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Research Article

Agronomic Diversity and Yield Potential of Short-Statured Adlay Selections (SSAS) at Gen_5

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ABSTRACT

Adlay (*Coix lacryma-jobi* L.) is a high value and climate-change resilient crop, considered as complementary to rice. However, most varieties are tall and therefore, prone to lodging. Thus, the development for short-statured adlay is of great need. This study determined the agronomic characteristics of 18 SSAS under Musuan conditions. Results revealed that the genotypes differed in all parameters, as per ANOVA. Seedlings germinated at 6–9 days after planting (DAP), flowered at 89.67-103.67 DAP, and matured at 160-181 DAP. Plant height at maturity was 115.17-176.13 cm where, five SSAS were <120 cm, namely: Gi 7-3-8 (T1), Gi 5-2-3 (T3), Gi 11-3-5 (T4), Gi 5-1-2 (T5) and Gi 3-1-1 (T9). Weight of 1000 seeds ranged from 82.25-118.47 g whereas, grain yield was 1,579-2,845 kg ha^{-1}. Nine of 18 SSAS yielded more than 2,000 kg ha^{-1}. Standardized Shannon-Weaver Diversity Index estimated high allelic diversity for six traits (H'=0.76-0.99): days to flowering, plant height at maturity, number of grains per panicle, weight of 1000 seeds, and grain yield that would enable selection for the more desirable phenotypes to be advanced to Gen_6. SSAS for evaluation in the next generation will be primarily selected based on plant height and yield potential.

Keywords: Adlay, breeding lines, plant height, semi-dwarf, short-stature

1. INTRODUCTION

Adlay (*Coix lacryma-jobi* L.), also known as aglay, tigbi, katigbi or battad, is one of the alternative staple crops that can help address food security and malnutrition among the Bukidnons. It is an indigenous crop to the Philippines, a member of the Family Poaceae, and a cereal that can be cooked like rice or corn, or ground into flour for baking, herbal teas, medicines and soup. Adlay grains can be also fermented and made into beer, as well as, other beverages (Healthbenefits times.com, 2016). The starch-forming adlay cultivars are being adopted as alternative to rice and corn. Alday is actually one of the crops included in the food sufficiency program since 2010. It is considered as a climate-change resilient crop with low-input requirement (Monteroyo & Aradilla, 2014). Hence, it can be a component crop in various agricultural landscapes.

Research and development initiatives have been pursued to improve food and nutrition security in the upland communities of Bukidnon and nearby areas. Further, innovative and science-based adlay production and value-adding technologies had been undertaken as well (Patricio et al., 2017). Nevertheless, the adlay varieties grown by farmers are still heterogeneous i.e. mostly tall and late-maturing lines (Aradilla, 2016; Aradilla, 2018). Adlay is perennial, monoecious, freely branching, and can grow to 3-4 meters that consequently leads to lodging concerns (Rivera, 2023). For grain yields, Aradilla (2016) reported that under Musuan conditions and organic production systems, adlay varieties recorded grain yields from 1.9 to 2.4 t ha^{-1}, with higher yields during the rainy season. Tall varieties are prone to lodging whereas, late-maturing varieties stay in the field longer and are vulnerable to adverse climatic conditions and attack of insect pests, birds and rodents.

Unfortunately, adlay has not advanced much to become a mainstream cultivated crop species in the Philippines (Bon et al., 2020). It is used as foodstuff by indigenous peoples in different villages across the country and grown as an alternative crop using subsistence farming practices (Slow Food, 2019). Adlay cultivation in the Philippines was documented in the 1920s by Wester (1922) in the provinces of Bukidnon, Cotabato and Mountain Province. He noted variability among the Philippine *Coix* populations, particularly on grain shape and size. Schaaffhausen (1952) noted the presence of several named varieties in the country.

