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Response of Adlay (*Coix lacyrma-jobi* L.) to Different Tillage Methods and Population Densities

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ABSTRACT

The country has endured food insufficiency brought about by several constraints that significantly decreased production, mainly of staple crops such as rice and corn. Adlay is a promising alternative staple crop. Several studies have been directed to exploit the full potential of adlay, but only a few have been conducted on its agricultural management practices related to tillage practices and population density. Hence, this study was conducted to evaluate the crop growth and yield performance, determine the appropriate management practices and assess its profitability per hectare basis in response to different tillage methods and population density. The experiment was laid out in nested design with a complete block in three replications having a population density of one plant hill^{-1} (P_1), two plants hill^{-1}(P_2) and three plants hill^{-1}(P_3) as the subplot nested within three tillage methods, mainly zero tillage (T_1), conventional tillage (T_2) and reduced tillage (T_3). Results revealed a significant effect of conventional tillage practice associated with early crop emergence and maturity. Three plant hill^{-1} population density stimulates early crop maturity, promotes the tallest plants and greater herbage yield. Longer panicle length, maximum number of filled grains, high percent fertility in effect of zero tillage practice, and one plant hill^{-1} population density are attributed to higher grain yield. Thus, zero tillage and one plant hill^{-1} are economically advantageous with the highest net return of PhP 76, 844.10 and PhP 67, 574.69 with a benefit-cost ratio of 1.78 and 1.50, respectively.

Keywords: Adlay profitability, alternative crop, population density, tillage method

INTRODUCTION

Adlay (*Coix lacryma-jobi* L.) is a weed crop belonging to the family Poaceae. Unknown to many Filipinos, adlay is utilized as cereal, served the same way as rice and is recognized to have a medicinal property (Aradilla 2016). Also, it is used as raw material in making flour and is a good alternative main ingredient for baking purposes (Domingo 2016; Salver 2019). Adlay has a nutritional component made up of starch (50%), protein (14 %) and fat (6%) (DA RFO8 2013). Furthermore, it is being processed into beverages such as wines, beers, coffee and tea (Gaitan 2013,

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being processed into beverages such as wines, beers, coffee and tea (Domingo 2016, Gaitan 2013, Manning et al 2017). It is also anticipated as an essential component in improving livestock production in the country.

The country has endured food insufficiency, one of the global problems, brought about by several constraints that significantly influence production, mainly of staple crops, rice and corn. Adlay is a promising crop as an alternative food source (Velasco 2010). Several studies have been conducted to exploit the full potential of the adlay as an alternative crop to rice and corn. The agriculture sector, researchers, agronomists and crop scientists collaboratively developed best cultural practices that further endorse its suitability and sustainability in different areas throughout the country.

Tillage practices and population density are among the management practices that can be manipulated in adlay production. Soil tillage is regarded as a valuable factor that influences soil properties and crop yield. Tillage considerably influences proportion of crop growth and yield and affects the sustainability of soil resources that may result in several outcomes depending on how it is practiced. Tillage has a multitude of impacts on the soil's physical, chemical and biological aspects. The effects of which could be favorable or detrimental, depending on the method used. In addition, tillage influences crop growth and development as it loosens the soil, enhances chemical reaction, and improves the soil's moisture condition. Judicious and appropriate adoption of tillage practices must be implemented to prevent deleterious results of unsuitable tillage (Alam et al 2014).

Plant population density is similarly crucial for gainful production. The production and partitioning of carbohydrates, composition of growth, and development and plant architecture are altered and influenced by plant density. Thus, negative consequences may occur once optimum plant density is exceeded (Sangoi 2000). Abuzar et al 2011 added that even under optimal growth, it is regarded as a factor determining the degree of competition among plants at which most plant growth parameters are affected influencing the potential yield of the crop.

