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Original Article

Physical characteristics and the relationship between genetic diversity, phenotypic diversity, heritability test and morphological character in several varieties of lowland rice (*Oryza sativa* L.)

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Abstract

Plant characteristics, genetic diversity, and heritability are some of the factors that influence rice growth and production. This study aims to determine the physical characteristics and the relationship between genotype variants, heritability tests, and genetic progress that can contribute to rice production in lowland irrigated rice fields. This study was conducted from October 2022 to March 2023 in North Buton Regency, Southeast Sulawesi. The design used in this study was a Randomized Block Design with 7 varieties and 3 replications. The research data were analyzed based on the procedures of variance, genetic variance, heritability, agromorphological characteristics, partial correlation, and cross tests. The results obtained showed that the highest plant height characteristics were found in Ciherang (110 cm), the highest plant age was found in Ciherang (120 days). The characteristics of the 7 varieties tested, lodging properties, 57.14% were somewhat resistant to lodging and 42.86% were resistant to lodging. Pest resistance properties, tungro resistance (8.04%), resistance to brown planthopper (57.14%), and resistance to leaf blight (85.71%). Furthermore, regarding the correlation relationship, dry grain yield is positively correlated with the number of productive tillers, plant height, panicle length, grain weight, number of empty grains, full grains, and weight per 1000 grains. The genetic variation values of plant height, number of panicles, grain weight, and weight per 1000 grains are higher in the Inpari-7, Inpari-11, Inpari-13, Inpari-14, Inpari-15, Inpari-20 varieties. The highest dry grain yield is found in Inpari-13, Inpari-15, and Inpari-20 compared to Ciherang.

Keywords: Rice variety, Low land rice, Characteristics, Genetic diversity, Heritability, Grain yield

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Introduction

Rice is a very important commodity in supporting the availability of food, animal feed, and industrial raw materials. The increase in population in every year highlights the importance of the availability of food ingredients such as rice to meet the food needs of the community. According to Susanto et al. (2015), the population growth rate of 1.9%, and the rate of rice consumption increasing by 1.34% per year resulting in a sharp increase in national rice demand. To meet the need for rice, efforts are needed to develop superior varieties that have high production (Dar et al., 2018).
Several superior varieties of irrigated rice fields that have high grain yields and have different physical characteristics such as the Inpari-7, Inpari-11, Inpari-13, Inpari-14, Inpari-15, Inpari-20 varieties (Center for Food Crop Research and Development, 2016). According to Mazid et al. (2013), genetically it can increase the diversity of traits, clarity of differences in relationships between varieties based on morphological characteristics. Selection of superior genotypes is determined qualitatively and quantitatively (Bustos et al., 2016). The influence of multigenes is shown through the action of different genes: additive, dominant, epistatic, or overdominant (Laidig et al., 2017).
In self-pollinating rice plants, population improvement is based on additive gene action. According to (Liu et al., 2019), gene expression is lower than in shoots at the differentiation stage. The effect of additive genes plays an important role at the level of variance as additive genes and variance are related to non-additive genes contained in gene combinations (Sowmiya et al., 2023; Vadodariya et al., 2023). According to (Chaudhary et al., 2023; Pallavi et al., 2022; Shrigovind et al., 2024), additive and non-additive gene action and environmental factors can control the expression of rice genotype traits.
The relationship between genotype variance, heritability test with Inpari rice production is very complex because many additive genes and environmental influences control it. This study aims to determine the physical characteristics of several varieties and the relationship between genotypic variance, phenotypic variance, heritability test and genetic progress that can contribute to increasing irrigated rice production.

