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Original Research Article

Phenology, Growth and Yield Performance of Adlay (*Coix lacryma-jobi* L.) Grown in Adverse Climatic Conditions

Agripina Rana-Aradilla

Department of Agronomy and Plant Breeding, College of Agriculture,
Central Mindanao University, University Town, 8710 Musuan, Bukidnon, Philippines

ABSTRACT

Adlay (*Coix lacryma-jobi* L.) is an additional staple crop in the Philippines to help attain food security. Growth and yield trials have been conducted, however, results vary from season to season. This study was conducted at the Agricultural Experiment Center, Central Mindanao University, University Town, Musuan, Bukidnon, Philippines to evaluate the phenology and field performance of the adlay grown under adverse climatic conditions. The experiment was laid out in RCBD with the six adlay cultivars as treatments (V1-Gulian, V2-Ginampay, V3-Tapol, V4-Pulot, V5-Kiboa, and V6-Dwarf) in four replications and conducted from December 2015 to September 2016. Each cultivar was planted in 16 square meter plot and spaced at a distance of 90cm between rows and 60cm between hills, with two seeds per hill. Of the 14 parameters measured, four significantly differed (plant height at maturity, number of grains per panicle, number of filled grains per panicle, and grain yield per hectare). Under unfavorable conditions, growth duration of adlay extended by two to three months. Findings suggest that all adlay cultivars were drought tolerant, except the Pulot cultivar.

Keywords: food security, cultivar, drought, tolerant, parameter.

INTRODUCTION

The insufficient supply of rice, the main staple in the Philippines, is one of the major problems that beset the country. Importation of rice had been done in the previous years to cope with the demand, but too expensive. One of the options was to search for alternative staple crop that may substitute rice and corn, and that is Adlay (*Coix lacryma-jobi* L.). Morphologically, it resembles rice and cooked grits taste like rice (Gaitan, 2013; DA-BAR, 2013).

Adlay is a tall grain bearing tropical plant from the family Gramineae or Poaceae. It is also called Job's tears of Asian origin. The cultivated race in Asia is the variety *lacryma-jobi* (Phogat et al, 2000). The mature plant bears shining, pear or tear-shaped capsules about 8-12 mm long. The shell is hard and of various colors: white, light brown, grey to black. It grows in hilly areas and has been a valuable famine-food. It is among the earliest grass brought into cultivation, a preliminary development is selection of soft-shelled forms. These are grown particularly in the Indo-China region and the Philippine Islands, and in aggregate are known as ma-yuen varieties. The siliceous shell is 30-70% of the whole fruit. It contains a grain not rice-like but can be favorably compared with other grains with respect to protein and fat contents. Minerals and fiber are low, and the grain contains the following approximations: water, 9.9-10.8%; protein, 13.6-19.1%; fat, 5.7-6.1%; carbohydrate, 58.5–62.7%; fiber, 8.4% and ash, 2.2-2.6%. According to the Bureau of Agricultural

Research (2013), when eating 100 grams per serving of Adlay, one is less likely to feel hungry compared to eating rice or corn. Adlay contains the highest food energy content of 356 kcal compared to white rice with 110 kcal and corn with135 kcal. It is high in carbohydrates (73.9), protein (12.8), fat (1.0) and dietary fiber (0.3). It is packed with minerals such as calcium, phosphorus, iron, niacin, thiamine and riboflavin. For medicinal purposes, it is used for the elimination of stones in the kidney and bladder, for setting right the menstrual order in women and as tincture or decoction for catarrhal infection of the air passage. A decoction of its roots is used as vermifuge for children (Jimo et al, 2001).

Adlay is usually propagated by seeds. The 1000 seed weight is 80-90 grams (Coles and Aradilla, 2013). The seed is dibbled 3-5cm at the start of the rains, after thorough land preparation and preferred spacing is 90 cm x 60 cm. Propagation by seed gives deeper rooting and consequently, better drought tolerance and higher grain yield. They also do well in any climate to which corn thrives and may tolerate wet areas for a short period (Tangcogo and Detalla, 2014).