The Philippine Department of Agriculture became interested in adlay and funded the first batch of program/project proposals in 2010-2011. Under the CMU-DA-BAR Adlay R&D Project, the study entitled "Food Security Through Increased Adlay Productivity in Unpredictable Environments in Musuan, Bukidnon: Development of Short-Stature, Early Maturing and High-yielding Lines with Resistance to Foliar and Stalk Rot Diseases" produced 60 short lines after the third trial through selection from a mixed population of the variety Ginampay in 2018. Genotypes were stored for some time at the CMU-Agricultural Experiment Center (AEC). These were tested for viability in 2021 and out of 60 lines, only 18 lines germinated but with low viability. After seed increase as Gen$_4$ in a screenhouse in 2021-2022, enough seeds were produced to evaluate the lines as Gen$_5$ in 2022-2023. This study determined the agronomic characteristics of 18 short-statured adlay selections (SSAS) under Musuan conditions, and estimated the phenotypic diversity per trait.

2. METHODOLOGY

Materials and Equipment. Good seeds of 18 G$_4$ short-statured adlay selections (SSAS) were prepared. Animal-drawn-plow and harrow were used for land preparation. String, meter stick, stakes, markers, and labels were used for field lay-out. Other materials included chicken dung, vermicast, seaweeds, fresh milk, molasses, Manila paper, plastic containers for preparation of organic fertilizer (vermitea), weighing scale, digital Vernier caliper, ruler, moisture tester, calculator, record book and camera for documentation.

Experimental Design and Treatments. This study was laid in a 464.60 m^2 area following the Randomized Complete Block Design (RCBD). Treatments were the 18 SSAS with three replications. Each replication block measured 5 m x 15.2 m with 2 m alleyways between blocks. A total of 18 5 m-long furrows per block spaced at 0.90 m were established. The treatments were T1 (Gi 7-3-8), T2 (Gi 10-1-2), T3 (Gi 5-2-3), T4 (Gi 11-3-5), T5 (Gi 5-1-2), T6 (Gi 3-1-8), T7 (Gi 8-6-3), T8 (Gi 9-3-1), T9 (Gi 3-1-1), T10 (Gi 1-1-2), T11 (Gi 11-1-3), T12 (Gi 10-1-3), T13 (Gi 1-5-2), T14 (Gi 2-1-1), T15 (Gi 9-1-3), T16 (Gi 10-3-4), T17 (Gi 7-5-5), and T18 (Gi 3-1-7).

Land Preparation. The experiment area was plowed and harrowed twice at weekly interval. Furrows were established after the second harrowing a day before planting.

Seed Selection, Pre-Treatment and Planting. Large good seeds of the treatments, with no apparent weevil infestation and mechanical injury were selected. Seeds per genotype were soaked in tap water for eight hours followed by eight hours of incubation for uniform germination. Pre-germinated seeds were sown in the furrows at a distance of 60 cm between hills with 5 seeds hill^{-1}, then covered with fine soil.

Vermitea Preparation. Vermicast (2 kg) was placed in a 20 L-capacity plastic container, added with 16 L tap water, 2 L molasses, 500 mL pure cow's milk and 250 mL seaweed extract. The container was covered with Manila paper and tied tightly. The mixture was allowed to stand for two weeks and protected from rain and direct sunlight until ready for use.

Fertilizer Application. Chicken manure was broadcasted at 4 tons ha^{-1}, uniformly distributed, and incorporated in the soil of the experiment area during the final harrowing. Vermitea was applied one month after seedling emergence until 90 days from germination at 4 L ha^{-1} per 300 L tap water, at two weeks interval.

Thinning, Hilling-up and Weed Management. Excess seedlings were thinned out one month after seedling emergence, leaving only two healthy seedlings per hill. This was followed by hilling up. Hand-weeding and spot weeding were done as needed.

Water Management. Rain was the primary source of moisture for the test crop. From September 2022 to March 2023, average rainfall was lowest on March 2023 (0.71 mm), followed by January 2023 (2.91 mm) and November 2022 (3.31 mm). Rainfall was highest on October 2022 (11.04 mm). During the field experiment, average maximum temperature was from 29.01 ^{0}C (January 2023) to 31.84 ^{0}C (March 2023). Hence, water sourced from a nearby pond was provided to the crop through sprinkler irrigation whenever necessary.

Pest Management. Insect pests and diseases were regularly monitored. Biological control measures were administered when pest populations were above the economic threshold level.

