DF-787
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RESEARCH ARTICLE Agricultural Science Digest

Agronomic Performance, Genetic Diversity and Yield Determining Traits of Heirloom Rice

Jerald Anthony C. Esteban[1], Lyrine A. Aparece[1], Rosalino B. Recto[1],
Roel Z. Rementizo[1], Edwin L. Solilap[1]

10.18805/ag.DF-787

ABSTRACT

Background: This study assessed the agronomic performance, pest and disease response, genetic diversity and yield-related traits of selected heirloom rice genotypes under the agroclimatic conditions of USeP Mabini Unit, Mabini, Davao de Oro, during the dry season.

Methods: A randomized complete block design was used with five genotypes replicated three times.

Result: Dampuan exhibited the highest early vigor and grain number per panicle, while Thailand and Romelietes achieved the highest grain yields of 3.49 and 3.56 t/ha, respectively. Pest and disease evaluations showed Thailand had the lowest incidence of stem borers and rice bugs, while Dinurado and Black Rice were most susceptible. All genotypes were resistant to rice blast, with false smut occurring at later growth stages. Economic analysis identified Thailand as the most profitable, generating PHP 31,976.28 net profit and 66.01% ROI. Grain filling percentage strongly correlated with yield (r = 0.98). Cluster analysis revealed Dinurado and Black Rice as genetically distinct, guiding varietal improvement.

Key words: Agronomic traits, Genetic diversity, Upland rice, Yield predictors.

INTRODUCTION

Rice (*Oryza sativa* Linn.) is the most important cereal crop and staple food for more than half of the global population (Esteban and Baldo, 2024). In the Philippines, rice plays a pivotal role in ensuring food security and supporting rural livelihoods. However, achieving rice self-sufficiency remains a persistent challenge due to rapid population growth, climate variability, pest and disease pressures, low productivity and the conversion of agricultural land to non-agricultural uses.

According to the Philippine Statistics Authority (PSA, 2024), rice production in the first quarter of 2024 dropped to 5.46 million metric tons (MMT), with 3.6 MMT from irrigated areas and 1.86 MMT from rainfed and upland farms. This indicates that upland rice production remains underutilized despite the country having vast rainfed and elevated lands, particularly in Mabini, Davao de Oro.

To date, there has been no comprehensive study in Mabini evaluating the adaptability, performance and genetic diversity of heirloom rice lines. Likewise, little is known about the yield-contributing traits most associated with high performance in local environments. Such information is vital for breeders, researchers and farmers in selecting or improving varieties suited to site-specific conditions (Wijayanti *et al*., 2023). Identifying superior genotypes with desirable agronomic traits can be achieved through statistical tools such as correlation and regression analyses, which reveal the magnitude and direction of associations between traits and yield. These analyses provide insights into which traits can be prioritized for varietal improvement and agronomic management.

[1]Crops and Soil Cluster, College of Agriculture and Related Sciences, University of Southeastern Philippines, Mabini Unit, Pindasan, Mabini, Davao de Oro, Philippines.

Corresponding Author: Jerald Anthony C. Esteban, Crops and Soil Cluster, College of Agriculture and Related Sciences, University of Southeastern Philippines, Mabini Unit, Pindasan, Mabini, Davao de Oro, Philippines. Email: jacesteban@usep.edu.ph

How to cite this article: Esteban, J.A.C., Aparece, L.A., Recto, R.B., Rementizo, R.Z. and Solilap, E.L. (2025). Agronomic Performance, Genetic Diversity and Yield Determining Traits of Heirloom Rice. *Agricultural Science Digest.* 1-8. doi: 10.18805/ag.DF-787.

Submitted: 19-08-2025 **Accepted:** 26-11-2025 **Online:** 17-12-2025

The study holds practical value for food security by identifying heirloom genotypes with superior performance, profitability and adaptability under Mabini conditions. It also emphasizes traits critical to enhancing yield, offering guidance for both crop management and breeding strategies. Integrating agronomic, economic and genetic assessments will further promote resilient and diversified farming systems, aligning with climate-resilient agriculture initiatives. Ultimately, this research provides baseline data and recommendations that can inform future extension programs and policy planning for the development of heirloom rice.