Material and Methods

Research location and time of research implementation

This research was conducted in Wa Ode Angkalo Village, Bone Gunu District, North Buton Regency, Southeast Sulawesi, Indonesia from October 2022 to March 2023. This research tested genetic variability, heritability, and genetic progress in 6 irrigated rice varieties (Inpari) and 1 non-Inpari variety (Ciherang). The research location is classified as a nutrient requirement condition of 300 kg Urea equivalent to 135 kg N per hectare, 150 kg SP-36 equivalent to 54 kg P per hectare and 75 kg KCl equivalent to 45 kg K per hectare (Husnain et al., 2020) and is grouped into dry land and dry climate with ultisol soil type. This research applied a Randomized Block Design (RBD) consisting of 7 varieties as experimental treatments 6 replications. The rice varieties tested included Inpari-7, Inpari-11, Inpari-13, Inpari-14, Inpari-15, Inpari-20, and the Ciherang variety as a comparison. These rice varieties were planted in a 20 m x 15 m plot using the legowo row planting model and a planting distance of 20 cm x 10 cm with 2 stems per hill. Rice seedlings were planted at 20 days after scattering. This is consistent with the findings of Singh et al. (2017), which stated that the most optimal age for rice seedlings to be transplanted for planting is 20 days after scattering. Weeding of rice was carried out twice, the first time at 21 days after planting (DAT) and the second time at 35-40 days after planting, and adjusted to the condition of weed development. The fertilizer dosage was established according the analysis findings from the paddy field soil test tool (PUTS), namely 300 kg ha-1 of urea, 150 kg ha-1 of SP-36, and 75 kg ha-1 of KCl, with a soil pH of 6.0. Nitrogen, phosphorus, and potassium (NPK) fertilization was carried out three times at a dose of 135:54:45 kg per hectare (Kumar et al., 2021).

Observed parameters

Observed parameters: plant height (cm), number of tillers per hill, panicle length (cm), number of panicles per hill, number of filled grains per hill, number of empty grains per hill, grain weight per hill (g), grain weight per hill (g), weight of 1000 grains (g), harvested dry grain yield and milled dry grain yield. Rice is harvested at physiological maturity or when the panicle turns 85-90% yellow with a serrated sickle at a height of 10 cm from the soil surface with a dry

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harvested grain moisture content of 21-26%, with a serrated sickle at a height of 10 cm from the soil surface (Azimi et al., 2018).

Data analysis

Statistical data analysis was carried out based on the Anova procedure (Tang and Zhang, 2013), genetic diversity analysis was carried out according to Friesen et al. (2016). Morphological characteristic analysis was carried out according to Azimi et al. (2018), correlation coefficient analysis and path analysis were carried out according to Seyoum et al. (2012). Correlation analysis between Y and X1, X2, X3, X4, X5, X6, X7, X8, X9, X10 in this case the expression of genes that can control the characteristics of the lowest or minor genes was carried out (Liu et al., 2019). Genetic diversity analysis was carried out according to Masuka et al. (2017). Analysis of the correlation relationship between grain yield and yield components was carried out using path analysis (Kiruthikadevi et al., 2020). Correlation analysis between Y and X1, X2, X3, X4, X5, X6, X7, X8, X9, X10:

Y = dried unhusked rice
X_1 = dried unhulled rice
X_2 = weight of 1000 grain
X_3 = weight of grain per clump
X_4 = weight of grain per tiller
X_5 = empty grain
X_6 = filled grain
X_7 = number of panicles
X_8 = length of panicles
X_9 = plant height
X_{10} = number of tillers

Analysis of genetic variance and heritability of VUB for Inpari 7, Inpari 11, Inpari 13, Inpari 14, Inpari 15, Inpari 20, and Ciherang rice in Southeast Sulawesi, Indonesia, is presented in Table 1.

Table-1. Analysis of genetic variance and heritability of Inpari rice varieties 7, Inpari 11, Inpari 13, Inpari 14, Inpari 15, Inpari 20, and Ciherang in Southeast Sulawesi, Indonesia.

Variance Sources (VS)	Degree of Freedom (DB)	Number of Squares (JK)	Mean Squares (KT)	Expectation of KT
Groups	3-1	JKk	KTk (M_3)	$\sigma^2e + 4\sigma^2k$
Genotypic	4-1	JKg	KTg (M_2)	$\sigma^2e + 3\sigma^2g$
Error	(3-1) (4-1)	JKe	KTe (M_1)	σ^2e

The error variance (σ^2e) = M_1, while $M_2 = \sigma^2e + 3\sigma^2g$, then the genetic variance becomes $\sigma^2g = \frac{M_1 - \delta^2{}_e}{3} = \frac{M_2 - M_1}{3}$. The phenotypic variance (σ^2p) = $\sigma^2g + \sigma^2e$ and each genotype was repeated four times, then the phenotype variance became $\sigma^2p = \delta^2 g + \frac{\delta^2 e}{3}$, so the heritability calculation became: $h^2 = \frac{\delta^2 g}{\delta^2 p} = \frac{\delta^2 g}{\delta^2 g + \frac{1}{3}\delta^2 e}$.