Harvesting and Postharvest Handling. Adlay grains were harvested when 90% of grains had turned brown per SSAS per replication. Panicles were cut and grains were threshed. These were sun-dried for two days, or when 14% seed moisture content was attained. Clean seeds per genotype were placed in labeled containers and stored in a chiller at the CMU-AEC. Stems of adlay genotypes were cut at the third node from the ground for ratooning a few days after harvest.

Data Gathered and Statistical Analyses. Five sample hills per genotype per block were randomly selected and tagged for data collection. Several data were gathered primarily eight data: plant height at maturity (cm); days to emergence, flower and maturity; number of productive tillers; number of grains per panicle; weight of 1000 seeds; and grain yield (kg ha^{-1}). Days to emergence was recorded seven days after sowing (DAS) when at least 50% of the planted pre-germinated adlay seeds per genotype per replication had emerged from the soil cover. Days to flowering was recorded from date of planting (DAP) up to when at least 50% of the plants per genotype per replication had flowered. Days to maturity was recorded from DAP up to harvest time, or when at least 90% of the grains per panicle had turned brown. Number of productive tillers was determined a day before harvest by counting the tillers that produced panicles from 5 sample hills/entry. Number of grains per panicle was recorded from 5 sample hills/entry. Weight of 1000 seeds was determined by counting 1000 random seeds/entry and weighed using a digital weighing scale, then adjusted to 14% MC following the formula: adjusted weight (g) = weight of 1000 seeds x (100 – actual MC)/86. Grain yield was calculated using the formula below:

$$\text{Grain Yield (kg ha}^{-1}\text{)} = \text{row yield (kg)} \times \frac{10{,}000\ \text{m}^2}{\text{EHA}} \times \frac{100 - \text{actual MC}}{86}$$

Where: EHA or effective harvest area is:

$= 0.9$ m DBR x 0.6 m DBH x 5 hills/entry = 2.70 m^2

DBR = distance between rows

DBH = distance between hills

Each data parameter was subjected to Analysis of Variance (ANOVA) in RCBD, and Tukey's test or Honestly Significant Difference (HSD) for treatment mean comparisons using MST/MStat-C. Standardized Shannon-Weaver Diversity Index (SSWDI, H') was computed per parameter for estimates of allelic richness or phenotypic diversity following Embate et al. (2020) and referred to the scale of Jamago & Cortes (2012). Shannon-Weaver Diversity Index (Shannon & Weaver, 1949 as cited by Embate et al., 2020) was standardized by requiring the number of states (N) for diversity estimates to be $\geq$10 (Jamago, 2000).

3. RESULTS AND DISCUSSION

3.1. Agronomic Variation

Adlay genotypes were selected for shorter height and acceptable or higher yields. Nonetheless, other agronomic traits were also characterized or evaluated to determine for stability and/or acceptability of these traits. Adlay usually matures in about 5 to 6 months during favorable conditions but may extend up to 8 months under unfavorable conditions (Aradilla, 2018). For days to emergence (DTE), flowering (DTF) and maturity, these parameters highly differed among the SSAS, as per ANOVA (Table 1). DTE ranged from 5.67 (T1) to 9 days after planting (DAP) (T11, T12 and T18). The difference of 3.33 days between these genotypes was significant. The other SSAS with 6 to 8 DTE were comparable to either T1 or the three late-emerging SSAS. As adlay is monoecious and largely cross-pollinating, although it can also self-pollinate, such differences for the three quantitative traits that were not selected for, could be attributed to allelic differences, as well as, influence of environmental factors.

Early seedling emergence is a desirable trait that could indicate vigor and may reduce crop maturity. Aradilla et al. (2013) reported that under favorable conditions, adlay seedlings emerged one week after planting. Tribucio & Aradilla (2015) recorded adlay to generally germinate within 5 to 7 DAP under normal environmental conditions. However, during unfavorable conditions, emergence was recorded at 13-17 DAP. Omallao (2022) also reported that DTE of dwarf adlay lines were at 7 DAP. Accordingly, seedling emergence of cereal crops are affected by several factors such as soil compaction, soil moisture, seed quality, and even soil temperature (Hakansson & Lipiec, 2015; Sadras et al., 2012; Bewley et al., 2013).