Thus, this study was conducted to assess the adaptability, genetic diversity and yield-related agronomic traits of selected heirloom rice lines under USeP Mabini, Davao de Oro. Specifically, it aimed to: (1) evaluate growth and yield performance, (2) assess genetic diversity based on quantitative traits and (3) determine the relationship between key traits and grain yield.

MATERIALS AND METHODS

The field trial was conducted in the Palayamanan Project Area of the University of Southeastern Philippines, College of Agriculture and Related Sciences, Tagum-Mabini Campus, Mabini Unit, Pindasan, Mabini, Davao de Oro, from January to June 2025 during the dry season. The experiment followed a Randomized Complete Block Design (RCBD) with five heirloom rice varieties as treatments replicated three times.

Before planting, one kilogram of soil samples was randomly collected at a depth of 30 cm using a soil auger, following the grid method. Samples were pulverized, air-dried for seven days and submitted to the Regional Soils Laboratory of the Department of Agriculture, Agdao, Davao City, for physico-chemical analysis. A week before sowing, the experimental area was plowed and harrowed to control weeds and improve soil tilth. The 364 m^2 area was divided into 15 plots, each measuring 3 × 3 m. Based on soil analysis, the recommended fertilizer rate (45-25-25 kg N, P_2O_5, K_2O ha^{-1}) was applied as 178.57 kg ha^{-1} of complete fertilizer and 43.47 kg ha^{-1} of urea, split into three applications: 50% at 21 DAS, 25% at 45 DAS and the remaining 25% at 75 DAS. Agro-climatic data, including rainfall, temperature and humidity, were also recorded.

Pre-germinated seeds were directly sown at five seeds per hill, spaced 25 × 50 cm apart and covered with soil. A protective net was installed seven days before sowing to minimize bird damage. Pest and disease management followed Integrated Pest Management (IPM) practices. Regular monitoring was conducted, while insect nets reduced infestations. Handpicking of pests such as rice bugs and stem borers served as mechanical control. When pest populations exceeded economic thresholds, cypermethrin was applied selectively, following label instructions on dosage, mixing, PPE use and safe disposal of containers to prevent environmental contamination.

Harvesting was done manually with a sickle once 85% of the grains turned golden yellow. Seeds were cleaned, sun-dried and stored. Standard agronomic and yield data were collected to minimize experimental error. Before statistical analysis, datasets underwent cleaning and a normality test. Outliers were identified using the box-and-leaf method and removed. Data were analyzed using Analysis of Variance (ANOVA) and when significant differences were detected, Tukey's Honest Significant Difference (HSD) test was employed to separate means.

Genetic diversity among heirloom rice was evaluated using quantitative traits. Data were standardized to z-scores for comparability. Cluster analysis was performed using the Unweighted Pair Group Method with Arithmetic Mean (UPGMA) to group varieties based on morphological and agronomic similarities. Pearson's correlation analysis determined associations between agronomic traits and grain yield, while regression analysis quantified the magnitude of these relationships.

RESULTS AND DISCUSSION

Agro-climatic conditions of USeP mabini unit

The summary of USeP agro-climatic conditions from January to June 2025 is presented in Table 1. The USeP Mabini site reflected a typical tropical lowland climate, generally dry with irregular but intense rainfall events. Most days had little to no rainfall (0-10 mm), though sudden heavy downpours occurred on January 5 (80.1 mm), January 26 (50.4 mm), February 20 (49.8 mm), April 20 (138 mm) and May 12 (144.6 mm). While the season was largely dry, these sporadic rains could disrupt field operations and affect crop water management.

Relative humidity (RH) was high in the mornings (86-98%) but dropped substantially in the afternoons, sometimes reaching as low as 25% during dry days. This fluctuation suggests mornings favored foliar disease development, while afternoons allowed drying, reducing prolonged leaf wetness. Wind speed was mostly calm to moderate, ranging from 0-5 m/s with occasional peaks of 6-7 m/s. These conditions influenced evapotranspiration, pest activity and potential crop lodging.

