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Seasonal effects on the morphological traits, yield characteristics, and nutritional components of ratooned adlay (*Coix lacryma-jobi* L.) varieties

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Abstract

Adlay (*Coix lacryma-jobi* L.) is a promising crop and an alternative staple food in the Philippines valued for its ease of cultivation and nutrient-dense content grains. One of the advantages in cultivating adlay is its capacity to produce new crop from the roots after harvest, also known as ratooning. However, there is limited information on the morphological and nutritive value of different ratooned adlay varieties at different seasons. This study was conducted to evaluate the morphological and nutritional components of the five ratooned adlay varieties across seasons. Trials were conducted during the dry season (January to June 2022) and wet season (July to December 2022) using randomized complete block design with four replicates. Seasonal variation in morphological traits, yield and nutritive value were observed in five ratooned adlay varieties. Ratooned adlay varieties had higher survival rate during the wet season. Gulian variety had the highest survival rate (52.85%) during the wet season while the average survival rate across varieties remained below 50%. Weight of 1000-seeds and yield of all ratooned adlay varieties were significantly different during the wet season compared to the dry season. Gulian variety had the highest yield of 1,705 kg/ha in the wet season while Tapol had the highest yield of 815 kg/ha during the dry season. Nutritionally, the Pulot variety had the highest fat content (2.65%) and Tapol had the highest fiber (3.13%) across both seasons, on average. Gulian variety had the highest grain yield during the wet season with 88.09% return of expenses while Tapol variety had the highest grain yield during the dry season but with -9.5% return of expenses among the ratooned adlay varieties in this study. The study highlights that season significantly affects ratooning efficiency of adlay varieties.

Introduction

Significant progress has been made in addressing global hunger over the years, with the 'Green Revolution' of the 1960s being a notable achievement in combating issues of hunger, malnutrition, and drought (ADB, 2000). However, climate change and growing global population are persistent challenges of food inadequacy. In the Philippines, and in most part of Asia and Pacific, rice remains the primary staple food. The Philippines has been the world's second-largest rice importer for the last four consecutive years, reflecting its rice insufficiency. This is due to the increased consumption coupled with a slight decline in production (Arcalas, 2022). Achieving a substantial increase in the current level of rice production is crucial, necessitating the expansion of cultivation areas, adoption of modern high-yielding varieties, increased inputs, and incorporation of advanced technologies to enhance productivity within a defined timeframe (Singh et al., 2012).

Adlay (*Coix-lacryma jobi* L.), also known as job's tears, Chinese pearl barley, coix seeds and hato mugi, has been proposed to be a potential solution to the problem of rice insufficiency in the Philippines due to its ease of cultivation and its highly nutritious grains. In the Philippines, it is locally referred to as adlay/adlai, aglai, katigbi or tigbi, owing to its tear-like grains (Reynoso, 2011; Sarmiento, 2012). Morphologically, adlay resembles rice and retains a rice-like taste, albeit with a subtle nutty undertone (Gaitan,2013; DA-BAR, 2013). One of the advantages in growing adlay is its good ratooning ability (DA-BAR, 2013; Abellon, 2013), which allows it to produce new shoots from the roots after most of the above-ground portion has been harvested. Ratooning practices are widely used in the cultivation of crops such as sugarcane, sorghum, banana, pineapple and rice. It enables the plant to generate subsequent crop for the next season. Adlay can yield two to three subsequent harvests after the primary crop is harvested (SMIARC Technoguide, 2013). It can also be used as an excellent herbage fodder (Jansen, 2006). The ability of the adlay for ratooning was already established, however, it is unclear whether varieties differ in terms of morphological traits, yield characteristics, and nutritional components across different seasons. Hence, this study aimed to evaluate the morphological traits and nutritional contents of the five ratooned adlay varieties during the dry and wet seasons.

Materials and Methods

Experimental site

The experiment was conducted at University of Southern Mindanao Agricultural Research and Development Center (USMARDC) in a flat, open area with no surrounding trees located at 7°6′33.1734″N and 12°50′50.5428″E. The whole area was divided into four blocks. Each block was further subdivided into five plots with a dimension of 2.7 x 4.8 meters. One-meter alley was provided between blocks and varieties with a total of 372.6 m^2. Trials were carried out during the wet and dry seasons.

Environmental conditions

The experimental site in Kabacan, Cotabato, Philippines is characterized by hot, humid and cloudy conditions. Temperatures typically range from 23°C to 35°C and are rarely below 22°C or above 38°C throughout the year (WeatherSpark.com, 2023). Kabacan is situated 24 meters above sea level and is a landlocked area within Cotabato province (PhilAtlas, 2020). The average monthly rainfall from January-June 2022 is 188.17 mm and increased to 237.6 mm from July-December 2022. Based on the available weather data at USMARDC, January to June was characterized by low rainfall and higher temperatures (dry season) while the period from July to December had higher rainfall and lower temperatures (wet season).