Table 1. Days to emergence (DTE), days to flower (DTF) and days to maturity (DTM) of 18 short-statured adlay selections (SSAS) grown at the CMU-AEC

SSAS		DTE	DTF	DTM
T1	Gi 7-3-8	5.67^{b}	90.67^{bc}	162.67^{b}
T2	Gi 10-1-2	7.33^{ab}	97.67^{abc}	165.33^{ab}
T3	Gi 5-2-3	7.33^{ab}	89.67^{c}	166.67^{ab}
T4	Gi 11-3-5	6.33^{ab}	90.00^{c}	163.67^{b}
T5	Gi 5-1-2	6.00^{ab}	90.33^{bc}	163.00^{b}
T6	Gi 3-1-8	7.67^{ab}	98.67^{abc}	173.67^{ab}
T7	Gi 8-6-3	7.00^{ab}	91.67^{bc}	170.00^{ab}
T8	Gi 9-3-1	7.00^{ab}	92.00^{bc}	163.00^{b}
T9	Gi 3-1-1	6.00^{ab}	90.00^{c}	168.00^{ab}
T10	Gi 1-1-2	7.00^{ab}	96.33^{abc}	171.33^{ab}
T11	Gi 11-1-3	9.00^{a}	92.33^{bc}	165.33^{ab}
T12	Gi 10-1-3	9.00^{a}	99.33^{ab}	166.33^{ab}
T13	Gi 1-5-2	8.00^{ab}	103.67^{a}	181.00^{a}
T14	Gi 2-1-2	8.00^{ab}	95.67^{abc}	161.67^{b}
T15	Gi 9-1-3	8.00^{ab}	92.67^{bc}	160.00^{b}
T16	Gi 10-3-4	8.00^{ab}	94.67^{abc}	160.00^{b}
T17	Gi 7-5-5	8.00^{ab}	93.00^{bc}	163.00^{b}
T18	Gi 3-1-7	9.00^{a}	93.00^{bc}	169.00^{ab}
F-test		**	**	**
CV (%)		14.08	3.16	3.07

Means with a common letter within a column are not significantly different at 5% level of probability, HSD.
** - highly significant

Determination of flowering time of crops is vital in hybridization, particularly the time of pollen shedding and stigmatic receptivity. Among the 18 SSAS, DTF ranged from 89.67 (T3) to 103.67 DAP (T13), with a two-week difference. Gi 5-2-3 (T3) was the earliest to flower but was comparable to 14 other SSAS with DTF ranging from 90-98.67 DAP. Elegido (2017) reported that DTF of these SSAS as Gen_3 ranged from 100-114 DAP. For dwarf adlay genotypes, Omallao (2022) reported 108-110 DTF. However, Aradilla (2018) noted that the dwarf adlay variety flowered earlier than other traditional adlay varieties. Moreover, Wicaksono (2022) recorded that adlay flowered significantly faster at about 90 DAP when adequate amount of irrigation was provided but the crop was partly grown during the dry season. Such phenomenon maybe explained as drought escape which is a classic adaptive mechanism of many crops. In this study, the reproductive stage of these genotypes started on November 2022 when rainfall was limited. Further, the 18 SSAS did not mature simultaneously. DTM ranged from 160 (T15 and T16) to 181 DAP (T13), with three weeks difference. However, Gi 9-1-3 (T15) and Gi 10-3-4 (T16) were comparable with 15 other SSAS with means ranging from 161.67-173.67 DAP. Eligido (2017) reported that DTM of these SSAS at Gen_3 ranged from 162 to 178 DAP. Omallao (2022) noted that dwarf adlay accessions matured on average at 163 DAP. Zhao et al. (2018) explained that variation in the growth period affects the crop's life cycle, i.e. shorter vegetative or reproductive growth may also lead to early maturity. In crop production, uniform maturity is an important trait for convenience in harvesting and harvest schedule.

Plant height at maturity (PHM) and number of productive tillers per hill (NPLH) are presented in Table 2 and both traits highly differed among the genotypes, as per ANOVA. PHM ranged from 115.17 (T3) to 176.13 cm (T13), with more than half a meter difference (60.96 cm). However, Gi 5-2-3 (T3) was comparable to nine other SSAS. Of the 18 genotypes, 15 were less than 150 cm at maturity. From the 15, 5 genotypes recorded less than 120 cm PHM. Currently, there is a Dwarf adlay variety which usually grows up to about 150 cm on average (Rivera, 2023).

