Available online at https://msubuug.edu.ph/journal

Asian Journal of Advanced Multidisciplinary Researches

ISSN: 2782-9057

Adaptability and Productivity of Adlay and Annual Crops Intercropping in Southern Bukidnon, Philippines

Agripina R. Aradilla[1], Ma. Stella M. Paulican[1], Maria Estela B. Detalla[1], Cleofe T. Apiag[1], Bethel Grace P. Taban[1], Junrie Anthony M. Remollo[1,] Carmelita N. Daculos[1] Christian Jade Indac[1]

[1]Department of Agronomy & Plant Breeding, College of Agriculture, Central Mindanao University, Musuan, Bukidnon, Philippines
Email: f.argipina.aradilla@cmu.edu.ph[1]

ABSTRACT

Adlay, a climate-resilient alternative cereal with numerous health benefits, is not yet cultivated in the geographically isolated and disadvantaged areas (GIDAs) of Southern Bukidnon, Philippines. This study aimed to determine the adaptability and productivity of adlay in replacement-series intercropping with annual crops of 3–4 months maturity. The treatments, arranged in three replicates, were as follows: T1 – Adlay + Sweetpotato, T2 – Adlay + Peanut, T3 – Adlay + Squash, T4 – Sole Adlay (Dwarf), T5 – Sole Sweetpotato, T6 – Sole Peanut, and T7 – Sole Squash. Data were analyzed using ANOVA, and treatment means were compared using the LSD test. Among the intercropping schemes, Adlay + Peanut proved to be the most productive and promising combination, yielding the highest LER, ATER, MAI, and ROI. A similar trial should be conducted under the same geographical conditions to verify these results.

Keywords: adlay intercropping, LER, ATER, MAI, ROI

1 INTRODUCTION

Adlay (*Coix lacryma-jobi* L.) of the Poaceae family is one of the alternative staple crops that help address food security and malnutrition among the Bukidnons, particularly in the geographically isolated and disadvantaged areas (GIDA) of the Southern parts of Mindanao, Philippines. Adlay can be cooked like rice or corn or ground into flour for baking, herbal teas, medicines, and soup. The grains can also be processed into beer and other beverages (Health benefits times.com, 2018). It is an important minor cereal with a high nutritional and medicinal value in Asian countries (Yu-Hua Fu et al., 2019). It has potential as a food and feed source. Tea is processed from parched seeds, while beers and wines are made from fermented grains. It is claimed to possess alternative medicinal properties for tumors, arthritis, beriberi, appendicitis, diabetes, dysentery, bronchitis, fever, and headache (Gaitan, 2013). Hung et al. (2003) mentioned that adlay seeds exert an anti-proliferative effect on human lung cancer in vitro and in vivo and might also prevent the development of tobacco carcinogen-induced tumors. Wu et al. (2007) stated that adlay has been considered as an old-fashioned herbal medicine for its biological activity and as a nourishing food because of its rich nutritional value and exceptional biological and useful effects on the human body. Adlai seeds were used in China to cure warts, chapped skin, rheumatism, and neuralgia, and as anti-inflammatory and anti-helminthic (Wang et al., 2010). It contains more energy, carbohydrates, protein, fat, and dietary fiber than rice and corn. It has three times more calories and six times more protein than rice and is said to be an antidote to diabetes (Our Farm by Earth Flor Inc., 2016). It is also packed with other minerals such as calcium, phosphorus, iron, niacin, thiamin, and riboflavin. Likewise, Chun *et al.* (2004) mentioned that the whole grain of adlay contains per 100g edible portion: water – 8.9g, energy – 333 Kcal, protein – 10.4g, fat – 5.3g, carbohydrates – 66.5g, and fiber – 10.5g. The hulled grains per 100g edible portion contain the following: water – 11.6g, energy – 361 Kcal, protein – 14.8g, fat – 4.9g, carbohydrate – 66.9g, fiber – 0.5g, Calcium – 47mg, riboflavin – 0.19mg, and niacin – 4.7mg. The amino acid content per 100g protein (16g N) is: tryptophan – 0.5g, lysine – 1.9g, methionine – 2.6g, phenylalanine – 4.9g, threonine – 3.0g, valine – 5.7g, leucine – 13.6g, and isoleucine – 3.9g.

The crop is considered climate-change resilient with low-input requirements (Monteroyo & Aradilla, 2014), thus it can be a component crop in various agricultural landscapes. Adlay differs from rice as it can tolerate poor soil conditions, grows well in sloping areas, is resilient to pests and diseases, and can withstand heavy rains and long dry spells (Loeffler, 2012). Mercado et al. (2016) reported that its roots can grow up to 3m into the subsoil, thus withstanding dry spells. On the other hand, increasing the productivity of a farm per unit area per unit time needs to be part of sustaining food production. Intercropping is one of these measures to maximize the utilization of farmlands. It offers farmers the opportunity to engage in nature's principle of diversity on their farms (Gorne & Aradilla, 2020). The Philippine government is pushing for the planting of adlay to ensure food security and fight against hunger and poverty. The planting of adlay as a staple food could also be a livelihood for farmers, indigenous peoples, rebel returnees, and those located in geographically isolated and disadvantaged areas to address food insecurity, hunger, and poverty. With longer crop maturity, intercropping adlay with other crops could be a form of farm diversification that may improve the socio-economic well-being of the farmers (PNA.gov.ph, 2020).