The weed-crop is not fertilizer intensive and is suited in less fertile and marginal soils (Monteroyo and Aradilla, 2014). It has nutrient components which fit the daily calorie needs of the human body. The crop is most abundant in Regions 9 and 10 and in the Cordillera Administrative Region (CAR). Like rice, it has also different cultivars such as Gulian, Ginampay, Pulot, Tapol, Kiboa, and Dwarf. It has been cultivated for food, and feeds of livestock. Other varieties were used to make bracelets and necklaces while the leaves were used as organic fertilizers (DA-BAR, 2013).

Adlay can tolerate an annual precipitation of 61 to 429 cm, and an average annual temperature of 41 to 50°F and a pH range of 4.5 to 8.4. Although an annual, it can be a perennial when allowed to develop ratoons. Seeds are hydro-primed in water for 8 hours and incubated for 6 hours prior to planting. Seedlings emerge as early as 7 days after sowing (Aradilla, 2016) under favorable conditions. It takes 5 to 5.5 months to mature and stalks are cut from the base and the grains are separated from the panicles by threshing. Threshed grains are sundried for 2 days before milling (Mostales and Aradilla, 2016).

The SANREM-CRSP studied different varieties of adlay for conservation agriculture production systems (CAPS) as a substitute to rice and maize in the Mindanao region. From CAPS perspective, it is appealing since it produces more biomass for mulch and also to mitigate soil erosion in sloping areas. Adlay is a climate-smart crop due its long rootstock that grows up to 150 cm. This serves as bio-pump that absorbs water which, in turn deter soil erosion. It can withstand torrential rains and can thrive in drought conditions. Adlay is a crop of the “bionic” kind (SANREM-CRSP, 2012) as cited in http://www.oired.vt.edu/sanremcrsp/adlai-grass-promises-conservation-agriculture-super-crop).

Limited or absence of rain or drought is generally defined at an extended period - a season, a year, or several years of deficient precipitation compared to the statistical multi-year average for a region that results in water shortage for some activity, group, or environmental sector (NDMC, 2008 as cited in www.fao.org/nr/aboutnr/nrl). Drought is a major stress factor that affects the growth and development of plants. Drought or soil water deficit can be chronic in climatic regions with low water availability due to changes in weather conditions during the period of plant growth (Alizadeh et al., 2014).

The first and foremost effect of drought is impaired germination and poor stand establishment of crops (Harris et al., 2002). Under severe water deficiency, cell elongation of higher plants can be inhibited by interruption of water flow from the xylem to the surrounding elongating cells

(Nonami, 1998). Drought caused impaired mitosis; cell elongation and expansion resulted in reduced growth and yield traits (Hussain et al., 2008). Water deficits reduce the number of leaves per plant and individual leaf size, leaf longevity by decreasing the soil's water potential. Drought induce reduction in leaf area is ascribed to suppression of leaf expansion through reduction in photosynthesis (Rucker et al., 1995). Among the earliest responses of plants to drought stress are the closure of stomata and growth inhibition of developing leaves (Chartzoulakis et al., 2002; Guerfel et al., 2009).

Cropping pattern is highly dependent on rainfall and other climatic factors which highly affect crop production. Aradilla (2016) mentioned that adlay can be planted anytime of the year provided there is enough moisture in the soil. Drought stress inhibits the dry matter production largely through its inhibitory effects on leaf expansion, leaf development and consequently reduced light interception (Nam et al., 1998). Drought at flowering commonly results in barrenness. A major cause of this, though not the only one, was a reduction in assimilate flux to the developing ear below some threshold level necessary to sustain optimal grain growth in corn (Yadav et al., 2004). Armilla (2011) concluded that drought condition significantly affected the days to maturity, plant height at harvest and number of productive tillers of first ratooned sorghum lines grown in Bukidnon, Philippines. Maturity was lengthened because the crop remains dormant in its vegetative stage and not all vegetative tillers were productive. Non-productive tillers were stunted while some wilted. The drought hampered the growth and development of the crop due to insufficient or even absence of soil moisture.