Experimental units, treatments and design

The five varieties of adlay evaluated for morphological traits, yield, and nutritional contents were Ginampay, Gulian, Kiboa, Pulot and Tapol during the dry and wet seasons. The experiments were carried out in a Randomized Complete Block Design (RCBD) with four replicates. Each plot consisted of four rows, with 9 hills per row.

Plant establishment and cultural management

After harvesting of main crops, the adlay stovers were cut immediately, leaving approximately 30 cm above the ground to facilitate ratooning. Goat manure was evenly applied in the area at a rate of two tons per hectare (SMIARC Technoguide, 2013), equivalent to 77.28 kg per plot, following the cutting of stovers. No additional fertilizer was applied in either season. Off-barring was performed four weeks after ratooning using animal-drawn implement to minimize weed growth. Hilling-up was subsequently done to control subsequent weed growth and to pile soil around the roots at 75 days after ratooning (DAR). Hand weeding was conducted regularly to prevent competition for sunlight, nutrients, water, and space between weeds and the adlay plants. Plants were irrigated daily during the early growth particularly when soil moisture was insufficient.

Figure 1. Experimental area of ratooned adlay.

Vegetative and yield trait parameters

Twelve randomly selected plants from the inner rows were used to measure the plant height at 30, 60, and 90 DAR, number of vegetative tillers, number of days to flowering, number of productive tillers, number of days to maturity (when 80% of grains were ripe), panicle length, total grains per panicle, percentage of unfilled grains, weight of 1000 seeds, grain yield, and harvest index.

The yield of ratooned adlay was assessed on a per-plot basis and converted into kilograms per hectare. For each plot, the number of harvested plants was recorded, and the seeds were separated and processed to determine both the seed weight and moisture content. This data was then utilized to standardize the grain yield to 14% moisture content (MC), following the formula:

$$\text{Yield (kg/ha)} = \text{plot yield (kg/ha)} \times \left(\frac{10{,}000\ \text{m}^2}{\text{EHA}}\right) \times \frac{100\text{-MC}}{86}$$

where: EHA – Effective Harvest Area

Harvest index was calculated using the following formula:

$$\text{Harvest index} = \frac{\text{grain yield (g)}}{\text{grain yield (g)} + \text{stovers (g)}} \times 100$$

Root morphology

Two adlay plants were randomly chosen from the inner rows within each plot at 75 DAR and at post-harvest. A trench was dug 30 cm away from the plant base on all four sides, creating a cube-like excavation to a depth of 45 cm. The plant was uprooted and the root system was cleaned with water. The roots were blot dried then root length and root diameter were measured. The fresh root weight was recorded and roots were oven-dried at 70°C for 72 hours and weighed to record the dry weight.

Nutritional components analysis

The parameters used to determine the nutritional components of the five ratooned adlay varieties were analyzed using the following method in Table 1.

Table 1. Methods used in characterizing the physiocochemical properties of adlay.

Parameters	Method
Total carbohydrates	% Carbohydrates = 100 - %moisture - %protein - %lipid - %mineral
Ash	Gravimetry (1975)
Moisture	Gravimetry (AOAC, 1975)
Protein	Kjeldahl (AOAC, 1975)
Fat	Soxhlet extraction (AOAC, 1975)
Fiber	Enzymatic-Gravimetry (AOAC, 1975)
Total sugar	Shallenberg and Birch (1975)

Data analysis

Comparative analysis was conducted to assess the significant effects of season, variety, and their interaction using two-way ANOVA (Analysis of Variance), when assumptions for normality and homogeneity of variance were met. When significant differences were observed, means were compared using Tukeys HSD as post hoc test.

Return of expenses (ROE) analysis

The ROE analysis per hectare per variety was determined by using the formula:

$$\text{Return of Expenses (ROE)} = \left(\frac{\text{Net Income}}{\text{Production Cost}}\right) \times 100$$