Furthermore, Berbec and Matyka (2020) stressed that in optimizing the most vital parameters in crop production, the ideal population density of cultivated species must be followed. Nonetheless, plant density is equally a significant agronomic factor that manipulates the micro-environment, thus, affecting the growth and yield of crops. It is, therefore, necessary to adopt the right planting density. Hence, this study is necessary to evaluate the crop growth and yield performance, determine the appropriate management practices and assess its profitability per hectare basis in response to the tillage method and population density.

MATERIALS AND METHODS

Experimental Area and Land Preparation

The study was established at the Department of Agronomy Experimental Area, College of Agriculture and Food Science, Visayas State University, Visca, Baybay City, Leyte, Philippines from November 21, 2021 to May 3, 2022.The experimental area is geographically located 10^{o} 44' 59" N to 124^{o} 47' 36" E, with an altitude of

17.37 m asl. A total land area of 659 m^2 was prepared according to the three-tillage method used in the study. For zero tillage, the area was sprayed with glyphosate-containing herbicides at a rate of 1.5 L ha^{-1}. In conventional tillage, the area was plowed and harrowed twice at weekly intervals. For reduced tillage, the area was sprayed with herbicides, plowed and harrowed once at weekly interval. Animal-drawn implements were used during the land preparation. Furrows were made at a distance of 0.9 m apart after the last harrowing.

Soil Sampling and Analysis

Soil samples for initial soil analysis were collected randomly from the experimental area at a depth of 20 cm using a soil auger. These were composited, air-dried and pulverized, sieved (2 mm wire mesh) and placed in a properly labeled zip lock bag. The samples were brought to the Central Analytical Services Laboratory (CASL), PhilRootcrops, Visayas State University, Baybay City, Leyte. These were analyzed for soil pH (potentiometric method at 1:2.5 soil water ratio), total N (modified Kjeldahl method), extractable P (Bray P-2 extraction method), and exchangeable K (1N NH_4OAc at pH 7.0 method) and % organic matter (Walkey & Black method). A separate ten soil samples were gathered from the experimental area using the core method for bulk density. Collected soil samples were oven-dried and weighed. After harvest, soil samples were once more randomly collected from each treatment plot for final soil analysis. These were composited, processed and analyzed for the same soil parameters mentioned above.

Experimental Designs and Treatments

The experimental area was laid out in a nested design with a complete block in three replications with population density as the treatments (subplot) nested within three tillage methods (main plot). Each treatment plot has a dimension of 4.2 m x 4.5 m (18.9 m^2) with five rows. Replication and treatments were separated by 1.0 meter and 0.5-meter alleyways, respectively. Treatments were as follows: tillage methods (T_1 = Zero tillage, T_2 = Conventional tillage and T_3 = Reduced tillage) and population density (P_1 = 1 plant $hill^{-1}$,P_2 = 2 plants $hill^{-1}$ and P_3 = 3 plants $hill^{-1}$.

Preparation of Seed and Establishment

Kiboa, an adlay variety, was used in the study. Prior to sowing, seeds were soaked in tap water for a maximum of 8 hours, followed by 4 hours of incubation. Five seeds $hill^{-1}$ was sown at the distance of 60 cm between hills at a depth of 2.5 cm from the soil surface.

Cultural Management Practices

Thinning was made two weeks after sowing, keeping the number of plant $hill^{-1}$ as indicated in the study. A fertilizer recommended rate of 60-30-30 kg N, P_2O_5 K_2O $ha^{-1}$was followed. Application of complete fertilizer (30-30-30 kg N, P_2O_5 K_2O ha^{-1}, K_2O) K_2O) was made ten days after sowing (DAS), whereas the remaining nitrogen was applied at 30 DAS in the form of urea. Hand weeding was facilitated using bolo to control weeds. Off-baring was facilitated four weeks after sowing (30 DAS), while hilling up was done at 45 DAS. Spraying of pesticides was facilitated due to the infestation of pests such as whiteflies and rice bugs.