Most of the genotypes commenced their reproductive stage on November 2022 when rainfall was inadequate. Inadequate availability of soil moisture has negative effects on plant growth, leading to decreased stem growth and plant height (Simonneau et al., 1993). Additionally, drought stress can reduce stem diameter as response to changes in the plant's internal water status. Various environmental factors can individually or collectively influence or impact overall plant growth and development (Miao et al., 2024), such as vertical growth. These factors include temperature, light, water, gas, soil and nutrients. Moisture stress effects on plant height at reproductive stage may be reduced or less significant, where vertical growth usually ceases for determinate annuals to favor reproductive preparation. Adlay however, is an indeterminate crop.

Table 2. Plant height at maturity (PHM), number of productive tillers per hill (NPTH), number of grains per panicle (NGP), weight of 1000 seeds (SW) and grain yields of the 18 Gen6 SSAS under Musuan conditions.

TRT	SSAS	PHM (cm)	NPTH	NGP	SW (g)	GY (kg ha^{-1})
T1	Gi 7-3-8	117.33^{fg}	6^{bc}	268^{ab}	103.60^{bc}	2,060^{b-e}
T2	Gi 10-1-2	150.18^{bc}	7^{b}	282^{ab}	91.88^{cde}	2,272^{a-d}
T3	Gi 5-2-3	115.17^{g}	7^{b}	230^{ab}	103.74^{bc}	1,707^{cde}
T4	Gi 11-3-5	118.93^{efg}	7^{b}	239^{ab}	91.83^{cde}	1,789^{b-e}
T5	Gi 5-1-2	119.97^{d-g}	6^{bc}	305^{ab}	87.63^{def}	2,346^{abc}
T6	Gi 3-1-8	143.93^{b-e}	10^{a}	373^{a}	82.35^{ef}	2,845^{a}
T7	Gi 8-6-3	141.63^{b-f}	6^{bc}	249^{ab}	96.23^{bcd}	1,641^{de}
T8	Gi 9-3-1	133.73^{b-g}	5^{c}	241^{ab}	92.45^{bcde}	1,579^{e}
T9	Gi 3-1-1	118.63^{efg}	6^{bc}	278^{ab}	82.39^{ef}	1,642^{de}
T10	Gi 1-1-2	129.77^{b-g}	6^{bc}	265^{ab}	86.73^{def}	1,698^{cde}
T11	Gi 11-1-3	154.57^{ab}	7^{b}	347^{ab}	93.52^{bcde}	2,248^{a-e}
T12	Gi 10-1-3	134.30^{b-g}	6^{bc}	266^{ab}	85.70^{def}	2,286^{a-d}
T13	Gi 1-5-2	176.13^{a}	7^{b}	204^{b}	18.47^{a}	2,179^{a-e}
T14	Gi 2-1-2	129.44^{b-g}	6^{bc}	337^{ab}	77.64^{f}	2,285^{a-d}
T15	Gi 9-1-3	144.63^{bcd}	10^{a}	274^{ab}	91.68^{cde}	2,416^{ab}
T16	Gi 10-3-4	141.13^{b-f}	6^{bc}	321^{ab}	94.08^{bcde}	1,904^{b-e}
T17	Gi 7-5-5	148.33^{bc}	5^{c}	251^{ab}	104.80^{b}	2,041^{b-e}
T18	Gi 3-1-7	126.95^{c-g}	6^{bc}	312^{ab}	85.15^{def}	2,473^{ab}
F-test		**	**	*	**	*
CV (%)		6.13	7.25	17.71	4.38	20.01

Means with a common letter within a column are not significantly different at 5% level of probability, HSD.
** - highly significant