Temperature patterns showed afternoon readings of 25-34°C, within the optimal range for heirloom rice growth. Significant rainfall lowered temperatures below 28°C, as observed on April 20 and May 12. The alternating warm and cooling effects created a balance favorable to rice development.

Overall, the six-month agro-climatic profile of USeP Mabini indicated that heirloom rice cultivation is feasible.

Table 1: Summary of agro-climatic conditions at USeP mabini, davao de Oro, philippines from January-June 2025.

Parameter	Observed range/description	Specific events (for rainfall)
Rainfall	Irregular; 0-10 mm on most days, punctuated by intense events	Jan 5 (80.1 mm), Jan 26 (50.4 mm), Feb 20 (49.8 mm), Apr 20 (138 mm), May 12 (144.6 mm)
Relative humidity (Morning)	86-98%	N/A
Relative humidity (Afternoon)	25-60% (on drier days)	N/A
Temperature (Typical afternoon)	25-34°C	N/A
Temperature (Rainy days)	Below 28°C	Apr 20, May 12
Wind speed (Typical)	0-5 m/s	N/A
Wind speed (Peak)	6-7 m/s	N/A

N/A: Not applicable.

The combination of intermittent rainfall, high but variable humidity, moderate winds and suitable temperatures provide conditions supportive of crop growth, though sudden downpours require careful management for water and disease control.

Agronomic characteristics

Growth performance

The Analysis of Variance (ANOVA) revealed significant differences in the growth performance of heirloom rice genotypes under USeP Mabini agro-climatic conditions (Table 2). At 30 days after sowing (DAS), Dampuan exhibited superior early vigor with the tallest seedlings (82.04 cm), significantly higher than Black Rice, which recorded the shortest (65.26 cm). Thailand, Romelietes and Dinurado produced intermediate heights (71.28-72.44 cm) without notable differences. At 70 DAS, Thailand attained the tallest mature plants (146.14 cm), though not significantly different from Dampuan (142.01 cm), Romelietes (137.36 cm) and Dinurado (134.78 cm). Black Rice consistently remained the shortest genotype throughout the growth stages.

Germination also varied significantly. Dinurado germinated last at 16.50 days, while Thailand germinated earliest at 6.75 days, reflecting differences in dormancy and adaptation. Morphological examination revealed that Dinurado seeds had a thick, hard palea, likely contributing to delayed emergence compared with the thinner-coated seeds of other genotypes.

Tillering capacity showed no significant variation in total tillers, with values ranging from 20.82 to 22.68 per plant. However, productive tiller counts differed: Black Rice produced the highest number (19.58), indicating superior grain-bearing efficiency, while Dampuan recorded the lowest (17.21), suggesting greater allocation toward vegetative growth than reproduction.

Flowering and maturity patterns also differed significantly. Dampuan flowered earliest (89.75 days), while Dinurado was latest (116.25 days). Black Rice, Thailand and Romelietes flowered at intermediate times (96.25, 102.75 and 105.75 days, respectively). Maturity followed similar trends: Dampuan matured earliest at 121.25 days and was harvested at 138.25 days, while Dinurado matured last at 141.75 days and was harvested at 147.50 days. The other genotypes exhibited intermediate durations, indicating balanced life cycles.

These findings highlight distinct growth strategies among heirloom rice genotypes, suggesting their differential suitability under specific agro-climatic conditions. The observed variations emphasize that productivity is strongly influenced by environmental interaction, underscoring the importance of matching genotype to location for efficient production. Such adaptability ensures that heirloom rice can be sustainably cultivated while maintaining high-quality yields (Najeeb *et al*., 2018).

Yield and yield components

A perusal of ANOVA revealed highly significant differences among genotypes for number of grains per panicle (NGP),

Table 2: Growth and yield performance of aerobic rice grown under USEP mabini, mabani, davao de oro agro-climatic conditions.