Adlay is a quantitatively short-day plant and requires high temperature, abundant rainfall, and reasonably fertile soils. In the tropics, it occurs from sea level up to 2,000m altitude. In Africa, it is often grown in villages and on abandoned fields (Jansen, 2006). In cropping systems, adlay could serve as a windbreak and fence and could be part of an ecological pest control due to its resistance to pests (Our Farm by Earth Flora, Inc., 2016). According to Virginia Tech (2012), adlay is a super crop due to its exceptional versatility, hardiness, and strength as a "bio-pump" crop. Similarly, Pandey & Roy (2011) mentioned that Adlay is also productive in waterlogged, acidic, and lateritic soils and on degraded, sloping areas. Hoang et al. (2013) also stated that adlay is a resilient crop as it is affected by very few diseases and pests and requires less attention.

It can grow in areas with low nutrient content that are no longer suited for upland rice. Monteroyo & Aradilla (2014) noted that adlay is highly responsive to organic fertilizers such as vermicast, and in other trials, with vermitea. Nonetheless, grain yield across trials differed due to variable weather conditions (Aradilla, 2016). Adlay grown during drought conditions significantly differed in plant height at maturity, grains per panicle, filled grains per panicle, and grain yield. Growth duration of the six cultivars tested was extended by 2-3 months. Gorne & Aradilla (2020) reported that fertilization schemes using inorganic

2 METHODOLOGY

2.1 Locale of Study.
The study was conducted in Bukang Liwayway, a barangay in the municipality of Kibawe, Southern Bukidnon, Philippines, with a geographical extent of 7^0 28' 20" to 7^0 30' 23" North and 125^0 0' 44" to 125^0 2' 17" East. It is constituted of seven Puroks and identified as one of the country's geographically isolated and disadvantaged areas (GIDAs) (Puno et al., 2022). This has an approximate area of 623.23 hectares with 307 households. The area's topography is mostly rolling, with the average slope of 31%, with the lowest and the highest elevations of 64 and 407 meters above sea level (masl). The area's climate belongs to type four with no distinct dry season and an annual precipitation average of 2,800 mm.

2.2 Soil Sampling and Analysis
Soil samples were obtained in a Z-pattern across the experimental field, air-dried, and a one-kilogram composite sample was submitted for routine analysis at the Soil and Plant Analysis Laboratory of the College of Agriculture, Central Mindanao University, University Town, Musuan, Bukidnon, Philippines. Analysis results revealed that the soil has a pH of 5.61 and an organic matter of only 0.46. It contains 5.61ppm of Extractable P and 42ppm of Extractable K. The recommended rate of organic fertilizer was 2-4 tons per hectare.

2.3 Experimental Design and Treatments
The study was laid out in an 800-square-meter area following the Simple Randomized Complete Block Design (RCBD). It was

fertilizers and chicken dung at different ratios on adlay significantly affected the days to flower, days to maturity, vegetative and productive tillers, panicle length, herbage and grain yield, as well as tillers and herbage yield of napier grass as an intercrop. The treatments imposed significantly influenced LER and ATER of the intercropping schemes. This research aimed to determine the adaptability and productivity of dwarf adlay with some annual intercrops in a replacement intercropping scheme grown within the agroclimatic conditions of Southern Bukidnon, Philippines.
divided into three blocks, and each block had seven plots with a 4 x 4 square meter dimension. The alleyways of 1.5 meters between blocks and 1.0 meters between plots were provided to facilitate field operations. The different treatments were replicated three times and assigned as follows: T1 - Adlay + Sweetpotato, T2 - Adlay + Peanut, T3 - Adlay + Squash. T4 - Sole Adlay (Dwarf), T5 - Sole Sweet Potato, T6 - Sole Peanut, and T7- Sole Squash.

Data gathered were analyzed using the ANOVA, and differences between treatment means were compared using the Least Significant Difference (LSD) test.

2.4 Cultural and Management Practices
2.4.1 Land Preparation.
The field was thoroughly prepared by plowing and harrowing twice at weekly intervals. After the final harrowing, furrows were set at 65cm apart for both sole and intercropping, done a day before planting of adlay and the intercrops.

2.4.2 Fertilization
Vermicast at the rate of 4 tons per hectare was applied by broadcast method during the final harrowing.

2.4.3 Selection of Planting Materials, Pre-Treatment, and Planting
Seeds of the test crops (dwarf adlay, peanut, squash) were well-selected in terms of seed size and free from weevil infestation and mechanical injury. For sweetpotato, apical cuttings with 25cm length were cut, selected, and defoliated before planting.

2.4.4 Planting of Sole crops
2.4.4.1 Sole Adlay

The seeds were soaked in water for eight hours, followed by incubation for six hours for uniform germination. Pre-germinated seeds were sown in the furrows at a distance of 60cm between hills with five seeds per hill. Sown seeds were subsequently covered with fine soil.

2.4.4.2 Sole Sweet Potato
Stem cuttings of sweet potato with a length of 25cm were planted in the ridge at a distance of 50cm apart with two cuttings per hill. Two-thirds of the cuttings were buried in the soil and then covered with fine soil.

2.4.4.3 Sole Peanut and **Sole Squash**
Seeds of peanuts were sown in the furrows at 30 cm hill distance with two seeds per hill, while seeds of squash were hill-dropped in the furrows at 1m between hills with two seeds per hill. The sown seeds were then covered with fine soil.

2.4.5 Planting of Intercrops
Adlay and intercrops were planted in a replacement series at a 1:1 row ratio. The furrows were set at 65 cm between crops, making the distance between two adlay rows 1.3 meters apart. Adlay was planted in the same manner as in sole cropping with a 60 cm distance between hills.

Other annual crops were planted in between adlay rows at hill distance and number of cuttings/seeds per hill similar to their sole cropping. Sweet potato cuttings were planted in the row at 50 cm apart with 2 cuttings per hill in **Adlay + Sweet Potato** intercropping, peanut at 30 cm apart with two seeds per hill in **Adlay + Peanut** intercropping, and squash at 1m apart with two seeds per hill in **Adlay + Squash** intercropping.