The 18 adlay genotypes were selected for shorter stature however, plant height is a polygenic trait governed by many genes and unfortunately, can be highly influenced by the environment. Although there was a significant reduction in PHM at Gen_5 i.e. about 55% of the SSAS were already less than 150 cm at maturity and 28% were less than 120 cm, these cannot be directly and solely attributed to change in allelic frequencies; hence, further evaluation is needed. One of the important contributors to adlay grain yield is the number of productive tillers per plant however, this trait was not part of the selection criteria. NPTH highly differed among the SSAS and ranged from 5-10 (Table 2). Gi 3-1-8 (T6) and Gi 9-1-3 (T15) recorded 10 NPTH that were significantly more productive than the 16 SSAS. Aside from genetic differences for NPTH, the less productive genotypes were more affected by stemborers. In contrast, T6 and T15 may also have some degree of resistance or tolerance to stemborer. Bohol (2018) and Omallao (2022) proposed that productive tiller development was affected by adverse climatic condition, zero tillage, and organic fertilizer application. Tribucio (2015) reported that stemborer infestation at the vegetative stage of adlay was moderate at 30-63%. However, according to Likhayo et al. (2018), stemborer infestation can have serious consequences on crops, particularly cereals like corn and sorghum. Stemborer insect larvae feed on plant stem, causing damage to the vascular tissue and impairing the plant's ability to transfer water and nutrients. This can lead to decreased plant development, lower yields, and plant senescence. As for grain yields of the SSAS and two yield components: number of grains per panicle (NGP) and weight of 1000 seeds (SW), the genotypes differed for all these traits (Table 2). These are also polygenic traits and can be highly influenced by the environment.

NGP means ranged from 204 (T13) to 373 (T6), with 169 grains panicle^{-1} difference between Gi 1-5-2 and Gi 3-1-8, respectively. Sixteen other SSAS were comparable to both T13 and T6, with NGP from 230 to 347. Aradilla (2018) and Omallao (2022) similarly reported variability in NGP among dwarf adlay genotypes. Lu et al. (2022) discussed that the number of grains of a cereal crop was mainly determined by panicle architecture and branch differentiation. Both parameters can be complex quantitative traits that are controlled by both genes and the environment, and their interaction. Moreover, panicle architecture and branch differentiation are closely associated with the phytohormone pathways and vascular development in the crop (Lu et al., 2022).

Seed weight is an indirect measure of seed size and is often positively associated with grain yield. Seed size and weight are important physical indicators that are frequently related to yield, market grade factors and harvest efficiency. In the study of Coles & Aradilla (2013), SW of different adlay varieties ranged from 80-90 g. For this study, means of SSAS ranged from 77.64 (T14) to 118.47 g (T13), with a 40.83 g difference. T13 (Gi 1-5-2) therefore, had the biggest seeds among the 18 genotypes. On the other hand, 10 SSAS were considered moderately sized with means from 91.68 to 104.80 g. According to Li et al. (2021), grain weight is a compound trait determined by grain length, width and thickness. These traits profoundly affect grain weight, aside from other biological pathways such as phytohormones and even photosynthesis (Chen et al., 2021).

Finally, grain yield also differed among the SSAS which ranged from 1,579 kg ha^{-1} (T8) to 2,845 kg ha^{-1} (T6), with a difference of 1,266 kg ha^{-1}. However, Gi 3-1-8 (T6) was comparable with eight other SSAS with means from 2,179 to 2,473 kg ha^{-1}. Numerically, 11 SSAS recorded grain yields greater than 2 tons ha^{-1}. These SSAS were selected from Ginampay grown under Musuan conditions. Mendoza et al. (2015) reported that under Taniangan, Tangub City conditions, Ginampay yielded with 3,413 kg ha^{-1}. Aradilla (2016) however, recorded a 5.28 t ha^{-1} yield of Ginampay under Musuan conditions cultivated from February to August 2014. For this study, tall Ginampay compared to the selected shorter lines yielded only 1,799.58 kg ha^{-1} (not shown in Table 2). Results are promising for some of the SSAS that have significantly reduced in height and have shown relatively good yields, such as T6 (Gi 3-1-8: 143.93 cm; 2,845 kg ha^{-1}), T18 (Gi 3-1-7: 126.95 cm; 2,473 kg ha^{-1}), and T15 (Gi 9-1-3: 144.63 cm; 2,416 kg $^{ha-1}$). Many of the selected lines were adapted to Musuan conditions.