Genotypes	DTG	PH (cm)		NOT	DTF	NOPT	DTM	DTH	NGP	PGPP	1000 SW	YTpH
		30 DAS	70 DAS									
Thailand	6.75^{c}	72.44^{ab}	146.14^{a}	20.93^{a}	102.75^{b}	17.60^{b}	127.50^{b}	141.25^{b}	475.82^{ab}	63.36^{a}	23.25	3.49^{a}
Black rice	7.75^{bc}	65.26^{b}	130.79^{b}	22.68^{a}	96.25^{c}	19.58^{a}	123.25^{c}	138.25^{c}	326.43^{c}	52.04^{b}	23.50	2.32^{b}
Romelietes	8.75^{b}	71.28^{ab}	137.36^{ab}	21.07^{a}	105.75^{b}	18.30^{ab}	127.50^{b}	141.00^{b}	445.91^{b}	68.99^{a}	21.50	3.56^{a}
Dampuan	7.50^{bc}	82.04^{a}	142.01^{ab}	20.82^{a}	89.75^{d}	17.21^{b}	121.25^{c}	138.25^{c}	539.01^{a}	46.99^{bc}	23.25	2.19^{b}
Dinurado	16.50^{a}	72.03^{ab}	134.78^{ab}	22.40^{a}	116.25^{a}	17.70^{b}	141.75^{a}	147.50^{a}	423.15^{b}	44.42^{c}	23.00	1.63^{b}
P-value	0.0000	0.0119	0.0127	0.0260	0.0000	0.0126	0.0000	0.0000	0.0000	0.0000	0.5172	0.0003
C.V. (%)	6.19	7.31	3.87	4.06	2.67	4.54	1.12	0.44	6.82	5.10	7.57	18.18

PH: Plant height (30 DAS: Days after sowing and 70 DAS: Days after sowing); DTG: Days to germinate; NOT: Number of tillers; DTF: Days to flowering; NOPT: Numbers of productive tillers; DTM: Days to maturity; DTH: Days to harvest; NGP: Number of grains per panicle; PGPP: Percentage of filled grains per panicle; 1000SW: Thousand weights of grains; YTpH: Yield tons per hectare.

percentage of filled grains per panicle (PGPP) and yield per hectare (YTpH) ($p<0.01$), while 1,000-seed weight showed no statistical difference ($p = 0.5172$) (Table 2).

Dampuan produced the highest NGP (539.01), followed by Thailand (475.82) and Romelietes (445.91), which were significantly greater than Dinurado (423.15) and Black Rice (326.43). This indicates Dampuan's superior panicle capacity, a valuable trait for breeding programs targeting grain number. For PGPP, Romelietes (68.99%) and Thailand (63.36%) outperformed other genotypes, reflecting superior grain filling efficiency. In contrast, Dinurado (44.42%) and Dampuan (46.99%) recorded low percentages despite their higher NGP, suggesting limitations in pollination or grain development under the prevailing conditions.

Seed size, expressed as 1,000-seed weight, did not differ significantly among genotypes, ranging from 21.50 g (Romelietes) to 23.50 g (Black Rice). This stability implies that seed weight is less influenced by genotype compared to other yield components under USeP Mabini conditions. On the other hand, grain yield varied significantly. Romelietes (3.56 t/ha) and Thailand (3.49 t/ha) achieved the highest yields, both statistically superior to other genotypes. Black Rice, Dampuan and Dinurado yielded lower, from 2.32 to 1.63 t/ha. Despite Dampuan's high grain number, its poor grain filling limited final yield. Similarly, Dinurado, with moderate NGP, was constrained by low grain filling and reduced productivity. Notably, Romelietes and Thailand yields exceeded the Northern Philippines' average upland rice yield of 2.54 t/ha reported by Acierto *et al*. (2020).

Overall, the results highlighted that yield and yield components of heirloom rice are strongly influenced by environmental factors. Ensuring genotype adaptability to specific agro-climatic conditions is therefore critical for achieving stable, high-quality and efficient production (Najeeb *et al*., 2018).