2.4.6 Biofertilizer Supplementation

A. Vermitea Preparation
Two-kilogram vermicast was placed in a 20-liter-capacity plastic container and held in place at the bottom of the container with a clean rock weight. This was added with 16L tap water, 2L molasses, 250 ml fresh milk, and 250g seaweeds. The rim of the container was covered with Manila paper and tied tightly. The setup was protected from raindrops and direct sunlight and allowed to stand for two weeks. The vermitea was filtered and ready for application in the field.

B. Application of Vermitea
It was applied one month after seedling emergence until 100 days after seeding. The rate of application at 30 DAS to 60 DAS was 50L vermitea per 200L of water per hectare (80ml vermitea in 320 ml water per plot) and sprayed to the leaves of plants at a two-week interval. At 61 DAS to 100 DAS, vermitea was applied at the rate of 50L per 400 liters of water (80ml vermitea: 640 ml water per plot) at the same interval of application. The biofertilizer was applied early at 7:00 to 8:00 A.M.

2.4.7 Thinning and Hilling-up
One month after seedling emergence of adlay, thinning of excess seedlings was done, leaving only two healthy seedlings per hill for uniform plant density per hill. This operation was followed by a hill-up operation. Subsequent hand weeding and spot weeding were also employed to minimize rat infestation.

2.4.8 Pest Control
Biopesticides using extract from madre de cacao (*Gliricidia sepium (*Jacq.) Walp) leaves were used to control insect pests attacking the crops in the field, and applied only when pest population was above the economic threshold level. This was prepared by pounding 1 kg of leaves, adding one liter of water, 4 tablespoons of mineral oil, and soaking overnight. The setup was filtered, and the liquid was added with 4 tablespoons of powdered soap and mixed well. The mixture was added with 4 liters of tap water in time for application done at 7:00 to 8:00 A.M. or at 5:00 to 6:00 P.M.

2.4.9 Water Management
Rainwater was the main source of moisture for the test crop. However, sprinkler irrigation was employed during dry spells, and water was sourced from a nearby pipeline.

2.4.10 Harvesting and Postharvest Handling
A. Adlay was harvested when 90% of the grains turned brown. The panicles were cut, and grains were threshed and dried under the sun for two days or until the moisture content of 14% was obtained.

B. Sole Crops and Intercrops to Adlay

1. Sweet Potato – The fleshy roots were harvested at 143 days after planting and were graded as to marketable and non-marketable yields. Marketable fleshy roots were free of any damage, uninfected with pests, and 100g to 500g in weight (Gobena et al., 2022). Nonmarketable fleshy roots were wounded, blemished, infected with pests, and weighed less than 100g.
2. Peanut – Peanut pods were harvested at 116-123 days after sowing, as evidenced by the yellowing of the leaves. Pods were sundried for 2-3 days before storage.
3. Squash – Fruits were harvested when signs of drying of the fruit stalks were observed.

2.5 Parameters Measured

A.1 Adlay as Sole Crop and Main Crop

1. Number of Vegetative Tillers – This was gathered at 60 days after sowing from 10 sample hills randomly selected from the data rows per treatment plot.
2. Plant Height at Maturity – This was taken at the maturity stage of the crop as evidenced by the change in color of the grains from green to brown. This was gathered from 10 randomly selected data plants per plot by measuring from the base to the tip of the panicle at harvest using a meter stick.
3. Number of Productive - This was obtained at harvest from the same 10 sample hills where the data on vegetative tillers were taken.
4. Panicle Length – This was determined by measuring the length of the panicles from the 10 randomly selected plants using a transparent ruler.
5. Weight of 1000 Seeds – This was obtained by weighing 1,000 seeds per treatment dried at 14% MC.
6. Grain Yield (kg/ha) – This was determined after drying the grains at 14% MC and was computed using the formula:

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

Where:

Effective Harvest Area (EHA_i) = DBR x DBH x 10 sample hills

(1.3m x 0.6m x 10 sample hills = 7.8)

Effective Harvest Area (EHA_m) = DBR x DBH x 10 sample hills

(0.65m x 0.6m x 10 sample hills= 3.9)

B. Traits of Annual Intercrops

B.1 Sweet Potato

1. Length of Main Vines – This was measured using a meter stick from the base to the tip of the main vine of 10 sample plants per plot taken at harvest.
2. Number of Lateral Vines – The data was gathered by counting the number of lateral branches of 10 sample plants per plot taken at harvest.
3. Days to Maturity – This was initially determined at 90 days after planting using two sample hills from the border plants. A fleshy root was taken and cut crosswise, and when the latex did not flow on the cut surface, the fleshy root was already mature. However, further sampling was undertaken at a 7-day interval when fleshy roots were still immature.
4. Length of Marketable Fleshy Roots – This was taken from ten sample 10 randomly selected marketable fleshy roots of ten sample hills per plot and measured using a transparent ruler.
5. Diameter of Fleshy Roots – The same samples used for length determination of fleshy roots were measured using a vernier caliper.
7. Weight of Marketable Fleshy Roots – This was determined by weighing all the marketable fleshy roots of 10 sample hills and weighing them using a digital weighing scale. The weight on a per-hectare basis was computed using the formula:

$$\text{Weight (kg/ha)} = \text{plot yield (kg)} \times \frac{10{,}000\ m^2}{EHA}$$

Where:

Effective Harvest Area (EHA_i) = DBR x DBH x 10 sample hills

(1.3m x 0.5m x 10 sample hills = 6.5)