The closeness of the relationship between characteristics using Pearson correlation analysis and trajectory analysis based on simultaneous equations (Azimi et al., 2018), using the formula: $\underline{C} = Rx^{-1}Ry$. The data obtained were analyzed using diallelic cross-analysis based on the Griffing Method-1 approach. The estimated heritability value (h^2) was used to estimate genetic progress. The population change means (ΔG) due to selection is calculated according to the formula (Ruan et al., 2017): $\Delta G = k\sigma_p h^2$, where k = standard selection differential and σ_p = phenotypic standard deviation.

Results and Discussion

Physical characteristics of several varieties of rice for irrigated rice fields

The characteristics of long grain shape are found in the Inpari-7 variety, while the long, slender grain shape is found in the Inpari-13 and Ciherang varieties, the slender grain shape is found in the Inpari-11, Inpari-14, Inpari-15, and Inpari-20 varieties. This is in accordance with Sutrisna et al. (2015), the shape of Inpari-7 grain is long, Ciherang and Inpari-13 are long, while Inpari-11, Inpari-14, Inpari-15, and Inpari-20 have a slender grain shape. Varietal characteristics regarding resistance to pests and diseases, from 7 varieties tested in the field showed different responses. Inpari-7 variety is resistant to blight and tungro disease, Inpari-11 variety is resistant to blight disease

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only, Inpari-13 is resistant to brown planthopper and blast disease, Inpari-14 is resistant to leaf blight and blast disease, Inpari-20 is resistant to brown planthopper and leaf blight disease and Ciherang variety is resistant to brown planthopper and leaf blight disease. The results of (Amalia et al., 2019), research showed that the brown planthopper population in Inpari-13 variety was lower (6.06 individuals per m2) than in Ciherang variety (12.44 individuals per m^2).

Table-2. Physical characteristics of several varieties of irrigated rice in Indonesia.

Variety	Plant height (cm)	Plant age (days)	The nature of lying down	Grain shape	Nature of hair loss	Average seed yield (t ha^{-1})	Potential seed yield (t ha^{-1})	Resilience properties
INPARI-7	104	110	MODERATE	Long	MODERATE	6.23	8.7	Resistant to leaf blight and tungro disease
INPARI-11	106	105	MODERATE	Slim	MODERATE	6.5	8.8	Resistant to leaf blight disease
INPARI-13	102	99	MODERATE	Long and slender	MODERATE	6.6	8.0	Resistant to brown planthoppers and blast disease
INPARI-14	103	113	RESISTANT	Slim	MODERATE	6.6	8.2	Resistant to leaf blight and blast diseases
INPARI-15	105	117	RESISTANT	Slim	MODERATE	6.1	7.5	Resistant to brown planthoppers and leaf blight.
INPARI-20	102	104	RESISTANT	Slim	SUSCEPTIB LE	8.8	8.8	Resistant to brown planthoppers and leaf blight.
CIHERANG	110	120	MODERATE	Long and slender	MODERATE	5.5	6.0	Resistant to brown planthoppers and leaf blight

Source: Center for Food Crop Research and Development (2016).

The tallest plant height characteristics were observed in the Ciherang variety (110 cm) and the lowest in Inpari-13 (102 cm) and Inpari-20 (102 cm) (Table 2). This is in accordance with the growth performance of the Ciherang variety (Fig. 1a) during the vegetative phase. The plant height of the Ciherang variety is higher than the results of research found by (Meliawati et al., 2023), which is around 80-100 cm. Furthermore (Listanto and Riyanti, 2016), found that the height of Ciherang rice plants at the age of 42 days after planting ranged from 82.17 cm to 89.17 cm.