Results and Discussion

There was a highly significant ($p<0.05$) interaction between season and variety in terms of survival rate of ratooned adlay. Survival rate of all varieties except Pulot variety were higher in the wet season compared to the dry season. Notably, Pulot had the highest survival rate during dry season at 28.25%, compared to 26.5% during wet season. In the wet season, the Gulian variety had the significantly ($p<0.05$) highest survival rate at 52.25% whereas Ginampay variety had the lowest survival rate at 24.25%. In both seasons, Ginampay variety consistently had the lowest survival rate (Table 2). The average survival rate of the five ratooned adlay variety in wet season is 33.25% while in the dry season is 23%. This finding is consistent with Gorne (2020) which observed high number of dead tillers in the ratooned adlay during the dry season. This could be possibly due to the adlay stomps drying more quickly during the dry season. As observed in other ratoon crops like sugarcane, drought stress is the most critical factor reducing ratooning ability and yield. In rice, another ratoon crop, 35% to 70% reduction in yield was observed (Wang et al., 2020), however damaged stubbles are minimized when soil moisture content is adequate at the maturity of the main crop (Hu et al., 2023). Fertilizer application also affects the ratooning ability of some crops. Organic fertilization reduced the number of dead tillers in adlay (Gorne, 2020), and in sugarcane (Singh et al., 2015).

Table 2. Survival rate and plant height at 30, 60 and 90 days after ratooning (DAR) of five ratooned-adlay during the dry and wet season.

Variety	Survival rate (%)		Plant height 30 DAR (cm)		Plant height 60 DAR (cm)		Plant height 90 DAR (cm)	
	Dry Season	Wet Season	Dry Season	Wet season	Dry Season	Wet season	Dry Season	Wet season
Ginampay	19.50 A c	24.25 B c	50.60 A a	42.03 A a	79.41 A a	91.12 B a	115.04 A a	168.38 B a
Gulian	20.25 A c	52.25 B a	49.47 A a	56.02 A a	79.79 A a	106.86 B a	129.82 A a	186.83 B a
Kiboa	21.75 A bc	32.00 B bc	40.08 A a	50.21 A a	67.92 A a	106.36 B a	135.73 A a	190.21 B a
Pulot	28.25 A a	26.50 B bc	52.94 A a	41.48 A a	80.88 A a	94.10 B a	133.35 A a	155.88 B a
Tapol	25.25 A ab	34.50 B b	46.10 A a	49.58 A a	78.60 A a	101.45 B a	147.04 A a	185.79 B a
s.d.	0.11	0.04	10.36	8.99	17.12	10.40	23.96	26.67

Means in a row for each variety with the same uppercase letters are not significantly different at p < 0.05 according to Tukey's HSD test.
Means in columns for each season with the same lowercase letters are not significantly different at p< 0.05 according to Tukey's HSD test.
s.d – standard deviation

Season also had a highly significant ($p<0.05$) effect on plant height at 60 and 90 DAR (Table 2). During the wet season, plant height of ratoon plants at 60 DAR, on average, were generally higher compared to the dry season (99.98 cm vs 77.32 cm, respectively). Similar result was observed at 90 DAR in which the average plant height was 177.42 cm during the wet season and 132.20 cm during the dry season. This might be likely due to adequate soil moisture content critical for nutrient uptake and plant growth. Increased plant height in wet climate has been observed in adlay (Ruminta et al., 2017). There were no significant differences in plant height among the five adlay varieties in either season, which was also observed in the study of Aradilla (2018).

Adlay is a climate-smart crop with a robust root system that can grow up to 150 cm. After 75 DAR, the root length of the varieties ranged from 20 cm to 24.75 cm during wet season with an average of 21.71 cm for the five adlay varieties, comparable to the average of root length during dry season which is 21.25 cm (Table 3). During the dry season, the Kiboa variety had the shortest root length with 15 cm, while Gulian had the significantly ($p<0.05$) longest root length with 32.25 cm. Variety and season had highly significant ($p<0.05$) interaction on root length. Among the adlay varieties, Gulian had the shortest root length during wet season but had the longest root length during dry season. On the other hand, Kiboa had longest root length during the wet season but the shortest during the dry season. This showed that root length differed in season and variety during ratooning. High significant ($p<0.05$) difference was observed in fresh root weight at 75 DAR in terms of season and variety. On average, the fresh root weight of the five ratooned adlay varieties during the dry season is 4.88 g while 8.02 g during the wet season. Pulot variety had the highest fresh root weight during the dry season at 6.38 g while Kiboa had the lowest at fresh root weight (2.50 g). The higher average monthly rainfall during the wet season was favorable for adlay ratoon plants, leading to heavier fresh root weight compared to the dry season. In terms of root dry weight at 75 DAR, Ginampay had the highest dry root weight at 1.85 g while Kiboa had the lowest at 0.38 g during dry season.

Table 3. Root length, fresh weight, diameter and dry weight at 75 days after ratooning (DAR) and after harvest.