MATERIALS AND METHODS

The materials and equipment used in the study were seeds of six adlay cultivars, sacks, farm implements (plow and harrow), post-harvest materials and equipment (scythe, canvas, sacks, thresher and blower), measuring devices (meter stick, weighing scale, seed moisture tester), string, marking pens, camera, record notebook and pen.

The study was laid out in a 646 square meter area following the Randomized Complete Block Design (RCRD) with the six adlay varieties as treatments, replicated four times. The size of the plot was 4m x 4m with 5 rows per plot. The distance between rows was 0.90 meter while distance between hills was 0.60 meter. There were three data rows and two border rows per plot with alleys between replications and plots of 1.5 meters. The different treatments were as follows: V1-Gulian; V2-Ginampay; V3-Tapol; V4-Pulot; V5-Kiboa, and V6-Dwarf.

The area was plowed and harrowed twice to break the soil clods and to obtain a favorable seedbed for the plants. After the final harrowing, furrows were set at 0.9 meters apart. Adlay seeds were hydro-primed by soaking in water for eight hours followed by six hours of incubation. Incubation was done by thoroughly covering the seeds with a dry cloth to ensure uniform germination. Pre-germinated seeds were sown at a distance of 0.60 meter and then thoroughly covered with fine soil. Thinning was done one month after planting to remove excess seedlings leaving only two healthy seedlings per hill. Hilling up cultivation followed, then hand weeding and spot weeding were done as the need arise for a weed-free field.

The main source of nutrients for the growing plants was vermi-tea applied at two weeks interval starting at 30 days after germination until one month before harvest at a ratio of 2tbsp vermi-tea per liter of water at a volume of delivery of 200-300 liters per hectare. The pests were controlled using appropriate homemade bio-pesticides whenever necessary. Rainfall was the main source of water, although supplementary irrigation was done once a week through sprinkler irrigation whenever necessary. The panicles were harvested when grains turned

80% brown. Stems were cut at three nodes from the base of the plant and grains were separated, threshed, winnowed and sun-dried for 2 days.

The following parameters were measured:

A. Agronomic Characteristics

1. Days to Emergence – This was taken when 50% of the seedlings emerged from the soil surface.
2. Plant Height – This was taken at 30, 60 and 90 days after planting using 10 sample plants per plot by measuring from the base of the plant to the tip of the longest leaf. At maturity, this was taken when 80% of the grains were already mature or 80% of the grains turned brown. Measurement was done from the base of the plant to the tip of the longest panicle of 10 sample plants per plot.
3. Number of Vegetative Tillers – This was taken at 75 days after planting by counting the numbers of tillers per hill using 10 sample plants per plot.
4. Days to Flower – This was taken when 50% of the plants per plot had flowered.
5. Days to Maturity – This was taken by counting the number of days from sowing to the time when 80% of the grains turned to brown using 10 sample plants per plot.

B. Yield and Yield Components

1. Number of Productive Tillers – This was obtained from 10 sample plants per plot taken at maturity.
2. Length of Panicle – This was taken from 10 sample plants per plot by measuring from the neck-node bearing the first panicle branch to the tip of the panicle.
3. Number of Grains per Panicle – This was obtained by counting the total number of grains from 10 sample plants per plot.
4. Number of Filled Grains per Panicle – This was determined by counting the number of filled grains from 10 sample plants per plot.
5. Weight (g) of 1000 seeds – This was determined by counting 1000 sample seeds per treatment and weighed using a digital weighing scale. This was computed using the formula:

$$\text{Weight (g) of seeds} = \text{weight (g) of 1000 seeds} \times \frac{100 - \text{MC}}{86}$$

6. Grain Yield (kg/ha) – This was determined after drying the grains to 14% MC and was computed using the formula:

$$\text{Yield (kg/ha)} = \text{plot yield (kg/ha)} \times \frac{10{,}000\ \text{m2}}{\text{EHA}} \times \frac{100 - \text{MC}}{86}$$

Where: Effective harvest area (EHA) = 5.4 square meters

Statistical Analysis

Data gathered were statistically analyzed using the Analysis of Variance (ANOVA) in Randomized Complete Block Design. Differences between treatment means were compared using the Honestly Significant Difference (HSD) Test.