Response to major insect pests and diseases

The response of heirloom rice genotypes to major insect pests was evaluated based on severity infestation ratings for stem borer (SBSI), rice bug (RBSI), black bug (BBSI) and planthopper (PHSI) at 30 and 70 days after sowing (DAS). ANOVA revealed significant differences ($p<0.01$) among genotypes for stem borer infestation at both stages and for rice bug infestation at 70 DAS, indicating variability in pest susceptibility (Table 3).

At 30 DAS, all genotypes except Dinurado showed slight stem borer damage (21-40%). Dinurado, however, recorded a significantly higher infestation (69.00%), classified as severe. By 70 DAS, Black Rice, Romelietes, Dampuan and Dinurado exhibited infestation levels of 57.00-63.00%, all within the extensively to severely damaged range (41-80%). Thailand recorded the lowest severity (33.00%), reflecting relatively higher resistance.

For RBSI, all genotypes showed no damage at 30 DAS, but severity increased by 70 DAS. Dampuan (79.00%) and Black Rice (77.00%) were severely damaged, while

Table 3: Heirloom rice genotypes response to major insect pests and diseases under USeP mabini, mabani, davao de oro agro-climatic conditions.

Genotypes	SBSI		RBSI		BBSI		PHSI		FSSI		RBlastSI	
	30 DAS	70 DAS	30 DAS	70 DAS	30 DAS	70 DAS	30 DAS	70 DAS	30 DAS	70 DAS	30 DAS	70 DAS
Thailand	25.50^{b}	33.00^{b}	00	62.00	00	00	00	00	20.00	22.50^{b}	00	00
Black Rice	31.50^{b}	63.00^{a}	00	77.00	00	00	00	00	20.00	27.50^{ab}	00	00
Romelietes	25.00^{b}	57.00^{a}	00	64.50	00	00	00	00	20.00	21.00^{b}	00	00
Dampuan	26.00^{b}	61.00^{a}	00	79.00	00	00	00	00	20.00	30.50^{a}	00	00
Dinurado	69.00^{a}	57.00^{a}	00	66.00	00	00	00	00	20.00	32.00^{a}	00	00
P-Value	0.0000	0.0000	-	0.0205	-	-	-	-	0.4449	0.0013	-	-
C.V. (%)	6.96	5.70	-	8.35	-	-	-	-	2.22	6.71	-	-

SBSI: Stem borer severity infestation 30 and 70 days after sowing; RBSI: Rice bug severity infestation 30 and 70 days after sowing; BBSI: Black bug severity infestation 30 and 70 days after sowing; PHSI: Plant hopper severity infestation 30 and 70 days after sowing; FSSI: False smut severity infestation 30 and 70 days after sowing; Rice blast severity infestation 30 and 70 days after sowing.

Disease damage rating scale (Burks and Brandi, 2005).

1-20%: No damage.

21-40%: Slightly damaged.

41-60%: Extensively damaged.

61-80%: Severely damaged.

81-100%: Completely damaged.

Romelietes (64.50%) and Dinurado (66.00%) were extensively damaged. Thailand recorded the lowest severity (62.00%), though still within the extensively damaged category. Significant differences (p = 0.0205) highlight variation in tolerance across genotypes during later stages.

No infestation from black bug and planthopper was observed at either stage, suggesting minimal field presence or high tolerance of the evaluated genotypes. Overall, Dinurado and Black Rice were the most susceptible, particularly to stem borer and rice bug, whereas Thailand consistently showed lower pest severity. Romelietes and Dampuan, despite high yield potential, displayed moderate susceptibility to rice bug at maturity.

Disease response was assessed for false smut (FSSI) and rice blast (RBlastSI) (Table 3). At 30 DAS, no significant variation in FSSI was recorded (p = 0.4449), with all genotypes showing uniform 20.00% severity, classified as no damage. This suggests early-stage resistance or low infection pressure during vegetative growth. By 70 DAS, however, significant differences (p = 0.0013) were observed. Dinurado (32.00%) and Dampuan (30.50%) recorded the highest severity, classified as slight damage. Romelietes (21.00%) and Thailand (22.50%) remained close to the no-damage threshold, indicating better tolerance. Black Rice showed an intermediate response (27.50%), with no statistical difference from either extreme.