Zhang et al. (2012) discussed that grain size and shape of cereals are important components determining grain yield. Except for seed shape, grain size and yield are polygenic traits generally governed by many quantitative trait loci (QTL) with either major or minor effects (Powder, 2022). Such collectively manifest as continuous variation in the quantitative traits like grain yield. Often, various QTL may also exhibit gene interactions, as well as, with the environment. Several traits were reported to be correlated with grain yield such as time of flowering, tiller production, crop height and weight of seeds (Hua et al., 2022).

3.2. Phenotypic Diversity

ANOVA results indicated significant to highly significant variation among the SSAS for every trait or crop parameter presented. HSD identified which SSAS differed from one another per trait or parameter, or if and when means per parameter were comparable. On the other hand, SSWDI (H') estimates the level of phenotypic diversity per trait or the magnitude of allelic richness per trait. H' ranged from 0.7809 to 0.8352 (Table 4), indicating high phenotypic diversity or allelic richness for six of the critical quantitative traits based on the scale of Jamago & Cortes (2012). These estimates suggest that there is more than enough variation for 6 of 9 traits (H'=0.76-0.99) of the 18 SSAS to be able to select for the more desirable or preferred phenotypes.

In this study, both plant height at maturity and grain yield were highly diverse. Shorter adlay lines that are also high-yielding are desirable that can be eventually approved as new adlay varieties. Based on the estimates of other traits, it may also be possible to also select for short stature, high grain yield, plus other desirable traits such as early maturity.

Table 3. Phenotypic diversity estimates of 18 short-statured adlay selections (SSAS) based on Standardized Shannon-Weaver Diversity Index (SSWDI).

QUANTITATIVE TRAIT	H'	LEVEL OF PHENOTYPIC DIVERSITY
Days to emergence	0.7239	Moderate
Days to flowering	0.8352	High
Days to maturity	0.8352	High
Plant height at maturity	0.8270	High
Number of productive tillers per hill	0.5171	Moderate
Number of grains per panicle	0.7895	High
Weight of 1000 seeds	0.7809	High
Grain yield	0.8176	High

Jamago & Cortes (2012) H' Scale: 0.00 (invariant, no diversity), 0.01-0.45 (low or poor diversity), 0.46-0.75 (moderate diversity), 0.76-0.99 (high diversity), 1.00 (maximum diversity)

4. CONCLUSIONS AND RECOMMENDATION

The 18 short-statured adlay selections (SSAS) grown at the CMU-AEC differed in all eight agronomic parameters presented, as per ANOVA. Plant height at maturity ranged from 115.17 to 176.13 cm. Gi 5-2-3 (T3) was the shortest but was comparable to nine other SSAS. Among these 10 short genotypes, 5 SSAS were less than 120 cm in height at maturity. On the other hand, grain yield ranged from 1,579 to 2,845 kg ha^{-1}. Gi 3-1-8 (T6) recorded the highest yield but was comparable to eight other SSAS with grain yields from 2,179 to 2,473 kg ha^{-1}. Numerically, 11 of 18 SSAS recorded grain yields greater than 2 tons ha^{-1}.

Moreover, SSWDI estimated moderate diversity for days to emergence and number of productive tillers per hill. In contrast, six traits including plant height at maturity and grain yield were estimated with high diversity. From these traits, selection of the more desirable genotypes (shorter plants and high-yielding) can be done. The SSAS that will be evaluated for the next generation will be assessed for early maturity and tolerance and/or resistance to major pests and diseases of adlay.

Author Contributions: ARAradilla primarily conceptualized this study, supervised its conduct, wrote the technical reports and the draft of this manuscript. JMJamago provided additional insights, data analysis and discussion, and finalized the manuscript for submission and revision after review. NBBaldo provided the adlay genotypes, additional conceptual insights and inputs on the methodology and discussion. CNDaculos did the data encoding and analyses. RB Bohol, BR Sarsuza and SKM Labis characterized the adlay lines and gathered the data. MGBallentes and MGMarin shared conceptual insights on insect pests and pathogens management, respectively. SMTDargantes, MEBDetalla, HLVEbuña, MSMPaulican, ROSalingay, BGPTaban, and JAMRemollo were all involved in the conceptualization. All authors concur to the publication of this paper.

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Data Availability Statement: Data are contained in the article. As such that the plant materials of this research are still breeding lines, availability of raw data and access to other datasets will be limited due to proprietorial concerns.

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