Harvesting

Harvesting was done as 85 % of the grains turned brown by cutting the stem and the base of the plant using a sharp sickle within the harvestable area with a dimension of 3 m x 2.7 m. The samples were threshed, sundried for three days to attain 14 % moisture content and winnowed prior to gathering the necessary data.

Data Gathered

The agronomic parameters gathered were the number of days from sowing to emergence, flowering and maturity, plant height at maturity, number of vegetative tillers hill^{-1} and herbage yield. The following data of yield and yield components collected were: number of productive and non-productive tillers hill^{-1}, panicle length (cm), total number of grain panicle^{-1}, number of filled and unfilled grains panicle^{-1}, percent fertility, weight (g) of 1,000 seeds and grain yield (t ha^{-1}).

Weeds per treatment plot were gathered randomly using a 50 cm x 50 cm quadrat. This was done prior to and after off-barring and hilling up. Fresh weight and dried weight of weeds were determined using a digital weighing scale. Meteorological data was collected from PAG-ASA Agrometeorological Station, Visayas State University, Baybay City, Leyte. Cost and return analysis of production was determined on a per hectare basis of gross income, net profit and benefit-cost ratio.

Analysis of variance (ANOVA) for the data collected was done using STAR software. A comparison among treatment means was made using Tukey's Honestly Significant Difference (HSD) test at 5% level of significance.

RESULTS AND DISCUSSIONS

The Study Site

Table 1 presents the initial and final result of soil analysis as influenced by different tillage methods and population density. Initial soil analysis results revealed that the experimental area had a soil pH of 5.28 with 1.24 percent organic matter, 0.11 total nitrogen, 25.97 mg kg^{-1} available phosphorus, 1.80 me 100 g^{-1} exchangeable potassium and a bulk density of 1.38 g cm^{-3}. Initial soil analysis results specified that the soil was strongly acidic with a deficit in nitrogen and low organic matter, contained a high amount of available phosphorus and exchangeable potassium (Landon 1991). The initial bulk density result showed an ideal bulk density for plant growth according to Umholtz (2013). Final soil analysis revealed that the soil pH and percent organic matter notable increased relative to the initial analysis. However, there was a reduction in total nitrogen, exchangeable potassium, and bulk density and a slight decrease in available phosphorous compared with the initial results. The decrease in total nitrogen, available relative to the initial analysis. However, it exhibited a reduction in total nitrogen, exchangeable potassium, bulk density and a slight decrease in available phosphorous compared with the initial results. The decrease in total nitrogen, available phosphorus and exchangeable potassium was associated with the nutrient acquisition by the crop during its growth and development (Gorne & Aradilla 2020).

Table 1. Chemical and physical properties of soil before planting and afterharvesting of adlay as influenced by tillage methods and population density

TREATMENT	pH (1:2.5)	OM (%)	TOTAL N (%)	AVAIL P (mg kg^{-1})	EXCH K (me $100g^{-1}$)	BULK DENSITY (g cm^{-3})
Initial	5.28	1.24	0.11	25.97	1.80	1.38
Final Soil Analysis						
Tillage Methods						
T_1 = ZT	6.18	1.27	0.05	24.59	0.66	1.18
T_2 = CT	6.23	1.31	0.08	26.71	0.68	1.03
T_3 = RT	6.22	1.23	0.06	24.21	0.59	1.13
Population Densities						
P_1 = 1 plant hill-1	6.21	1.26	0.06	25.39	0.66	1.13
P_2 = 2 plants hill-1	6.24	1.24	0.05	24.63	0.65	1.11
P_3 = 3 plants hill-1	6.18	1.31	0.07	25.49	0.61	1.09

Source: Central Analytical Services Laboratory, PhilRootcrops, Visayas State University, Visca, Baybay City, Leyte, Philippines