No symptoms of rice blast were observed across genotypes at both growth stages, indicating uniform resistance or absence of conducive environmental conditions. This suggests that under the USeP Mabini agro-climatic conditions, the evaluated genotypes exhibit broad tolerance to blast.

Taken together, false smut emerged as the more critical disease concern in the dry season. While absent at early growth, differences at 70 DAS identified Dinurado and Dampuan as more susceptible, whereas Romelietes and Thailand showed better resistance. False smut is recognized as an emerging global rice disease, with significant outbreaks reported in the Philippines and Asia (Adhikari, 2024; Gbadenya, 2024). Integrating resistance to this disease into heirloom rice breeding programs is therefore crucial.

Overall, heirloom rice responses to insect pests and diseases were strongly influenced by environmental conditions, underscoring the importance of adaptability trials to ensure high-quality and efficient production (Najeeb *et al.*, 2018).

Economic viability

The data in Table 4 highlighted the economic performance of heirloom rice genotypes under USeP Mabini conditions. Among the five varieties, Thailand proved the most profitable, with a Potential Gross Income (PGI) of PHP 80,416.28, Net Profit (NP) of PHP 31,976.28 and a Return on Investment (ROI) of 66.01%. This strong financial return identifies Thailand as the most viable option for farmers seeking profitability in aerobic rice systems.

Romelietes also showed favorable results, recording a PGI of PHP 64,820.44, NP of PHP 16,380.44 and ROI of 33.81%. Although lower than Thailand, it still provides substantial returns, making it another suitable choice. In contrast, Black Rice and Dampuan achieved only marginal profitability, with ROIs of 10.36% and 4.45%, respectively. Black Rice's NP reached PHP 5,020.05, while Dampuan earned just PHP 2,157.93, suggesting that large-scale adoption would require either cost reduction or price incentives to improve competitiveness.

Dinurado performed the poorest, incurring a negative NP of PHP -10,873.41 and an ROI of -22.44%, meaning production costs outweighed income. This makes Dinurado economically unsuitable under the current conditions.

Thailand and Romelietes present the best prospects for profitable heirloom rice production, while the other varieties require further support through breeding or input optimization.

Genetic diversity analysis

The dendrogram revealed two major diversity clusters among the heirloom rice genotypes (Fig 1). The closest cluster grouped Thailand and Romelietes, reflecting strong morphological and agronomic similarity. Both displayed moderately high plant height, similar growth duration, high yields (3.49 and 3.56 t/ha) and comparable resistance to stem borer and rice bug, suggesting shared ancestry or genetic makeup. Dampuan clustered next with this group, showing moderate similarity. While it had similar plant stature and tiller number, Dampuan differed in flowering time, produced the highest grains per panicle and had slightly lower yield, indicating potential value for complementing traits in breeding.

Table 4: Economic viability of heirloom rice genotypes grown under USeP mabini, mabani, davao de oro agro-climatic conditions.

Variety	TPC (PHP)	PGI (PHP)	NP (PHP)	RPC (%)
Thailand	48,440.00	80,416.28	31,976.28	66.01
Black rice	48,440.00	53,460.05	5,020.05	10.36
Romelietes	48,440.00	64,820.44	16,380.44	33.81
Dampuan	48,440.00	50,597.93	2,157.93	4.45
Dinurado	48,440.00	37,566.59	-10,873.41	-22.44

TPC: Total production cost; PGI: Potential gross income; NP: Net profit; ROI: Return on investment; PHP: Philippine peso.

Market prevailing price- PhP 23.00.

In contrast, Black Rice and Dinurado appeared as the most divergent. Black Rice was separated due to lower yield, smaller plant height and higher pest susceptibility, particularly to the stem borer. Dinurado was the most distantly clustered, with longer germination and flowering, the highest productive tillers, but the lowest yield, highlighting its uniqueness.