	75 DAR								After harvest							
Variety	**Root length (cm)**		**Fresh root weight (g)**		**Dry root weight (g)**		**Root diameter (mm)**		**Root length (cm)**		**Fresh root weight (g)**		**Dry root weight (g)**		**Root diameter (mm)**	
	Dry season	Wet season	Dry season	Wet season	Dry season	Wet season	Dry season	Wet season	Dry season	Wet season	Dry season	Wet season	Dry season	Wet season	Dry Season	Wet season
Ginampay	17.25 A c	21.25 A a	6.25 A a	9.12 B a	1.85 A a	2.25 B a	1.40 A ab	1.47 A a	21.75 A c	21.25 B a	7.75 A a	5.75 B a	2.40 A ab	3.75 B a	1.28 A a	1.45 A a
Gulian	32.25 A a	20.00 A a	6.25 A a	8.25 B a	1.65 A b	1.88 B a	1.06 A c	1.33 A a	33.50 A a	21.25 B a	9.21 A c	7.21 B a	2.62 A a	3.00 B a	1.30 A a	1.39 A a
Kiboa	15.00 A c	24.75 A a	2.50 A b	7.12 B a	0.38 A d	1.62 B a	1.27 A bc	1.22 A a	29.25 A ab	24.75 B a	6.30 A bc	4.3 B a	1.84 A bc	2.75 B a	1.37 A a	1.23 A a
Pulot	19.00 A bc	21.12 A a	6.38 A a	8.25 B a	1.62 A b	2.00 B a	1.31 A ab	1.38 A a	19.50 A c	21.62 B a	5.51 A bc	3.51 B a	1.33 A c	3.50 B a	1.41 A a	1.39 A a
Tapol	22.75 A b	21.44 A a	3.00 A b	7.38 B a	0.70 A c	2.12 B a	1.54 A a	1.38 A a	28.50 A b	21.88 B a	7.43 A ab	5.43 B a	2.37 A ab	3.35 B a	1.34 A a	1.38 A a
s.d	3.94	6.74	3.01	1.94	0.89	0.61	0.21	0.21	3.94	6.05	3.18	1.39	0.86	0.6	0.22	0.27

Means in a row for each variety with the same uppercase letter are not significantly different at $p < 0.05$ according to Tukey's HSD test
Means in columns for each season with the same lowercase letter are not significantly different at $p < 0.05$ according to Tukey's HSD test
s.d – standard deviation

The dry root weight of the five ratooned adlay varieties at 75 DAR ranged from 1.62 g to 2.25 g during wet season while 0.38 g to 1.85 g during dry season. Generally, the dry root weight at 75 DAR during wet season was higher compared to the dry season, with a difference of 3.67 g. Ginampay variety showed the greatest dry root weight in both season.

The Tapol variety had the significantly widest root diameter at 75 DAR during dry season measuring 1.54 mm, while Gulian had the significantly smallest root diameter at 1.06 mm. The root diameter of the five ratooned varieties ranged from 1.22 mm to 1.47 mm during the wet season. The average root diameter for the wet season and dry season were comparable, at 1.356 mm and 1.316 mm, respectively. According to Wang et al. (2009) and Chen et al. (2007), roots exhibit considerable adaptability and can modify their growth and development in response changing environmental conditions. In rice, which also has a ratooning capacity, roots with diameters ranging from 0.5 to 2.0 mm are classified as fine roots, (Zobel and Waisel, 2010). Roots with smaller diameters are typically shorter and primarily responsible for water and nutrient uptake, while larger diameter roots tend to be longer and serve as the main conduit for transporting water and nutrients to the shoot (Blouin et al., 2007; Eissenstat & Yanai, 2002).

At harvest, Gulian had the longest root length (33.50 cm) while Pulot had the shortest (19.50 cm) during the dry season. During the wet season, the root length of the five varieties ranged from 21.25 cm to 24.75 cm. A statistical difference ($p \leq 0.05$) was observed in terms of variety, season and their interaction. Root length was longer during the dry season with an average of 26.5 cm, a difference of 4.35 cm compared to the wet season which had an average of 22.15 cm. The varieties Gulian, Tapol and Kiboa had longer roots during the dry season. Pulot on the other hand had a shorter root length during the dry season while Ginampay had comparable root length across the seasons. This variation maybe attributed to the shifting of biomass allocation from stems and leaves to roots, as root growth depend also on soil water availability in addition to crop management (Eziz et al., 2017). Beside soil water availability, root growth is influenced by plant genotype, soil biology and physico-chemical properties, and crop management (Vasconcelos et al., 2003).