According to Bot and Benites (2005), an increase in pH level is due to natural buffer capacity recovery of the soil with the increase in organic matter. Bauer (1974) reported that the higher the organic matter content, the lower the soil bulk density. Busari et al (2015) cited other literature on the diverse impact of tillage practices on soil pH. Some reported that zero tillage lowers soil pH level while others mentioned that intensity of tillage causes soil pH to decreases. While Blomme et al (2002) observed a reduction of 26% and 27% in soil bulk density as affected by the tillage system at a depth of 5 cm and 20 cm, respectively. According to Chapepa et al (2020), an increase in soil pH is also linked with tillage input that enhances surface and sub-surface soil mixing. Moreover, planting density is concluded to significantly influence the chemical properties of the soil (Duan et al 2019). Moreover, the result indicated that decreased final bulk density was associated with the intensity of soil manipulation and root proliferation with population density.

The highest total weekly rainfall was observed during April 9-15, December 10-16 and February 26 – March 4, in decreasing order, while the lowest was recorded on January 8- 14 (Figure 1). Escasinas and Zamora (2019) cited that mean annual rainfall under VSU conditions reached as high as 2,809.6 mm within the last 32 years. The high amount of rainfall recorded during the study was due to the typhoon that resulted in crop lodging. Agusta et al (2022) reported that the incidence of extreme weather such as heavy rainfall coupled with high wind velocity has a deleterious impact on crop production as it affects the availability of sunlight, pollination, grain sterility during the reproductive stage and promotes grain shattering. Favorable temperature was recorded within the study period, with minimum temperature ranging from 22.8-26.8 degrees Celsius, while maximum temperature ranged from 26.0-30.5 degrees Celsius. The recorded average daily relative humidity was around 87% to 95%. Relative humidity of 60-70% is beneficial for crop growth (agritech.tnau.ac.in); thus, relative humidity beyond this range promotes the development of disease caused by fungi and bacteria. Highest total sunshine hours week-1 were recorded during April 16- 22, while the lowest was recorded in the whole month of January. Song and Jin (2020) observed a reduced corn yield by 8% because of a decrease in sunshine hours. Sunshine hours requirement per day of various cereals crops ranges from 4 to 7 hours (Wang et al 2018).

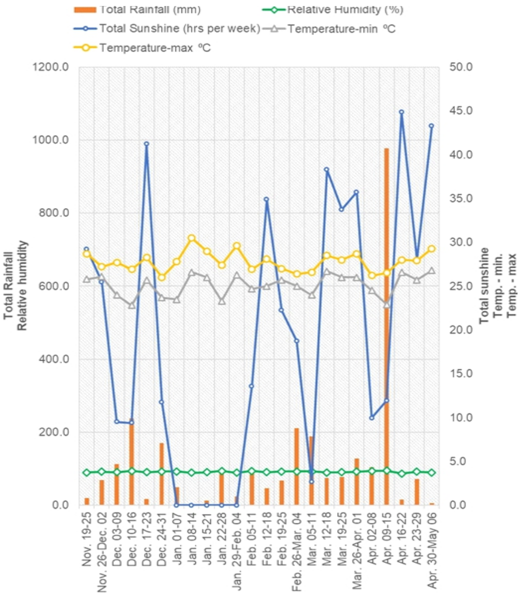

Figure 1. Weekly total rainfall, average minimum and maximum temperature, mean relative humidity and total sunshine hours throughout the duration of the study

Nonetheless, there was no significant effect on the weed parameters of adlay at 28, 42 and 56 DAS as influenced by different tillage methods and population densities, except on the dry weight and fresh weight of weeds at 28 and 56 DAS, respectively. Findings are consistent with Kanteh et al (2013), who reported that high weed biomass is recorded with a decrease in plant density. The most prevalent weed species observed in the study area include purple nutsedge (*Cyperus* *rotundus* L.), itch grass (*Rottboellia cochichinensis* Lour), torpedo grass (*Panicum repens* L.) and touch me not plant (*Mimosa pudica* L.). Though the result is insignificant, soil tillage generally influences the occurrence of weeds. Inversion of soil suppresses the weed seed to germinate successfully; however, weed seed dormancy and incidence highly rely on the type of tillage used (Morris et al 2010).