Effective Harvest Area (EHA_m) = DBR x DBH x 10 sample hills

(0.65m x 0.5m x 10 sample hills = 3.25)

B.2 Peanut

1. Plant Height at Maturity – This was obtained at harvest to be measured from the base of ten sample plants to the tip of the stem using a meter stick.
2. Days to Maturity – This was obtained by counting the number of days from planting to the harvesting of mature pods per treatment.
3. Pod Length – This was based on the average length of 10 randomly selected pods from 10 sample plants per treatment.
4. Number of Seeds per Pod – This was determined by counting the number of seeds in 10 randomly selected pods from 10 sample plants per treatment.
5. Weight of 1000 seeds – This was randomly selected per treatment and weighed using a digital weighing scale.
6. Bean Yield (kg/ha) – This was computed using the formula below:

$$\text{Bean Yield (kg/ha)} = \text{plot yield (kg)} \times \frac{10{,}000m^2}{EHA} \times \frac{100 - \%MC}{88}$$

Where:

Effective Harvest Area (EHA_i) = DBR x DBH x 10 sample hills

(1.3m x 0.3m x 10 sample hills = 3.9)

Effective Harvest Area (EHA_m) = DBR x DBH x 10 sample hills

(0.65mx 0.3m x 10 sample hills = 1.95)

B.3 Squash

1. Days to Flower - This was recorded from planting to the time when at least 50% of the plants per treatment flowered.
2. Main Vine Length - This was measured using a meter stick from the base to the tip of the main vine of 4 sample plants per plot and was taken at harvest.
3. Number of Lateral Branches - The data was gathered by counting the number of lateral branches of 4 sample plants per plot to be taken at harvest.
4. Days to Maturity - This was obtained by counting the number of days from planting to the first harvest of mature fruits per treatment.
5. Fruit Yield - This was determined by weighing all the mature fruits from 4 sample hills and weighing them using a digital weighing scale. The weight on a per-hectare basis was computed using the formula:

$$\text{Yield (kg/ha)} = \text{plot yield (kg)} \times \frac{10{,}000 \, m^2}{EHA}$$

Where:

Effective Harvest Area (EHA_i) = DBR x DBH x 4 sample hills

(1.3m x 1.0m x 4 sample hills = 5.2)

Effective Harvest Area EHA_m) = DBR x DBH x 4 sample hills

(0.65m x 1.0m x 4 sample hills = 2.6)

2.6 Statistical Analysis.

The gathered data were statistically analyzed using the Analysis of Variance (ANOVA). The differences among treatment means were compared using the Least Significant Difference (LSD) test.

C. Productivity in an Intercropping Scheme

1. Land Equivalent Ratio – This determines the productivity of the area utilized for an intercropping scheme. This is the ratio of the area under sole cropping to the area under intercropping needed to give equal amounts of yield at the same management level. It is the sum of the fractions of the intercropped yields divided by the sole-crop yields. LER was computed using the formula (Gliessman, 2014):

$$LER = \frac{Yp_i}{Ym_s} \sum$$

Where:

Yp_i = yield of each crop in the intercrop or polyculture

Ym_s = yield of each crop in the sole crop or monocrop

2. Area Time Equivalent Ratio (ATER – This provides a more realistic comparison of the yield advantage of intercropping or monocropping in terms of time taken by the component crops in the intercropping systems. It was calculated below as described by Hiebsch and McCollum (1987) as cited by Nagwa et al. (2014):

$$ATER = \frac{Yai}{Yam} \times \frac{Ta}{Ts} + \frac{Ybi}{Ybm} + \frac{Tb}{Ts}$$

Where:

Yai and Ybi = yields of crops a and b in intercropping, respectively

Tam and Tbm = time taken by crop a and crop b, respectively

Ts = time taken by the intercropping (whole) system

3. Monetary Advantage Index (MAI) – This provides information on the economic advantage of the intercropping system. The higher the MAI value, the more profitable the cropping system. It was calculated as (Wiley, 1979) as cited by Mekuanint (2020):

$$MAI = \frac{(\text{values of combined intercrops}) \times (LER-1)}{LER}$$

4. Return on Investment (ROI) – This is a performance measure used to evaluate the efficiency or profitability of an investment or to compare the efficiency of several different investments. It directly measures the amount of return on a particular investment, relative to the investment's cost. It was calculated as:

ROI = net income/total production cost

3 RESULTS AND DISCUSSIONS

3.1 Adlay as Sole Crop and as Main Crop

Intercropping of some annual crops, such as sweetpotato, peanut, and squash in between rows of adlay at a 1:1 row ratio, has been shown to have more benefits, which enhance productivity per unit area. As shown in Table 1a, Adlay (dwarf variety) with or without intercrops did not vary in terms of its number of vegetative tillers (5-7 tillers), height at maturity (146-155cm), days to maturity (171-172 DAS), number of productive tillers (5-9 tillers), and panicle length (53-65cm). Numerically, data show that the presence of the intercrops in between rows of adlay seemed to influence the development of more vegetative tillers as well as an increase in height, possibly as a response to interspecific competition. Similarly, adlay as a main crop had more tillers than its sole crop, indicating that the presence of intercrops enhanced the development of productive tillers. However, the maturity of adlay was more or less the same. Nonetheless, Aradilla (2018) mentioned that dwarf adlay matures in approximately 149 DAS under adverse climatic conditions in Musuan, Bukidnon, Philippines. Carlobos (2023) recorded dwarf adlay with more vegetative tillers in combination with annual intercrops (6-7 tillers) than as a sole crop with only 4 tillers on average. He also noted that dwarf adlay was significantly taller (163-168cm) in the intercropping scheme than as a monocrop (160cm). Maturity of grains differed only in about 1-2 days with adlay + peanut and adlay + mungbean to mature earlier (164-165 DAS).