Agro-meteorological Data

Data on rainfall, temperature and relative humidity during the entire period of the study were gathered from the Agro-meteorological Station of Central Mindanao University, University Town, Musuan, Bukidnon, Philippines.

RESULTS AND DISCUSSION

Seedling Emergence

Result shows that the number of days to emergence of the different adlay cultivars were not significantly different which ranged from 13 to 17 days after sowing (DAS). The earliest to emerge were Pulot and Dwarf and the latest to emerge was Ginampay (Table 1). Adlay seedlings had slow emergence and poor seedling establishment due to very low moisture in the soil. Tribucio and Aradilla (2015) observed that adlay under normal environmental conditions emerged in 5 to 7 days after sowing. According to Harris et al., 2002; Chartzoulakis et al., 2002; Guerfel et al., 2009, during drought, seeds have impaired germination, poor growth and inhibition of developing leaves are the earliest response of plants to water deficiency.

Table 1. Days to emergence, and plant height of six adlay cultivars grown under adverse climatic conditions

Adlay Cultivars	Days to Emergence (DAS)	Plant Height (cm)			
		30 DAS	60 DAS	90 DAS	Maturity, DAS
Gulian	14	35	60	85	233[a]
Ginampay	17	36	80	86	221[a]
Tapol	15	37	70	83	221[a]
Pulot	13	37	68	90	181[b]
Kiboa	16	38	68	88	219[a]
Dwarf	13	40	56	78	149[c]
F-test	ns	ns	ns	ns	**
CV (%)	14.95	11.49	17.82	12.30	5.18

Means having common letters are not significantly different at 1% level of probability, HSD.
ns - not significant; ** - highly significant; DAS – days after sowing

Plant Height at 30, 60, 90 DAS and at Maturity

Statistical analyses show no significant variations in plant height of the adlay cultivars at 30, 60 and 90 DAS which ranged from 35 to 40 cm, 56 to 80cm, and 78 to 90cm, respectively (Table 1). However at maturity, the height of treatment plants significantly differed of which Gulian, Ginampay, Tapol and Kiboa had comparable heights followed by Pulot with Dwarf as the shortest cultivar. Mostales and Aradilla (2016) noted that the same cultivars differed in height at maturity. Drought stress decreased stem growth, and plant height, and the stem diameter shrinks in response to changes in the internal status (Simonneau et al, 1993). Cell elongation can be inhibited by water interruption from xylem vessels to the elongating cells under severe water deficit. Severe heat stress can decrease stem growth resulting to decrease in height (Nonami, 1998; Prasad et al, 2006a).

Vegetative and Productive Tillers

Tiller numbers among cultivars did not significantly differed which ranged from 5 to 7 pieces (Table 2) which conforms to the results of Sacuram and Aradilla(2012). Vegetative tillers of adlay during drought were lesser than when grown under normal field conditions. However during rainy season, adlay produced 17-19 tillers/hill (Mostales and Aradilla, 2016). Prasad et al., (2008) mentioned that drought and heat stress affects the whole-plant processes influencing germination, emergence, leaf, root, and tiller development.

Under adverse climatic conditions, Adlay seed crops had longer vegetative growth, and when the rain comes, more tillers developed and produced panicles. Productive tillers ranged from 10 to 13 pieces (Table 2) which implies that the original vegetative tillers of seed crops produced more tillers as a response to after-drought conditions. Blum et al (1990) said that rice plants develop tillers at the same time but stops when under drought stress and upon recovery, the rate increases immensely. Traits or organs are often compensated by either recovery or excess growth because of adverse effect throughout a phase, or a trait is compensated by increased tillers or branches. The negative effect of one phase can be compensated by recovery and excess growth of other organs (Prasad et al. 2008).