Agronomic characteristics

Data on the growth characteristics of adlay as influenced by different tillage methods and population density is presented in Table 2. Results showed that tillage practices significantly influenced the days from sowing to emergence and maturity and plant height (cm). However, all agronomic characteristics except the number of days to emergence were significantly affected in response to population densities. Hence, no interaction was observed between tillage methods and population densities. It implied that under conventional tillage practices, early seed emergence was stimulated compared to reduced and zero tillage. Results of the study confirm the findings of Barut and Çelik (2010).

Table 2. Agronomic characteristics of adlay as affected by tillage method and population densities

TREATMENTS	NUMBER OF DAYS FROM SOWING TO			VEGETATIVE	PLANT	HERBAGE
	EMERGENCE	FLOWERING	MATURITY	TILLERS HILL $^{-1}$	HEIGHT (CM)	YIELD (t ha^{-1})
Tillage Method						
T1 = ZT	6.33a	98.67	159.44a	15.74	375.98a	20.89
T2 = CT	5.67b	95.67	154.33b	15.20	358.51b	20.48
T3 = RT	6.11a	96.22	155.67b	16.11	358.03b	19.87
HSD Test	**	ns	*	ns	*	ns
Population Density						
P1 =1plant hill^{-1}	5.89	98.22a	157.78a	14.69b	360.66b	20.28b
P2 =2plants hill^{-1}	6.33	96.33b	156.33b	15.22b	362.29b	19.67b
P3 =3plants hill^{-1}	5.89	96.00b	155.33c	17.14a	369.56a	21.28a
HSD Test	ns	**	**	**	*	**
Tillage Method x Population Density						
HSD Test	ns	ns	ns	ns	ns	ns
C.V.(a) %	03.19	2.77	1.34	12.63	2.78	6.80
C.V.(b) %	17.31	1.11	0.42	05.72	1.49	3.69

However, contrary to the report of Khan et al (2008), a delay in crop emergence was observed in conventional tillage compared to reduced tillage. Some scholars cited that under normal and favorable environmental conditions, adlay seed emerged within 5-7 days after sowing (Aradilla 2018; Gorne and Aradilla 2020). Barut and Çelik (2010) reviewed that delayed seed germination and emergence in zero tillage are due to crop residues and moist soil conditions. Also, Peigné et al (2007) reported that due to a lower temperature and high plant residue in the soil surface area under conservation tillage, crop emergence is impeded.

Moreover, Liu et al (2022) observed a delay in winter wheat maturity under a no-tillage system. Desta et al (2021) reported that the delay in crop maturity under zero tillage was attributable to more soil water availability and minimal evaporation. Equally, zero tillage was found to result in lower root length density (RLD) and root surface area density (RSD) at tillering stage which in effect delayed crop maturity (Guan et al 2015). Still, maximum plant height was recorded under zero tillage in this study. Comparable result was observed in conventional (T_2) and reduced (T_3) tillage. This result was consistent with Buah et al (2017) and Imran et al (2013) but contrary to the study of Ozturk and Sogurt (2016). On the other hand, early flowering P_2 and P_3 and a shorter maturity period were associated with the crop architecture. Chapepa et al (2020) cited that high plant densities provide faster closing of the canopy, which in turn stimulates quicker maturity. Hence, the study revealed that as plant population density increases from 1 to 3 plants hill^{-1}, maturity period of adlay decreases. This conforms with the study of Amanullah et al (2009). However, the result was inconsistent with the claim of Rossi and Braojos (2003), where delayed crop maturity was observed at a higher plant density.