Statistically, adlay differed significantly in the weight of 1000 seeds and grain yield. Adlay with sweetpotato intercrop had the heaviest seed weight (89.87g), which did not significantly vary from the weight of adlay with squash intercrop (87.07g). Adlay with peanut intercrop had the lightest seed weight of 80.60g. Meanwhile, seeds of sole adlay weigh 85.40g (Table 1b). Paulican et al. (2016) noted that adlay intercropped with some locally grown vegetables obtained yields that ranged from 2,189kg/ha to 3,050 kg/ha. A higher yield of adlay was obtained in an intercropping scheme with grain legumes. Adlay with mungbean had the highest yield (3,050 kg/ha), followed by Adlay + pigeonpea (2,978 kg/ha).

The yield of adlay in an intercropping scheme in Southern Bukidnon obtained a lower yield, although the presence of the intercrops in between rows of adlay did not show an adverse effect on the main crop. The area grown to adlay was a marginal soil. The area was slightly rolling with some rocky portions, wherein adlay performed poorly. It was previously grown to continuous cropping of corn in a conventional manner employing inorganic fertilizers and chemicals, including, among others, herbicides to control weeds. Soil test results indicate that it has a pH of 5.61 and an organic matter of only 0.46. It contains 5.61ppm of Extractable P and 42ppm of Extractable K. The results imply that the soil was moderately acidic with low nitrogen content. The results further suggest that the application of organic fertilizer such as vermicompost and vermitea on adlay with or without intercrops did not influence the yield, which may not be sufficient to meet the needs of the crop/s in an intercropping scheme. In the study of Carlobos (2023), he noted that adlay + peanut had more tillers than other combinations; had longer panicles (60cm), heavier seed weight (90g), and the highest grain yield (1,938kg/ha).

Table 1a. Number of vegetative tillers, height at maturity, and days to maturity of adlay with annual intercrops in Southern Bukidnon, Philippines sowing

Cropping System	Number of vegetative tillers	Plant height at maturity, cm	Days to maturity, DAS
Sole Adlay	5	146.33	172
Adlay + Sweetpotato	6	154.67	171
Adlay + Peanut	7	153.27	171
Adlay + Squash	7	151.03	172
F-test	ns	ns	ns
CV (%)	25.75	6.12	0.15

ns = not significant DAS – days after

Table 1b. Yield and yield component parameters of adlay with annual intercrops in Southern Bukidnon, Philippines

Cropping System	Number of productive tillers	Panicle length, cm	Weight of 1000 seeds, g	Grain yield, kg/ha
Sole Adlay	5	65.27	85.40^{b}	881.41^{a}
Adlay + Sweetpotato	7	53.43	89.87^{a}	381.09^{b}
Adlay + Peanut	8	65.33	80.60^{c}	1138.38^{a}
Adlay + Squash	9	61.90	87.07^{ab}	934.45^{a}
F-test	ns	ns	**	*
CV (%)	21.94	13.78	2.27	23.76

Means with common letters are not significantly different at 5% level of probability, LSD.
ns = not significant * = significant
** = highly significant

3.2 Traits of Annual Crops as Sole Crops and as Intercrops

The sole sweet potato had shorter main vines (414.3cm), while as an intercrop to adlay, it had longer main vines (457.8cm). On the other hand, both crops produced the same number of lateral vines (3 pcs) as well as their maturity (143 DAP). The difference in the length of vines between the sole sweet potato and those intercropped in rows of adlay implies that there was interplant competition between the two crop species in terms of the limited resources in the field, particularly sunlight, since sweet potatoes were partially shaded with adlay (Table 2a). There was a similar trend for the plant height of sole peanut and peanut as an intercrop to adlay. Sole peanut was shorter (62.73cm), whereas as an intercrop, it had a height of 70.70cm. Nonetheless, their maturity differed such that the sole peanut matured earlier (116DAS) compared to the peanut as an intercrop (123DAS). The earlier maturity of the sole intercrop may be attributed to its full exposure to sunlight. However, for squash, those as an intercrop to adlay had shorter vines (380cm) compared to sole squash with 560.80cm. Squash as an intercrop had fewer lateral vines (2.17 pieces) and matured earlier at 124 DAS. The sole squash had more lateral vines (about 3 pieces) but matured later (146DAS) (Table 2a). The crops showed different behavior in terms of stem elongation, which may be possibly influenced by the light factor and shading. Carlobos (2023) recorded sweet potato as an intercrop of adlay and had shorter vines than as a sole crop, but the same number of lateral vines and a one-day difference in maturity. The sole crop matured a day ahead of time as an intercrop. On the other hand, peanut and mungbean as intercrops were of shorter heights compared to as sole crops. However, the sole peanut matured 5 days ahead of time when grown as an intercrop, and the sole mungbean matured a day ahead of time when grown as an intercrop. Results imply that sole crops mature earlier than those grown in combination with adlay due to intra- and or interspecific competition among crop species.

