals, which can be cut within the study's treatment range without significantly impacting the days to maturity, plant height, or number of tillers.

Nevertheless, the study found that taller cutting heights of 20-30 cm increased the number of grains per tiller ($P=<0.01$) and percent filled grains($P=<0.05$). Increasing grains per tiller of 20-30 cm cutting heights aligns with the findings of several studies. The findings show that increasing cutting heights affects the yield and yield components, consistent with Nakano *et al*.'s (2020) rice research. In the same way, Mareza *et al*. (2016) observed comparable outcomes in other grain crops. Furthermore, Higher cutting heights specifically result in larger yields, providing substantial knowledge of the physiological reactions to varying cutting lengths (Sugimoto *et al*., 2019).

Previous studies have found the importance of cutting heights of rice ratooning, but there are no references in the earlier reports showing different cutting heights of adlai. Chen *et al*. (2023) found that a stubble-cutting height of 30 cm increases the ability of ratooning by promoting higher stubble biomass and nitrogen content, resulting in higher rice yield for the ratoon crop. This is evident in the study of Wang *et al*. (2020) of rice ratooning that produces 60% of the main crop's yield but requires 50% less resources and labor input.

Additionally, rice ratooning enhances grain quality, boosts farmers' profits, and reduces greenhouse gas emissions. Moreover, Yang *et al*. (2024) indicated that secondary rice crops typically surpass primary rice crops in quality when the stubble height is 30 cm. The findings were supported by Nakano *et al*. (2023), who stated that the grain yield of ratoon rice was greater when cut at a higher height. The increased grain production with a taller cutting height was due to more spikelets from higher NSC levels and LAI. Additionally, Escalada and Plucknett (1977) reported that the effect of cutting heights diverges across different seasons and under varying nitrogen applications of sorghum ratooning. Their findings revealed that the higher cutting heights when matched with nitrogen application levels of 200-250 kg/ha, increased yield during winter. However, an opposite effect was observed during the spring.

Conversely, the study of Shin *et al*. (2015) claimed that harvesting the main crop stubble at a height of 10 cm increased ratoon rice grain yield. Furthermore, Yang *et al*. (2022) strengthen the claims that the lower the cutting height, the higher the yield potential of ratoon rice. However, several factors might affect ratooning yield, including fertilizer, availability of water, cutting schedule, and environmental circumstances. Adlai requires less agricultural input and is more resilient to climate change compared to other cereals. Overall, the finding suggests that the Guinampay variety of adlai can be ratooned from 15-30 cm without significantly affecting the overall growth and yield performance. These results show its practical application and serve as a guide for local farmers to better agricultural practices.

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Conflicts of interest

The authors declare no conflict of interest.

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