Consequently, higher population density exhibited a greater number of vegetative tillers hill^{-1} and influenced the plant height. Hasanuzzaman et al (2009) opined that the number of plants per hill influenced the tiller numbers. Nevertheless, increasing plant population density is closely associated with intraspecific competition for below and above-ground growth resources such as nutrients and light (Zhai et al 2018). This means higher population density leads to overcrowding, thus limiting light penetration within the canopy, causing stem elongation. Yu et al (2021) found that due to the increase in synthesis of gibberellic acid (GA) and stimulation on the signaling GA3-oxidase in leaf collar tissue as a result of high plant density, it induces internode elongation. Furthermore, higher adlay plant density produced greater herbage yield per unit area as a result of the increase in plant height under three plants hill^{-1}. Cusicanqui and Lauer (1999) concluded that an economic trade-off favoring herbage yield than grain yield would result as plant population density increases.

Yield and Yield Characteristics

Data on yield and yield components of adlay in response to different tillage practices and population densities are presented in Table 3. Results exhibited a significant effect of tillage practices on the number of filled grains panicle^{-1}, total number of grains panicle^{-1}, percent fertility and grain yield of adlay. However, tillage methods did not influence the number of productive and non-productive tillers, panicle length, total number of unfilled grains and weight of 1,000 seeds of adlay. Similarly, population density highly influences nearly all the parameters studied on adlay, excluding the number of unfilled grains panicle^{-1}, total number of grains panicle^{-1}, and weight of 1,000 seeds. No significant interaction was exhibited between tillage methods and population densities.

Zero tillage recorded the highest number of filled grains panicle^{-1}, total number of grains panicle^{-1}, percent fertility and grain yield (t ha^{-1}). Statistically, this treatment (T_3), however, was at par with conventional tillage. Imran et al (2013) claimed similar results in their study where higher grain yields of rice and wheat were recorded in zero tillage. Wang et al (2021) remarked that appropriate tillage practices can boost grain yield. According to Busari et al (2015) crop yield as influenced by tillage is linked with its effects on root growth and nutrient use efficiency. Guan et al (2015) found that high root surface area density and root length density observed in zero tillage during the later stage of crop growth effectively promoted root growth at the grain filling stage.

Malhi and Lemke (2007) reported that an increase in root mass under zero tillage is attributed to a high population of soil micro and macro-organism creating channels and a high number of bio pores facilitating root growth. High root density was found at the topmost layer under zero tillage, where high accumulated nutrient is present (Du Plessis 2003). According to FAO (2003), the following characteristics, such as better water infiltration and high soil fertility, which increase water storage and efficiency, are attributed to higher yield in zero tillage system.

On one hand, the number of tillers per hill, particularly productive tillers, are regarded as significant yield components of the crop. Three plants hill^{-1} recorded the maximum productive and non-productive tillers hill^{-1}. The longest panicle was attained at one plant hill^{-1} and the shortest at two and three plants hill^{-1}, with results at par with each other. Some literature reported that a higher number of tillers hill^{-1} potentially yield greater grain. However, it does not always mean a higher economic yield. Evidently, the study revealed a higher grain yield at one plant hill^{-1}. This is perhaps linked to a longer panicle, a greater number of filled grains and higher percent fertility than that of two plants hill^{-1} yet at par with threefilled grains and higher percent fertility than that of two plants hill^{-1} yet at par with three plants hill^{-1}.

With increasing plant density, Yang et al (2019) found that ineffective tillers statistically increase as late-emerging are shaded by early emerging tillers. Fujita and Yoshida (1984) stated that a dense plant population reduced root and tiller growth due to heavy mutual shading. This means that at a high density of plants, the potential number of productive tillers was significantly reduced due to shading and competition. At some point, amplified intraspecific and interplant competition led to tiller mortality (Nie et. al., 1997). Tiller loss or mortality can be observed relative to the number of vegetative tillers at 75 DAS.