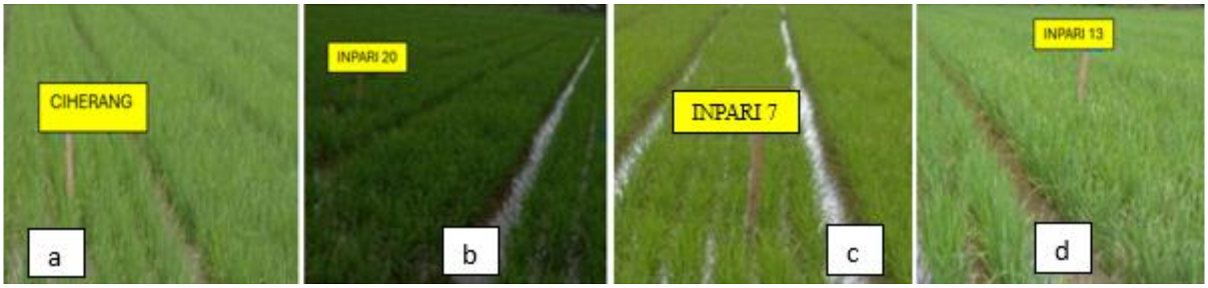

Figure-1. Appearance of 4 rice varieties in the vegetative phase from 7 varieties tested in the field.

The highest or longest plant age was in the Ciherang variety (120 days) and the lowest or shortest in the Inpari-13 variety (99 days), the characteristics of the lodging properties generally have a slightly resistant to lodging 57.14% and 42.86% resistant to lodging. The shedding properties, only 1 variety has the property of easily falling (14.29%) and 6 varieties (85.71%) have the property of being resistant to falling. The grain shape in general has a slender grain shape (57.14%), a long slender grain shape 28.57% and a long grain shape 14.29%. The lowest average grain yield was found in the Ciherang variety (5.50 t ha-1) and was lower than the Inpari-20, Inpari-13, Inpari-14, Inpari-15, and Inpari-17 varieties (Table 1). This is supported by the performance of rice varieties in the generative phase (Figure 2). According to Khasanah et al. (2025), the seed yield of the Ciherang variety was lower (5.0 t ha-1) than Inpari-32 (6.0 t ha-1).

The physical characteristics of Inpari-7, Inpari-11, Inpari-13, Inpari-14, Inpari-15, Inpari-20, and Ciherang that have been tested in the field (Table 3) show that the highest number of tillers was found in the Inpari-20 (23.33) and Inpari-13 (20.40) varieties. This is supported by the performance of Inpari-20 and Inpari-13 which is quite good (Figures 2b and 2d) compared to the Ciherang variety (Figure 2a).

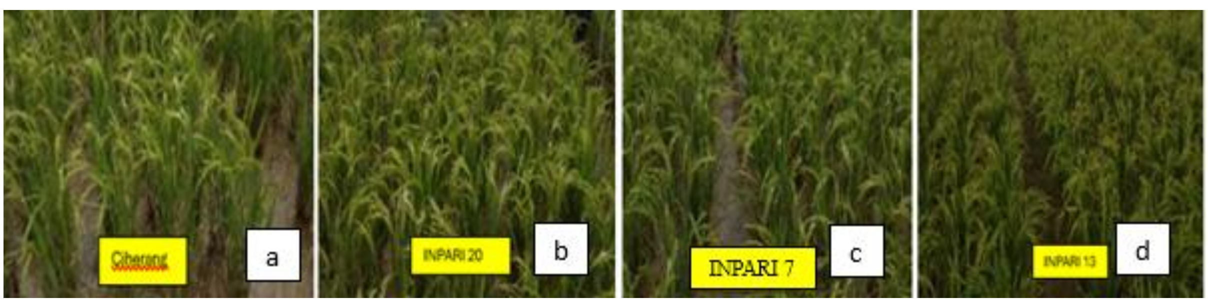

Figure-2. Appearance of Inpari 20, Inpari-15, and Inpari-13 varieties which have the highest grain yield and 1 control variety (Ciherang) in the generative phase.

The highest panicle length characteristic was found in Inpari-13 (20.27 cm) and the lowest in Inpari-7 (16.87 cm). While the lowest number of panicles was found in Inpari-15 variety (9.27) and the lowest number of grains per panicle was in Inpari-7 (41.80 seeds). The lowest number of empty grains was found in Inpari-7, while the weight of grains per panicle did not show any significant difference. The highest weight of grains per hill was found in Inpari-20 variety (60.34 g) and in the Inpari-20 variety, the highest 1000-grain weight was found at 23.32 g. The highest dry grain yield was found in Inpari-13 (5.49 t ha-1) and Ciherang (4.87 t ha^{-1}) was the lowest yielding variety, likewise the lowest dry grain yield was found in Ciherang variety (3.02 t ha-1) (Table 3). This is according to Chairum (2013), the dry grain yield of Inpari-13 harvest is higher (7.90 t ha-1) compared to Ciherang (6.10 t ha-1).