Days to Flower and Maturity

The six adlay cultivars did not vary in the flowering dates which ranged from 172-177 DAS (Table 2). Dwarf flowered earlier than the rest of the cultivars. Similar observations were noted in their maturity dates which ranged within 232 to 237 DAS. Mostales and Aradilla (2016); Omblero and Aradilla (2012) observed that days to maturity of adlay ranges within 153 to 160 DAS during wet season planting. Prasad and Staggenborg (2008) opined that drought and heat stress affect the whole-plant from germination, growth and development, floral initiation, pollination, fertilization, seed development, yield and quality.

Table 2. Number of vegetative tillers, number of productive tillers, days to flower and days to maturity of six adlay cultivars grown under adverse climatic conditions

Adlay Cultivars	Number		Days (DAS)	
	Vegetative tillers	Productive Tillers	Flower	Maturity
Gulian	7	12	177	237
Ginampay	5	10	175	235
Tapol	5	11	174	233
Pulot	7	13	178	235
Kiboa	6	10	176	237
Dwarf	6	11	172	232
F-test	ns	ns	ns	ns
CV (%)	15.67	19.06	3.24	1.91

ns - not significant; DAS - days after sowing

Panicle Length, Grains per Panicle and Filled Grains per Panicle

Adlay panicles were of comparable lengths which ranged from 84 cm (Dwarf) to 107 cm (Tapol). However, grains per panicle vary significantly and Dwarf had the most grains (471 pcs) while the rest of the cultivars had comparable grains of 254 to 332 pcs. Filled grains per panicle likewise significantly differed. Dwarf had the most number of filled grains (324 pcs) and the least number of unfilled grains was in Tapol (144 pcs). All adlay cultivars were highly adapted to unfavorable conditions, except Pulot (Table 3). Tribucio and Aradilla (2015) noted that Dwarf cultivar has the highest number of grains per panicle during normal cropping season. The different cultivars had different response mechanisms to drought. Supplemental irrigation during the growing season can result in a significant increase in water use efficiency (WUE) and consequently the grain yield (Tavousi et al., 2015). Traits or organs affected by water insufficiency may produce higher grain numbers but partially filled grains, or poor grain yield can be compensated by increase grain quality (Prasad et al. 2008).

Table 3. Panicle length, grains per panicle, filled grains per panicle, adjusted 1000-seed weight and adjusted grain yield of six adlay cultivars grown under adverse climatic conditions

Adlay Cultivars		Average Number		Adjusted	Adjusted
	Panicle length (cm)	Grains panicle	Filled grains/ Panicle	1000-seed weight (g)	grain yield (kg/ha)
Gulian	95	324^{b}	186^{b}	95.42	$1,534^{a}$
Ginampay	100	318^{b}	189^{b}	92.77	$1,168^{a}$
Tapol	107	254^{b}	144^{b}	89.86	$1,259^{a}$
Pulot	87	332^{b}	198^{b}	92.66	500^{b}
Kiboa	89	263^{b}	156^{b}	92.09	$1,631^{a}$
Dwarf	84	471^{a}	324^{a}	91.43	$1,658^{a}$
F-test	ns	**	**	ns	**
CV (%)	16.24	18.54	27.85	12.95	30.08

Means having common letters are not significantly different at 1% level of probability, HSD.
ns - not significant; ** - highly significant