Longer panicle length was reported to contribute to a maximum grain yield per panicle (Anwari et al 2019). Escasinas et al (1981) found that panicle length declined as population density increased. In a study conducted by Fujita and Yoshida (1984) on several sink organs competition for photosynthates, it was found that greater sink size of the culm of taller plant height adversely affects panicle growth during panicle development. Wang et al (2021) explained that the grain filling stage is adversely influenced by increasing plant population. They found that a reduction in photosynthetic activity in maize was enhanced by highly dense plant population; in effect, this led to a reduction in grain filling rate and grain weight. Gorne and Aradilla (2020) stated that dense plant population per unit area led to a higher number of unfilled grain per panicle, which caused a reduction in percent fertility. Escasinas et al (1981) further reported a reduction in the number of grains per panicle as plant population density increased. Tabo et al (2002) remarked that lesser plant density can compensate for higher yield with a more productive panicle. Zhai et al (2018) mentioned that the intensity of competition increases as population density increases, reducing the relative resource availability for individual plants, which influence adversely the grain yield per plant. Muli (1995) reported a negative consequence in the mean yield per

Table 3. Yield and yield characteristics of adlay as affected by different tillage methods and population densities

TREATMENTS	NUMBER OF		PANICLE	NUMBER OF		TOTAL		WEIGHT	
	PRODUCTIVE TILLERS ($hill^{-1}$)	NON-PRODUCTIVE TILLERS ($hill^{-1}$)	LENGTH (cm)	FILLED GRAINS ($panicle^{-1}$)	UNFILLED GRAINS ($panicle^{-1}$)	NUMBER OF GRAINS ($panicle^{-1}$)	PERCENT FERTILITY (%)	OF 1,000 SEEDS (g)	GRAIN YIELD ($t\ ha^{-1}$)
Tillage Method									
T_1 = Zero Tillage	13.06	1.22	63.80	145.33a	18.19	163.52a	88.86a	84.67	1.60a
T_2 = Conventional Tillage	12.11	1.27	59.80	131.59ab	16.76	148.34ab	88.47ab	83.72	1.45ab
T_3 = Reduce Tillage	12.43	1.53	58.95	112.69b	17.44	130.13b	85.47b	84.19	1.21b
HSD Test	ns	ns	ns	*	ns	*	*	ns	*
Population Density									
P_1 = 1 plant $hill^{-1}$	11.16c	0.76c	64.77a	145.62a	16.03	161.66	89.54a	86.89	1.50a
P_2 = 2 plants $hill^{-1}$	12.34b	1.29b	59.89b	120.56b	17.71	138.27	86.74ab	83.17	1.33b
P_3 = 3 plants $hill^{-1}$	14.10a	1.98a	59.88b	123.43ab	18.64	142.08	86.52b	82.53	1.43ab
HSD Test	**	**	*	*	ns	ns	*	ns	*
Tillage Method x Population Density									
HSD Test	ns	ns	ns	ns	ns	ns	ns	ns	ns
C.V.(a) %	6.85	19.39	9.39	13.65	19.66	12.77	2.28	7.71	13.71
C.V.(b) %	6.68	17.55	6.21	15.07	16.21	14.14	2.67	7.58	09.34

Means with the same letter within a column are not significantly different at 5% HSD level
ns – not significant
* – *significant*
** – *highly significant*

plant in response to increasing population density in beans and beet.

Profitability Analysis

Adlay profitability analysis as influenced by different tillage practices and population density under Leyte climatic condition is presented in Table 4. Based on the official website of the Department of Agriculture, adlay seeds (unmilled) are sold at a farmgate price of around PhP 50.00 – PhP 100.00 per kilogram (kg). Average price was taken as basis for the computation of the profitability analysis.