Season had an influence in the fresh root weight of the five varieties after harvest. The average of fresh root weight was higher during the dry season, at 7.24 g, compared to 5.24 g during the wet season. Ample rainfall and consistent water availability during the wet season provided sufficient soil moisture, which is generally favorable for plant growth. In contrast, the dry season, with lower average monthly rainfall, resulted in increased allocated photosynthates to roots to enhance nutrient uptake, leading to higher average of fresh root weight during this period. No significant differences were observed in the dry root weight among varieties but significant differences were noted between seasons, indicating that the season had an effect on the root dry weight. The average root dry weight during wet season was 3.27 mm while 2.11 mm during the dry season. On the other hand, the average root diameter at harvest were statistically similar across seasons, suggesting that the season had no impact on the root diameter of the five ratooned adlay varieties. The average root diameter during the wet season is 1.42 mm while 1.34 mm during the dry season.

It can be observed that number of vegetative tillers during the wet season was higher than during the dry season, with average of 8.83 and 5.80, respectively (Table 4). Among the varieties, Kiboa had the highest number of vegetative tillers across seasons (9.75 during the wet season and 7.02 during the dry season), while Ginampay had the least number of tillers (8.00 during the wet season and 4.49 during the dry season). Tillering appeared to be influenced by the amount of rainfall during the growing period, in agreement with the study of Mostales and Aradilla (2016), which reported that adlay produced the highest number of tillers during rainy season or when sufficient moisture was available. Varietal difference was highly significant ($p<0.05$) in the number of vegetative tillers which suggests that different varieties have distinct characteristics in this regard. However, these five adlay varieties showed no differences in vegetative tillers under adverse conditions (Aradilla, 2018).

Table 4. Number of vegetative tillers, number of productive tillers, number of days to flowering and number of days to maturity of the five ratooned adlay in dry and wet season.

Variety	Number of vegetative tillers		Number of Productive tillers		Number of days to flowering		Number of days to maturity	
	Dry season	Wet season	Dry season	Wet season	Dry season	Wet season	Dry season	Wet season
Ginampay	4.49 A c	8.00 B a	4.11 A c	8.76 A a	71.50 A a	74.75 A a	150.00 A a	156.00 A a
Gulian	6.98 A a	9.10 B a	6.14 A ab	10.90 A a	75.50 A a	66.50 A a	130.25 A c	141.75 A a
Kiboa	7.02 A a	9.75 B a	6.53 A a	10.50 A a	70.00 A a	72.75 A a	132.75 A c	137.75 A a
Pulot	5.27 A b	7.42 B a	5.10 A bc	10.00 A a	81.75 A a	72.00 A a	133.75 A c	127.00 A a
Tapol	5.22 A bc	9.88 B a	4.85 A c	10.62 A a	71.50 A a	66.75 A a	141.75 A b	141.75 A a
s.d.	1.80	1.22	1.56	1.28	9.65	7.86	15.21	8.66

Means in a row for each variety with the same uppercase letters are not significantly different at $p<0.05$ according to Tukey's HSD test.
Means in columns for each season with the same lowercase letters are not significantly different at $p<0.05$ according to Tukey's HSD test.
s.d. – standard deviation

There were more productive tillers during the wet season, on average of 10.16, compared to 5.35 during the dry season. Kiboa had the highest number of productive tillers during the dry season at 6.53 while Ginampay had the least number of productive tillers, at 4.11. Despite the increased rainfall during the wet season, its uneven distribution might have led to insufficient soil moisture, potentially impacting plant growth. This suggests that the number of productive tillers is greatly affected by both varietal differences and seasonal conditions. However, the establishment of the main crop influenced also the performance of the subsequent ratoon plants; as crop tiller was significantly related to the main crop's tiller numbers (Torres et al., 2020). In addition, excessively low or high soil moisture levels can reduce the number of ratoon tillers.

No significant difference was observed in the number of days to flower across seasons, however, adlay ratoon crops took longer to flower during the dry season with an average of 74.05 days compared to the 70.55 days during the wet season. Highly significant ($p\leq0.05$) varietal differences were observed in the number of days to maturity (at 80% ripe grains). Pulot variety matured earlier during the wet season, with 10-20 days ahead than other varieties. This imply that days to maturity was greatly affected by varietal differences. In rice crop, the number of days to maturity for the ratoon crop was 59-73% of the total growth duration of the main crop (Zheng et al., 2023). In this study, the number of days to maturity of ratooned adlay was 72-83% of the total growth duration of the main crop during dry season and 71-87% during the wet season. A prolonged maturity period can be a limitation for ratooning, as it increases the probability of ratoon crops being vulnerable to adverse weather conditions. On the other hand, a short growth period due to high temperatures also can result in low grain yield (Ma, 2022).

The average panicle length during the wet season was significantly ($p<0.05$) shorter with an average of 51.96 cm compared to 59.96 cm during the wet season (Table 5). The difference might be due to the higher and more evenly distributed rainfall during the wet season compared to the dry season. Soil moisture content, which is strongly associated with microbial activity, influences the availability of nitrogen in the soil. Increased soil moisture improves nitrogen absorption and fixation (Morugan-Coronado et al., 2018). The enhanced absorption of nitrogen may contribute to the longer panicle length during the wet season.