Table 2a. Height or vine length, number of lateral vines, and days to maturity of annual crops grown as a sole crop and as an intercrop to adlay in Southern Bukidnon, Philippines

Cropping System	Height/ Vine length at maturity, cm	Number of lateral vines	Days to maturity, DAS
Sweet potato			
Sole Crop	414.3	3	143
Intercrop	457.8	3	143
Peanut			
Sole Crop	62.73		116
Intercrop	70.70		123
Squash			
Sole Crop	560.80	2.75	116
Intercrop	380.00	2.17	124

3.3 Yields of Annual Crops as Sole Crops and as Intercrops

As shown in Table 2b, sweet potato as a sole crop had longer marketable fleshy roots (11.82cm) as compared to when grown as an intercrop to adlay (11.45cm). But the fleshy roots of sole sweet potato were slightly smaller in diameter (4.58cm) than as intercrop in adlay (4.62cm). It was noted that sole sweet potato had a higher yield (marketable fleshy roots) than as an intercrop to adlay with 4,367 kg/ha and 1,800kg/ha, respectively. The results imply that such low yield in the adlay + sweet potato intercropping may be due to competition for nutrients, soil moisture, space, and sunlight. For peanut, the pod length of the sole crop is slightly shorter (3.14cm) than the pod length of the intercrop peanut (3.25cm). In terms of the number of seeds per pod, there was a slight difference. Peanut as an intercrop to adlay had more seeds (2.3 pcs), while from the sole crop, it had only 2.27 pcs/pod. However, the sole peanut had heavier seeds (1000 seed weight) than the peanut as an intercrop to adlay, with 520g and 506.7g, respectively. Moreover, sole peanut obtained a higher yield (2,511 kg/ha) compared to as an intercrop of adlay with only 1,199 kg/ha. The AgrisFao (2022) mentioned that PSB Pn 12 (Biyaya 12) is a 3-seeded peanut variety that has a pod yield of 2.5 – 2.8t/ha and a seed yield of 1.344 – 1.87 t/ha. For squash, it had a higher yield (13,145 kg/ha) as a sole crop. As an intercrop to adlay, it only had a fruit yield of 2,521 kg/ha. A lesser yield was produced by the squash intercrop, most probably due to intra-competition in mixed cropping for the limited resources per unit space.

Table 2b. Yield traits of annual crops grown as sole crop and as intercrop to adlay in Southern Bukidnon, Philippines

Cropping System	Length MFR, Cm	Diameter MFR, cm	Pod length, cm	No. seeds/ pod	Weight 1000 seeds, g	Shelling percentage , %	Yield, kg/ha
Sweetpotato							
Sole Crop	11.82	4.58					4,367
Intercrop	11.45	4.62					1,800
Peanut							
Sole Crop			3.14	2.27	520.0	78.13	2,511
Intercrop			3.25	2.3	506.7	77.87	1,199
Squash							
Sole Crop							13,145
Intercrop							2,521

MFR = marketable fleshy roots

3.4 Productivity of Adlay and Annual Crops Intercropping

Knowing and understanding the competitive and monetary advantage in an intercropping system plays a critical role in recommending the cropping system for a particular farm. Some of the measures in determining the efficiency of intercropping advantage over pure stand yields include Land Equivalent Ratio and Return on Investments.

1. Land Equivalent Ratio (LER)

As shown in Table 3, adlay intercropped with peanut had the highest land equivalent ratio (LER) of 1.769, followed by adlay with squash with 1.252, and the least LER was adlay with sweetpotato with only 0.844. Paulican et al. (2016) recorded 1.0 to 2.5 LER in adlay and locally grown vegetables intercropping in Musuan, Bukidnon, Philippines, indicating a yield advantage in intercropping than in monoculture. According to Gliessman (2014), when the LER is lower than one, the intercropping negatively affects the growth and yield of crops grown in mixtures. Among the intercropping mixtures, adlay + peanut had the highest LER. It was mentioned by Zang et al. (2015) that cereals and legume intercropping had been widely used due to its interspecific promotion and niche complementation. Further, Ijoyah & Fanen (2012) said that a 1:1 ratio of maize to soybean intercropping had the greatest intercrop yield and highest LER of 1.87 and 1.86 during 2009 and 2010 planting, respectively. The said authors also concluded that growing two or more crops together had higher productivity per unit area.

2. Area Time Equivalent Ratio (ATER)

Area time equivalent ratio (ATER) compares the yield advantage of intercropping over monocropping in terms of time taken by component crops in the intercropping system. The time taken by adlay was based on the number of days to maturity, which also holds true for the different intercrops. The total time (Ts) by the entire cropping system was based on the maturity of adlay, being the last crop to mature.

Among the cropping systems, adlay with peanut had the highest ATER of 1.6256, followed by adlay intercropped with squash with 1.1923. The lowest ATER was obtained by adlay with sweet potato. The result implies that the best intercropping mixture is adlay intercropped with peanut. Gorne & Aradilla (2020) noted that adlay with napier grass had higher ATER compared to a monocropping system. Hiebsch & McCollum (1987) proposed to use ATER in the comparison between intercrop versus monoculture comparisons, of which cropping system duration or time of land occupancy was not considered in the computation for LER. The same authors concluded that most crop mixtures utilize land area and time (area time) at about the same efficiency as pure stands of the mixture's components.

3. Monetary Advantage Index (MAI)

Monetary advantage index (MAI) provides information on the economic advantage of the intercropping system. The higher the MAI value, the more profitable the cropping system.

The adlay intercropped with peanuts showed the highest and positive monetary value of 126,339 compared to other cropping systems. This was followed by adlay with squash with 48,030. However, adlay and sweet potato mixtures had a negative monetary value of 22,210. Mekuanint (2020) found that maize-soybean intercropping proved to be profitable, having positive MAI. This indicates that such a crop combination was more advantageous in terms of yield and monetary value. Likewise, Obiero et al. (2013) mentioned that positive monetary values imply that such a cropping system is feasible. Hence, the most feasible cropping system for Southern Bukidnon, Philippines, is adlay intercropped with peanuts because it has the highest MAI.

4. Return on Investment (ROI)

Return on investment (ROI) is a performance measure used to evaluate the efficiency or profitability of an investment or to compare the efficiency of a number of different investments. It directly measures the amount of return on a particular investment, relative to the investment's cost.