The cluster analysis confirmed significant genetic diversity based on phenology, yield and pest resistance. These differences support strategic parent selection, where crosses between genetically distant lines such as Dinurado × Thailand or Black Rice × Romelietes could maximize heterosis. This finding concurs with Rauf *et al*. (2010), emphasizing the importance of conserving and improving heirloom rice germplasm.

Correlation analysis of agronomic traits to yield

The correlation analysis of agronomic traits with yield is presented in Table 5. Results revealed that among the evaluated traits, the percentage of filled grains per panicle exhibited a very strong positive correlation with yield (r = 0.98). This finding clearly indicates that the percent filled grains is the most critical determinant of yield performance among the studied traits. Genotypes with a higher proportion of well-filled grains consistently produced greater yields, highlighting the importance of reproductive efficiency in rice productivity. This observation is consistent with the reports of Salunkhe *et al*. (2024), who also identified a positive direct effect of filled grains on yield per plant. On the other hand, the study of Sujata *et al*. (2021) that grain yield had a significant and positive association with the total number of tillers per plant, number of productive tillers per plant, test weight, panicle length and panicle fertility. These results underscore the need to prioritize this trait in both breeding programs and crop management strategies to maximize yield potential.

Plant height at 70 DAS showed a moderate positive correlation with yield (r = 0.49), suggesting that taller plants may contribute indirectly to yield through improved biomass accumulation or enhanced panicle support. Although not a strong predictor alone, moderate plant height may complement other yield-related traits, especially when combined with reproductive efficiency. Similarly, the number of grains per panicle showed a weak positive correlation with yield (r = 0.17). While traditionally considered a yield component, its limited influence here suggests that grain

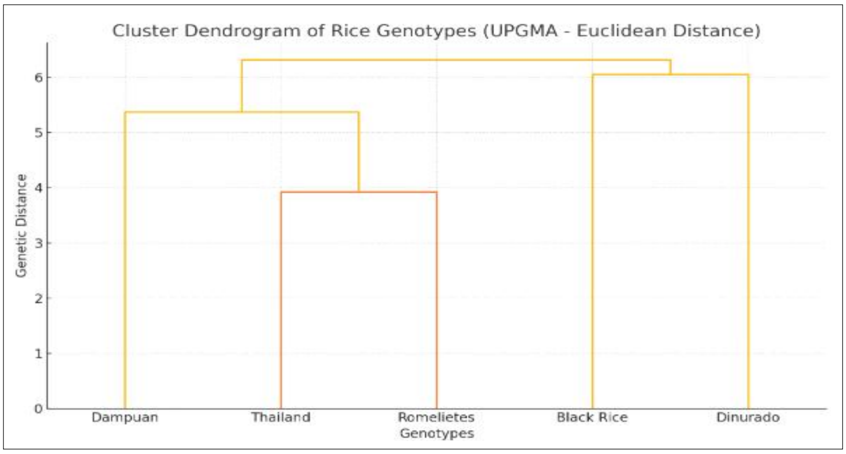

Fig 1: Cluster dendrogram generated using UPGMA (average linkage clustering) and euclidean distance based on the standardized 14 agronomic and morphological traits of five heirloom rice genotypes grown under USeP mabini, mabani, davao de Oro agro-climatic conditions.

Table 5: Correlation analysis of agronomic traits to yield.

	Correlated traits	Coefficient of correlation (R)	Strength of correlation
Yield	Percent filled grains	+0.98	Very strong correlation
	Plant height at 70 DAS	+0.49	Moderate correlation
	Grains per panicle	+0.17	Weak correlation
	Days to maturity	+0.03	Negligible correlation
	Days to flowering	-0.09	Negligible correlation
	Plant height at 30 DAS	-0.13	Weak correlation
	Number of productive tillers	-0.37	Moderate correlation
	1000 seed weight	-0.53	Moderate correlation
	Number of tillers	-0.62	Moderate correlation
	Days of germination	-0.63	Moderate correlation

Table 6: Regression analysis on predicting yield from key agronomic traits.