The effect of fertilization on panicle length was also reported in the study of Perlas and Batanes (2014), with fertilized adlay plants having longer panicle compared to unfertilized plants (Gorne, 2020). The ratooned adlay varieties were significantly different during the wet season in their panicle length. Tapol had the longest panicle length at 67.95 cm and Gulian had the shortest panicle length at 52.17 cm in the dry season.

Table 5. Panicle length, number of grains per panicle and unfilled grains (%) of the five ratooned-adlay varieties in dry and wet season.

Variety	Panicle length (cm)		Number of grains per panicle		Unfilled grains (%)	
	Dry season	Wet season	Dry season	Wet season	Dry season	Wet season
Ginampay	58.91 A bc	49.78 B a	145.64 A a	184.05 B a	22.21 A a	15.48 B a
Gulian	52.17 A c	50.95 B a	149.62 A a	190.48 B a	19.60 A a	10.94 B a
Kiboa	58.00 A bc	56.31 B a	171.12 A a	177.28 B a	19.50 A a	15.23 B a
Pulot	62.75 A ab	50.94 B a	155.53 A a	184.52 B a	20.74 A a	13.37 B a
Tapol	67.95 A a	51.84 B a	153.05 A a	167.04 B a	21.22 A a	14.94 B a
s.d.	5.19	7.67	25.40	14.96	5.00	2.43

Means in a row for each variety with the same uppercase letters are not significantly different at p<0.05 according to Tukey's HSD test.
Means in columns for each season with the same lowercase letter are not significantly different at p<0.05 according to Tukey's HSD test.
s.d. – standard deviation

The total number of grains per panicle was significantly ($p<0.05$) higher during wet season, with an average of 180.67, compared to the dry season with an average of only 154.99. This implies that season had an effect in the grain filling of adlay (Table 5). Grain filling in some cereals like sorghum has been identified as the most sensitive or crucial stage to moisture stress (Sarshad et al., 2021). Adequate water or moisture is essential for proper grain development (Emes et al., 2003). Limited water supply and extreme temperatures can negatively impact the photosynthetic processes and the partitioning of assimilates, leading to decreased grain yield (Farooq et al., 2009). Further, there was a decrease of enzymes such as sucrose, starch synthase, adenosine diphosphate and glucose pyrophosphorilase (Chaitanya et al., 2001).

Average percentage of unfilled grains (%) was significantly lower during the wet season at an average of 13.99 while 20.65 during the dry season. This suggests that season greatly affected the grain filling of adlay during ratooning. Grain filling directly determines the quality of grain and yield in crops such as wheat, maize and rice (Ma et al., 2023). There was difference in the rainfall distribution during the first three months of the wet and dry season in this study which might affect the grain filling of the five adlay varieties in both seasons. In rice, it was observed that aside from season difference the ratoon grain filling is closely linked to the grain filling performance of the main crop (Hu et al., 2023).

The average 1000-seed weight (Table 6) during the wet season is significantly ($p<0.05$) higher, on average 86.40 g, than the average during the dry season (76.05 g). Ginampay had the heaviest 1000-seed weight (92 g), while Gulian had the lightest (79.25 g) during the wet season. Ginampay had also the heaviest 1000-seed weight during the dry season and Tapol with the lightest (65.25 g). It was also observed that Tapol, Pulot and Kiboa had more than 10-g difference in the 1000-seed weight between the two seasons, while Gulian and Ginampay had differences of only 2 g and 7 g, respectively. It could be concluded that season might influence the quality and size of grains. In the study of Joshi et al. (2015), the quality of grains in ratoon rice was greatly affected by the environment in which factors like water availability, temperature, fertilizer application, and salinity stress play crucial roles. Specifically for rice, nitrogen fertilizer application has been shown to enhance grain yield (Zhou et al., 2022).

Table 6. 1000-seed weight, grain yield and harvest index of the five ratooned-adlay varieties during the dry and wet season.