1000-Seed Weight and Grain Yield

The 1000-seed weight of the six adlay cultivars did not significantly vary ranging from 90g to 95g. Numerically, seeds of Gulian were heavier compared to seeds of the other five cultivars. Across trials, Aradilla (2016) recorded that the six adlay cultivars has mean seed weights of 77g to 83g. On the other hand, adjusted grain yield of the six cultivars significantly differed. Dwarf had the highest yield of 1,658 kg/ha, followed by Kiboa, Gulian, Tapol, and Ginampay with yields of 1,631 kg/ha, 1,534 kg/ha, 1,259 kg/ha and 1,168 kg/ha, respectively. Pulot had the lowest yield of only 500kg/ha. Sarvestani, et al (2008) said that reduction in grain yield results from infertile panicle and filled grain percentage. Bouman & Tuong (2001) said that the maintenance of high plant water status and plant functions at low water potential, and the recovery of plant function after water stress are the major physiological processes that contribute to the maintenance of high yield under drought stress.

Agro-meteorological Data

Adlay was planted during dry season and eventually drought in 2016.The crop has a temperature requirement of 15°-20°C with high rainfall that usually is in excess of 1500 mm (www.fao.org/ag/agp/agpc/doc/gbase/data/pf000205).

The average rainfall, temperature and relative humidity during the conduct of the study are presented in Figure 1. Water insufficiency in the experimental site was already experienced since the last quarter of 2015 then severe drought was noted from January to March of 2016. Enough rain started in April and May while June had the heaviest downpour.

The mean temperature during the study period ranged within 26.27^{o}C (February 2016) to 28.9^{o}C (June 2016) and the average relative humidity was within 56.13% (February 2016) to 80.55% (September 2016).

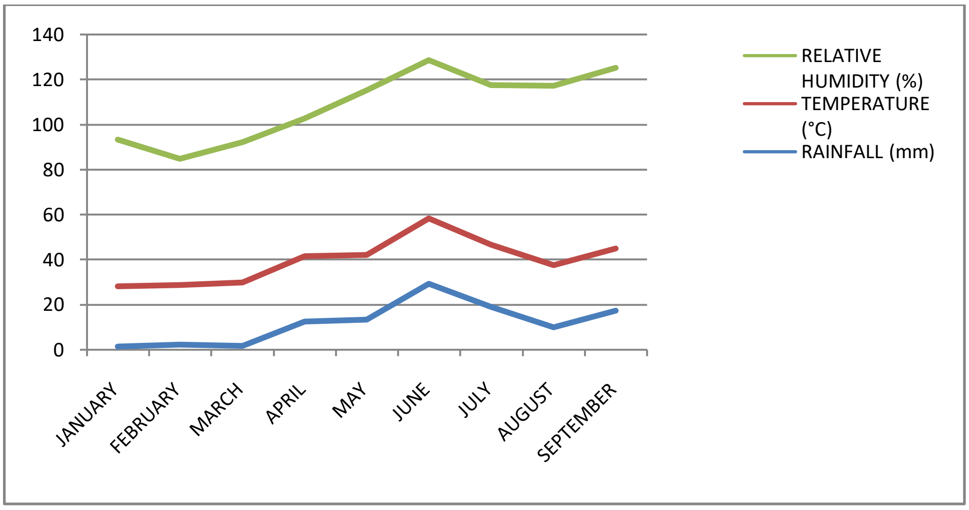

Figure1. Rainfall, temperature and relative humidity at the experimental site, January 2016 to September 2016

CONCLUSION

Germination, growth and development of six adlay cultivars were affected by adverse climatic conditions. Further, delayed seedling emergence, stunting, prolonged growth cycle, more unfilled grains and low yield were noted. Of the 14 parameters studied, only four parameters showed significant variation among cultivars: plant height at maturity, number of grains per panicle, number of filled grains and grain yield per hectare. All other parameters measured did not differ among varieties. It was noted that all the test crops can tolerate prolong drought, except Pulot cultivar which implies that these cultivars could be planted during dry season. Although adlay could be grown in drought-prone areas, this must be provided with supplementary irrigation so as not to compromise yield. Similar trials may be conducted employing intermittent irrigation in fields planted to the crop, particularly during periods of low or absence of soil moisture.

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