Among the cropping systems studied, adlay with peanut as an intercrop had the highest return per peso invested, followed by adlay + squash in a 1:1 row ratio. The adlay + sweetpotato combination had only an ROI of 1.10. The adlay + peanut combination had the highest ROI because it had the highest yield, and is therefore the most promising cropping system for Southern Bukidnon, Philippines.

Intercropping promotes interaction between crops, and this practice is also a form of crop insurance against total failure in a crop enterprise, yield increment, and high monetary returns (Ijoyah, 2012). Further, intercropping is the most appropriate cropping system for the maintenance of soil productivity (Ijoyah & Dzer, 2012). Moreover, LiYan-Hong et al. (2021) observed that intercropping provides greater benefits than monoculture.

Table 3. Productivity of adlay in an intercropping scheme with some annual crops in Southern Bukidnon, Philippines

Cropping System	Grain yield of adlay (kg/ha)	Yield of intercrops (kg/ha)	LER	ATER	MAI	ROI
Sole Adlay	881.41					
Sole Sweetpotato		4,366.70				
Sole Peanut		2,511.20				
Sole Squash		13,145.30				
Adlay + Sweetpotato	381.09	1,800.00	0.844	0.7741	-22,210	1.10
Adlay + Peanut	1,138.38	1,198.70	1.769	1.6256	126,339	4.52
Adlay + Squash	934.45	2,521.40	1.252	1.1923	48,030	1.66

LER = Land Equivalent Ratio
MAI = Monetary Advantage Index
ATER = AREA Time Equivalent Ratio
ROI = Return on Investment

4 CONCLUSIONS AND RECOMMENDATIONS

Based on the results, only the weight of 1000 seeds, the grain yield of adlay, and the yields of annual intercrops significantly differed. Adlay with peanuts had the highest grain yield among the cropping systems studied. The different annual crops, as sole crop and as intercrop to adlay, significantly differed in plant height or vine length, and maturity. Sole crops and intercrops also differed in their yields. Annual crops as a sole crop had a higher yield compared to as an intercrop with adlay. Nevertheless, adlay with peanut was the most productive and promising combination in the study site, with the highest LER, ATER, MAI, and ROI. It is recommended that a similar study be conducted in areas with the same geographical conditions to verify the results. Further, the study should be conducted earlier in the wet season, with other annual crops such as grain legumes (mungbean, rice bean, soybean, pigeonpea) and leafy vegetables as intercrops. Moreover, adlay and the intercrops should be grown organically with the use of different kinds of organic fertilizers and liquid biofertilizers to boost productivity.

5 REFERENCES

[1] AgrisFAO. (2022). PSB Pn (UPL Pn 12) - a newly released Valencia peanut variety at the IPB, UPLB. *Philippine Journal of Crop Science*. IN: https: agrisfao.org.

[2] Aradilla, A.R. (2016). Phased Planting: Determining the best time to plant adlay (*Coix lacryma-jobi* L) in Southern Bukidnon, Mindanao, Philippines. *International Journal of Education and Research*. Vol. 4, No. 5.pp. 419-430.

[3] Aradilla, A.R. (2018). Phenology, Growth, and Yield Performance of Adlay (*Coix lacryma-jobi* L) Grown in Adverse Climatic Conditions. *International Journal of Research and Review*. Vol. 5, issue 3. pp. 16-25.

[4] Carlobos Jr., R.A. (2023). Productivity of Adlay (*Coix lacryma-jobi* L.) Intercropped with Annual Crops in Hindangon, Valencia City, Bukidnon. Unpublished BS Thesis. Central Mindanao University, Musuan, Bukidnon.

[5] Chun, K.S., Chiang, W. & Kou, M. L. (2004). Effect of Adlay on azoxymethane-induced colon carcinogenesis in rats. *Food Chemistry and Toxicology*. 42:1, 339-347.

[6] Gaitan, K.G. (2013). Adlai: a rice-like versatility. IN: https://devcomconvergence.com.

[7] Gliessman, S.R. (2014). Agroecology: The Ecology of Sustainable Food Systems. 3rd ed. CRC Press. 406 pp. IN: https://books.google.com.ph/books?isbn=1498728464.

[8] Gobena, T.L., Asemie, M.M. & Firisa, T.B. (2022). Evaluation of Released Sweet Potato (*Ipomoea batatas* L. (Lam) Varieties for Yield and Yield-related Attributes in Semen-Bench District of Bench-Sheko Zone, South-Western Ethiopia. *Heliyon*. In: Pubmed.ncbi.nlm.nih.gov.36276733.

[9] Gorne, N.D. & Aradilla, A.R. (2020). Adlay (*Coix lacryma-jobi* L.) and Napier grass (*Pennisetum purpureum* Schum.) intercropping and fertilization schemes as a smart strategy for food and feed production. *Annals of Tropical Research,* Vol. 42 (1). pp. 56-71.

[10] Health Benefits Times. (2018). Jobs tears facts and health benefits. IN:

https://www.health benefitstimes. Com.>jobs-tear.

[11] Hiebsch, C.K. & McCollum, R.E. (1987). Area-×-Time Equivalency Ratio: A Method of Evaluating the Productivity of Intercrops. *Agronomy Journal*, 79, 15-22. http://dx.doi.org/10.2134/agronj1987.00021962007900010004x.

[12] Hoang, T.L., E. Simelton, V.T. Ha, D.T. Vu, T.H. Nguyen, V.C. Nguyen & Phung, Q.T.A. (2013). Diagnosis of farming systems in agroforestry for livelihoods of smallholder farmers in Northwestern Vietnam Project. Working Paper No. 161. Hanoi, Vietnam: ICRAF Southeast Asia Regional Program. IN: https: //www.worldagroforesty.org/downloads/publications/pdf.