Cost and return analysis revealed that zero tillage provides a higher yield of 1.600 t ha^{-1} resulting in a gross income of PhP 120,000.00, based on the average prevailing market price of PhP 75.00 per kilogram adlay seeds (unmilled). Second highest grain yield of 1.447 t ha^{-1} was recorded in conventional tillage, realizing a gross income of PhP 108,525.00. Lowest grain yield (1.217 t ha^{-1}) and gross income (PHP 91,275.00) were observed in reduced tillage. Lowest cost of production was recorded in zero tillage. Consequently, zero tillage yielded the highest net return of PhP 76,844.10 and a benefit-cost ratio of 1.78.

In response to population density, one plant $hill^{-1}$ obtained the maximum grain yield of 1.503 t ha^{-1}, providing a gross income of PhP 112,725.00 and a production cost of Php 45,150.31. Hence, this treatment (P_1) resulted in the highest net return of PhP 67,574.69 and a benefit-cost ratio of 1.50. Whereas lowest grain yield (1.327 t ha^{-1}), gross income (PHP 99,525.00), and net return (PHP 54,332.71) were exhibited at two plants $hill^{-1}$ thus resulting in a benefit-cost ratio of 1.20.

Having a benefit-cost ratio of greater than one implies that the production of adlay is potentially profitable, providing a positive net return on investment. Nonetheless, tillage practices and population density affect the productivity of adlay.

Table 4. Summary of cost and return of adlay production under different tillage methods and population densities

TREATMENT	GRAIN YIELD (t ha^{-1})	GROSS INCOME* (PhP ha^{-1})	PRODUCTION COST (PhP ha^{-1})	NET RETURN (PhP ha^{-1})	BENEFIT COST RATIO
Tillage Methods					
T_1 = ZT	1.600	120,000.00	43,155.90	76,844.10	1.78
T_2 = CT	1.447	108,525.00	47,558.90	60,966.10	1.28
T_3 = RT	1.217	91,275.00	44,914.98	46,360.02	1.03
Population Densities					
P_1 = 1 plant $hill^{-1}$	1.503	112,725.00	45,150.31	67,574.69	1.50
P_2 = 2 plants $hill^{-1}$	1.327	99,525.00	45,192.29	54,332.71	1.20
P_3 = 3 plants $hill^{-1}$	1.433	107,475.00	45,287.17	62,187.83	1.37

*Note: Based on the average prevailing market price of PhP 75.00 per kilogram adlay seeds (unmilled).

CONCLUSIONS

Kiboa, an adlay variety, exhibits early seed emergence under conventional tillage in contrast to zero and reduced tillage. Zero tillage cause delayed in maturity of adlay, but the plants grew tallest and produced a higher grain yield of 1.60 t ha^{-1} than those under reduced tillage yet at par with conventional tillage. This could be due to more filled and total grains per panicle and higher fertility. Delayed in the number of days from sowing to flowering and maturity of adlay was observed in P_1. However, P_2 and P_3 population densities show early flowering, while P_3 resulted in a shorter maturity period. Subsequently, maximum vegetative tillers $hill^{-1}$, tallest plant, high herbage yield (t ha^{-1}), and a greater number of productive and non-productive tillers $hill^{-1}$ was observed in three plants $hill^{-1}$. On the other hand, longer panicle, maximum number of filled grain and high percent fertility contributed to greater grain yield of 1.50 t ha^{-1} at one plant $hill^{-1}$ compared with two plants $hill^{-1}$ but at par with three plants $hill^{-1}$.

Zero tillage is a promising management practice for adlay production, providing a higher net return and least production cost, thus, realizing a high benefit-cost ratio in comparison with conventional and reduced tillage. While population density of one plant hill-1 exhibited similar promising results. It means adlay production is an economically advantageous source of income for Filipino farmers.

RECOMMENDATIONS

Adlay production under zero tillage practice and a population of 1 plant per hill is suggested providing a higher net return and benefit-cost ratio on investment. With the viability of adlay production, a market study must be conducted to evaluate its market feasibility. Henceforth, a similar study is likewise recommended in another season to validate the result.

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