Predictor	Coefficient (B)	Interpretation
Per cent filled grains per panicle	+0.0710	For every 1% increase in filled grains, yield increases by 0.071 t/ha (Holding other variables constant).
Plant height (70 DAS)	+0.0410	Slight positive effect on yield, but not statistically significant.
Grains per panicle	-0.0011	Slight negative effect (possibly due to multicollinearity or indirect effects).
Intercept (Constant)	-6.46	Baseline yield when all predictors are zero (not meaningful alone).

number may not be a major constraint under the given conditions. These results align with findings by Salunkhe *et al.* (2024), who noted that plant height and panicle number positively contribute to grain yield.

Negative correlations were observed for several traits, implying reduced productivity when these traits increased. Days to germination (r = -0.63) and number of tillers (r = -0.62) were both strongly negatively correlated with yield. Similar results were reported by Xie *et al*. (2024), who showed that tiller regeneration rate negatively affected yield and Fuxian *et al*. (1997), who noted that sink size of the main crop inversely influenced ratoon rice tillering. These findings suggest that delayed emergence and excessive tillering may reduce resource use efficiency, crop uniformity and panicle development under aerobic conditions.

Additionally, 1000-seed weight displayed a moderate negative correlation with yield (r = -0.53), indicating a possible trade-off between grain weight and number due to assimilate partitioning. Productive tillers also showed a weak negative correlation (r = -0.37), suggesting that not all tillers effectively contribute to yield. Other traits, including plant height at 30 DAS, days to flowering and maturity, had negligible correlations (-0.13 to +0.03), confirming their limited direct influence. Overall, percent filled grains, plant height and grains per panicle remain the most crucial yield-associated traits.

Regression analysis of yield-determining traits

To determine which agronomic traits most significantly influence grain yield in heirloom rice genotypes, a multiple linear regression analysis was conducted using three predictor variables identified from prior correlation analysis: percent filled grains per panicle, plant height at 70 DAS and number of grains per panicle (Table 6). These traits were chosen for their agronomic relevance and observed positive correlations with yield, confirming earlier findings of Salunkhe *et al.* (2024).

Among the predictors, percent filled grains per panicle had the largest and most positive coefficient (β = 0.0710), indicating that each one-percentage-point increase in grain filling corresponded to an estimated 0.071 t/ha increase in yield, holding other factors constant. This highlights grain filling as the strongest determinant of yield, reflecting efficient pollination, nutrient availability and successful reproductive development. These results align with Sahu *et al*. (2021), who emphasized the role of grain filling in relation to inter-spikelet distance, particularly noting poor filling in compact panicles with numerous spikelets.

Plant height at 70 DAS exhibited a moderate positive effect (β = 0.0410), though not statistically significant. This suggests taller plants may slightly enhance biomass and light interception, but are secondary contributors compared to grain filling efficiency. Surprisingly, the number of grains per panicle showed a negative but non-significant coefficient (β = -0.0011), possibly due to collinearity with filled grain percentage or trade-offs between grain number and filling efficiency under resource-limited aerobic conditions.

Improving grain filling percentage presents the greatest potential for yield enhancement in heirloom rice cultivated under aerobic conditions in Mabini, while plant height and grain number play supportive but less decisive roles.

CONCLUSION

The Dampuan genotype exhibited the highest early plant vigor, while Romelietes and Thailand achieved the highest grain yields at 3.56 and 3.49 t/ha, respectively. In contrast, Dinurado showed the longest crop duration and lowest yield, underscoring the need to align maturity and grain development with upland aerobic conditions. Clustering analysis revealed Thailand and Romelietes shared similar agronomic traits, while Dinurado and Black Rice were genetically distinct. Percent filled grains per panicle (r = 0.98) was the strongest yield determinant, supported moderately by plant height. Thailand and Romelietes proved most desirable, combining high yield, efficient grain filling and strong profitability.

ACKNOWLEDGEMENT

The authors would like to thank the University of Southeastern Philippines (USeP) for supporting their research endeavors.

Conflict of interest

The authors declare that the research was conducted without any commercial or financial relationships that could potentially create a conflict of interest.

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