[13] Hung, W.C. & Chang, H.C. (2003). Methanolic extract of Adlay seed suppresses COX2 expression of human lung cancer cells via inhibition of gene transcription. *Journal of Agricultural Food Chemistry*. 51 (25): 333-337.

[14] Ijoyah, M. & Dzer, D. (2012). Maize (Zea mays) as affected by time of planting in Makurdi, Nigeria. *ISRN Agronomy*: 1-7. DOI: 10.5402/2012/485810.

[15] Ijoyah, M.0. (2012). Review of intercropping research: studies on cereal-vegetable based cropping system. *Scientific Journal of Crop Science*, 1(3):55-62.

[16] Ijoyah, M.O. & Fanen, F.T. (2012). Effects of different cropping patterns on performance of maize soybean mixtures in Makurdi, Nigeria. *Scientific Journal of Crop Science*, 1(2):39-47.

[17] Jansen, F.C.M. (2006). *Coix lacryma-jobi* L.IN:http://www.database.prota.org/dbtwwwpd/exe/dbtwpub.htm.

[18] LiYan-hong, Lei Wang, Deyang Shi & Shuting Dong. (2021). Yield advantage of a maize-peanut intercropping system. IN: research square.com.files/rs-163681.

[19] Loeffler A. (2012). Research in sustainable agriculture identifies climate-smart crops at experimental plots in the Philippines. Virginia Tech Daily. IN: https://www.vtnews.vt.edu/articles/2012/10/101912-oired-adlaigrass.html.

[20] Mercado Jr, A.R., R.D. Lasco & Reyes, M.R. (2016). How Filipino farmers cope with climate change through conservation agriculture with trees. World Agroforestry. In: https://www.world agroforestry.org/downloads/Publications/pdf/BC16190.pdf.

[21] Merkuanint, T. (2020). Competition indices and monetary advantage index of intercropping maize (*Zea mays* L.) with legumes under supplementary irrigation in Northern Ethiopia. *Journal of Cereals and Oil Seeds*, Vol 11 (1): pp 30-36.

[22] Monteroyo, M.P. & Aradilla, A.R. (2014). Response of Job's Tears (*Coix lacryma-jobi* L.) to Varying Levels of Vermicast. *Transactions of the National Academy of Science and Technology of the Philippines (NAST-PHL)*. Vol 35, Issue 1. P. 48. IN: Nast.ph//images/pdf.

[23] Obiero, C.A., R. Birech, J. Malinga & Freyer, B. (2013). Effect of intercropping castor with maize and beans on growth, yield and seed oil content. *International Journal of Plant Research*. IN: https://www.researchgate.net/publications.

[24] Our Farm by Earth Day Flora, Inc. (2016). Ancient Adlai: an answer to food security. IN: https://downtoearthph.com/tag/adlai.

[25] Pandey, K.C. & Roy, A.K. (2011). Forage Crops varieties. Indian Grassland and Fodder Institute. Jhansi. IN: http://www.scribid.com/doc/54421060.

[26] Paulican, M.S.M., A.R. Aradilla & Detalla, M.E.B. (2016). Adlay intercropping with some locally grown vegetables. Terminal Report of DA-BAR Funded Research. CMU, Musuan, Bukidnon.

[27] PNA.gov.ph. (2020). Government pushes for adlai as new solution to hunger. IN: https//www.pna.gov.ph>articles.

[28] Puno, G.R., A.S. Olpenda, R.C.C. Puno, L.F. Lacandula, I.V. Maghuyop & Villar, R.G. (2022). GIS-based Mapping of Flashflood Susceptible Areas in Bukangliwayway, Kibawe, Bukidnon IN: https://js.cmu.edu.ph/uploads/cmujs-natsci76_PERSPECTIVE1.pdf.

[29] Virginia Tech. (2012). Research in sustainable agriculture identifies climate-smart crop at experimental plots in the Philippines. IN: https://www.vtnews.vt.edu/articles/2012/10/101912-oired-adlaigrass.html.

[30] Wang, C. Y., Wu, S.C., Ng, C.C. & Shyu, Y. T. (2010). Effect of Lactobacillus-fermented Adlai-based milk on Lipid metabolism of Hamster fed Cholesterol-enriched diet. *Fund Research International*. Vol 43. pp. 819-824.

[31] Wu, T.T., Charles, A.L. & Huang, T.T.C. (2007). Determination of the contents of the main biochemical compounds of Adlay (*Coix lachryma-jobi*). *Food Chemistry*. 104 (4): 1509-1515. DO 10.1016/J *J.FoodChem*. 2007.02.027.

[32] Yu-Hua Fu, C. Yang, Q. Meng, F. Liu, G. Shen, M. Zhon, & Ao, M. (2019). Genetic Diversity and Structure of *Coix lacryma-jobi* L. from Its World Secondary Diversity Center, Southwest China. *International Journal of Genomics*. IN: hindawi.com/journal/ejg.

[33] Zhang, N.N., Y.M. Sun, Y.M. Wang, J.S. Yang, H. Juan & Scow, K. (2015). Effects of intercropping and rhizobial inoculation on the ammonia-oxidizing microorganisms in rhizospheres of maize and faba bean plants. *Applied Soil Ecology*, 85:76-85.

6 ACKNOWLEDGMENT

The researchers are indebted to Central Mindanao University for the immense support and to the land owner, Hon. Gomercindo B. Patalita, the Barangay Captain of Bukangliwayway, Kibawe, Southern Bukidnon, Philippines, for lending the area for the experiment, and to the Research Aides for their effort in performing the assigned task despite the distance of the experimental site from Central Mindanao University.