Variety	1000–seed weight (g)		Grain yield (kg/ha)		Harvest index	
	Dry season	Wet season	Dry season	Wet season	Dry season	Wet season
Ginampay	85.00 A a	92.00 B a	681.44 A c	910.05 B b	29.92 A a	22.50 B a
Gulian	77.25 A bc	79.25 B c	751.76 A b	1,705.93 B a	29.58 A a	24.00 B a
Kiboa	74.00 A c	87.75 B ab	770.50 A ab	881.39 B b	26.49 A a	26.00 B a
Pulot	78.75 A b	91.50 B a	708.99 A bc	940.70 B b	26.87 A a	24.50 B a
Tapol	65.25 A d	81.50 B bc	815.48 A a	1,069.89 B b	26.58 A a	22.50 B a
s.d.	6.85	6.98	370.22	64.72	0.03	0.05

Means in a row for each variety with the same uppercase letters are not significantly different at $p<0.05$ according to Tukey's HSD test.
Means in columns for each season with the same lowercase letter are not significantly different at $p<0.05$ according to Tukey's HSD test.
s.d. – standard deviation

Highly significant ($p<0.05$) differences were observed among the grain yield of five adlay varieties of ratooned adlay in terms of season, variety and its interaction. The average grain yield during the wet season is 1,101.59 kg while 745.63 kg during the dry season. During dry season, Tapol had the highest grain yield at 815.48 kg among the five varieties and Ginampay with lowest grain yield at 681.44 kg. In wet season, Gulian had the highest grain yield at 1,705.93 kg and Kiboa had the lowest at 881.39 kg. It was noted that yield of Gulian had almost 1000 kg (56%) difference between the two seasons, although there was a 12%-25% reduction in the grain yield of the other four varieties during the dry season. The large variation suggests genetic differences among varieties. In the study of Sumael et al. (2023), there is a 47% average reduction from the new plant to the ratoon in wet season and 26.4% average reduction in dry season. This substantial reduction in adlay yield across both seasons suggests that while ratooning reduces yield, it remains a viable option for farmers with limited resources for new cropping. Yield reduction had been observed in other ratoon crops such as sugarcane, where yields ranging from 40 to 50 tons per hectare are considered low (Xu et al., 2021). Similar reduction of ratoon yield from main crop was also observed in sorghum (Ardiyanti et al., 2019; Mourtzinis et al., 2016). The reduction could be attributed to fertilizer application particularly nitrogen and increased insect, disease and weed pressures (Zhou et al., 2022).

There was no statistical significance among the five adlay varieties ratooned during wet and dry season in terms of harvest index which ranged from 22.50% to 26% during wet season and 26.49% to 29.92% during dry season. However, harvest index was generally higher during the dry season with an average of 27.89%, compared to 23.90 % during wet season. It implies that season had an effect on the harvest index of the five ratooned adlay varieties.

Nutritional components

The crude fat (%) content of the five adlay varieties had highly significant ($p<0.05$) differences in terms of variety, and the season and variety interaction (Table 7). During the wet season, the average crude fat content of the five varieties is 1.74% while 1.64% during the dry season. The highest crude fat content was recorded for Pulot during wet season (3.34%) and during dry season (1.96%). This indicates that Pulot crude fat content is highest among the adlay varieties across seasons. The average crude protein content of the five ratooned adlay varieties was higher during the dry season (18.06) compared to wet season (11.28%) with difference of 6.78%. This suggests that season affected crude protein level of ratooned adlay plants. Crude fiber was significantly ($p<0.05$) affected by season, variety and their interaction. Average crude fiber was higher during the wet season that is 1.82% compared to 0.87% during the dry season. Ginampay had the highest crude fiber content across seasons, at an average of 2.15%, while Gulian had the least content at 0.69%. This implies that crude fiber content differed among varieties and seasons. Total carbohydrates was higher during wet season with an average of 83.47% while 77.87% during the dry season. Moreover, Gulian had highest total carbohydrates content during both wet and dry seasons, with an average of 82.13%. Combined analysis revealed that total carbohydrates of the ratooned adlay was highly affected by season. Studies on cereals, whole grains, rice and the like, contains complex carbohydrates or starches. During dry season, heat stress could decrease the starch content but increase the grain protein and mineral concentrations (Ben Mariem et al., 2021). The results of this study were in contrary with C3 cereals. Despite lower rainfall during the dry season, adlay ratooned crops exhibited higher total carbohydrates, averaging at 83.47%.

In terms of ash content, the average of the five adlay varieties was 1.66% during the wet season, which is comparable to the 1.57% during the dry season This connotes that ash content differed among varieties but not affected by seasonal changes. On the other hand, moisture content was higher during wet season, at an average of 13.28%, compared to 12.44% during dry season. This implies that moisture content is influenced by season. Climate change is decreasing food nutrition as evidenced from nutritional science. It affects food by decreasing food diversity, nutrient density, and food safety that has impact on global food security (Ducker, 2022). The total sugar content of the five ratoon adlay varieties during wet season was 1.20 is comparable to the 1.33 during the dry season which is. It was observed that Ginampay with highest sugar (1.74%) content during dry season had the lowest sugar content (1.01%) during wet season. On the other hand, Pulot had highest sugar content in wet season (1.37%) but lower (1.26%) during dry season.

Return of expenses (ROE)

Among the five adlay varieties evaluated as ratoon crop during the dry season, Gulian variety obtained the highest return of expenses (ROE) across seasons at 88.09% with net income of P39,927 per hectare (Table 8). On the other hand, Kiboa variety had deficit income of 1,001 per hectare and had an ROE of -2.22%. During the dry season, all the five varieties had deficit income. Tapol had the lowest deficit at -9.5% ROE while Pulot had the largest deficit at -21.27% ROE. Only Gulian and Tapol had the average positive ROE across seasons, while the other varieties all showed negative ROE.

Table 7. Crude fat, crude protein, crude fiber, carbohydrates, ash content, moisture content and total sugar content of the five ratooned adlay varieties in dry and wet season.

Variety	Crude fat (%)		Crude protein (%)		Crude fiber (%)		Carbohydrates (%)		Ash (%)		Moisture content (%)		Total sugar (%)	
	Dry Season	Wet Season	Dry Season	Wet season	Dry Season	Wet season	Dry Season	Wet season	Dry Season	Wet season	Dry Season	Wet season	Dry Season	Wet season
Ginampay	1.80 A ab	0.77 A d	17.87 A a	11.17 B a	1.17 A a	3.13 B a	77.88 A a	82.94 A a	1.35 A bc	1.99 A a	12.76 A a	13.12 B a	1.74 A a	1.01 A b
Gulian	1.54 A c	1.69 A b	16.91 A a	10.46 B a	0.59 A d	0.79 B d	79.19 A a	85.06 A a	1.78 A ab	1.83 A a	12.26 A a	13.34 B a	1.20 A a	1.10 A b
Kiboa	15.00 A c	24.75 A a	2.50 A b	7.12 B a	0.38 A d	1.62 B a	1.27 A bc	1.22 A a	29.25 A ab	24.75 A a	6.30 A bc	4.3 B a	1.90 A bc	1.21 A ab
Pulot	1.96 A a	3.34 A a	17.39 A a	9.56 B a	0.83 A c	1.85 B b	78.10 A a	83.58 A a	1.72 A ab	1.66 A ab	12.23 A a	13.39 B a	1.26 A a	1.37 A a
Tapol	1.30 A d	1.84 A b	19.41 A a	13.21 B a	1.01 A b	1. 89 B b	77.11 A a	81.66 A a	1.16 A c	1.40 A b	11.89 A a	13.33 B a	1.55 A a	1.33 A a
s.d	0.25	0.94	2.51	1.62	0.22	0.8	2.4	1.59	0.35	0.28	0.64	0.27	0.41	0.16

Means in a row for each variety with the same uppercase letter are not significantly different at $p < 0.05$ 05 according to Tukeys HSD test
Means in columns for each season with the same lowercase letter are not significantly different at $p< 0.05$ according to Tukeys HSD test
s.d. – standard deviation

Table 8. Cost and return analysis of five adlay varieties ratooned during dry and wet season.

Variety	Grain yield (kg/ha)		Production cost (Php)		Gross income (Php)		Net income (Php)		Return of expenses (ROE)		
	Dry season	Wet season	Dry season	Wet season	Dry Season	Wet season	Dry Season	Wet season	Dry Season	Wet season	Mean (%)
Ginampay	681	910	45,010	45,085	34,072	45,503	-10,938	418	-24.3	0.9	-11.7
Gulian	752	1705	45,025	45,325	37,588	85,252	-7,437	39,927	-16.52	88.09	35.78
Kiboa	771	881	45,040	45,070	38,525	44,070	-6,515	-1,001	-14.46	-2.22	-8.34
Pulot	709	941	45,025	45,085	35,450	47,035	-9,576	1,950	-21.27	4.33	-8.47
Tapol	815	1070	45,055	45,130	40,774	53,495	-4,281	8,365	-9.5	18.53	4.51

Price assumption is Php50/kg (hulled grain)

1US$ = Php58.38

Conclusion

Based on the findings of the study, season had a significant effect on the ratooning performance of the five adlay varieties. The survival rate of ratooned adlay was higher during the wet season compared to the dry season, although both seasons had below 50% average survival rate. This season effect was reflected in grain yield, with only the Gulian variety exceeding a one-ton grain yield during the wet season, achieving 88.09% ROE. Additionally, Gulian had also the highest number of vegetative and productive tillers. However, return of expenses during the dry season was negative for all the five varieties, indicating that ratooning is only viable during the wet season, with Gulian as the preferred variety. Nutritional components were also influenced by season and varied among the different varieties.

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No potential conflict of interest was declared by the authors.

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