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Table-3. Physical characteristics of inpari-7, inpari-11, inpari-13, inpari-14, inpari-15, inpari-20 and ciherang which have been tested in the field.

	Agronomic Characteristics										
Variety	**Number of tillers**	**Plant height (cm)**	**Length of panicle (cm)**	**Number of panicles**	**Number of filled grains**	**Number of empty grains**	**Grain weight per panicle (g)**	**Weight of grain per clump (g)**	**Weight of 1000 seeds (g)**	**Seed yield of dry harvest ed grain (t ha^{-1})**	**Seed yield of dry milled rice (t ha^{-1})**
Ciherang (control)	15.87b	85.27c	19.13b	18.40b	59.80c	9.86b	2.68 Ns	43.10b	19.97b	4.87a	3.02a
Inpari -7	16.47b	73.80a	16.87a	16.47b	41.80a	2.87a	2.52 Ns	41.50b	21.76b	5.16b	3.36c
Inpari -11	14.33b	86.93c	18.40b	14.33b	53.87b	5.27b	2.59 Ns	36.89a	19.34a	5.18b	3.36c
Inpari -13	20.40c	70.87a	20.27c	19.73b	63.87c	16.87c	2.70 Ns	54.39b	22.91b	5.49c	3.51c
Inpari -14	17.40b	71.40a	18.20b	17.40b	48.80b	4.00b	2.45 Ns	42.67b	20.81b	5.12b	3.06b
Inpari -15	9.40a	81.60b	19.20b	9.27a	59.20c	10.07b	2.69 Ns	38.83b	22.03b	5.10b	3.17b
Inpari -20	23.33c	75.13b	19.33b	23.33b	49.87b	3.20b	2.57 Ns	60.34c	23.32c	5.04b	3.14b

The numbers followed by the same letter in the same column were not significantly different according to Duncan's test at the 0.05 level.

Partial correlation of some characteristics of inpari rice genotypes

The results of the partial correlation analysis between genotype characteristics showed very significant positive values, except for the parameters of grain weight per panicle (varieties Inpari 11, Inpari 15, Inpari 20 and Ciherang), 1000-grain weight (Inpari 14 and Ciherang), and dry harvest production (Inpari 11, Inpari 14 and Ciherang) (Table 4). If the value of the characteristics of the Inpari rice genotype increases, its production will also increase. By increasing the number of tillers, grain filling, panicles, and the weight of 1,000 grains, rice production can be improved. The high correlation between various characters and production characters can be important information for rice plant beginners and the government as well as for other stakeholders in rice variety development programs at the farmer level. According to Billa et al. (2024), “there is a positive and significant correlation between grain yield per plant with the number of productive tillers per plant, 1000-grain weight, panicle length, and the number of filled grains per panicle”. Furthermore, (Talekar et al., 2022), “stated that dry grain yield in rice lines is positively correlated with panicle length and 1000 grain weight.”

The correlation analysis between the superior rice variety Inpari and Ciherang indicates a close relationship among these traits. The closer the level of closeness of the relationship, the better the characteristics of the Inpari rice genotype tested. The relationship of several characters of Inpari-7, Inpari-11, Inpari-13, Inpari-14, Inpari-15 and Inpari-20 rice has a very significant positive correlation with panicle length, number of panicles, grain content, grain weight per panicle, grain weight per clump with dry harvest production. According to Sahithi et al. (2023), “the highest genetic progress as a percentage of the average was observed in plant height, number of productive tillers per plant, number of grains per panicle, biological yield per plant, test weight, number of grains per panicle, and harvest index.” The genetic characters of Inpari rice tested experienced an increase during the development period and showed a close relationship with the Ciherang rice variety. According to Susanto et al. (2015), agronomic characters can differentiate several varieties that cannot be distinguished based on their morphological characters. Therefore, correlation between different genotypes is needed to be able to know that these characters can be used as a selection guide for plants that have high productivity (Saito et al., 2018). The results of the partial correlation analysis between the genotype characteristics of the rice varieties Inpari-7, Inpari-11, Inpari-13, Inpari-14, Inpari-15, Inpari-20 and Ciherang showed a significant to very significant effect (Table 4).

Table-4. Partial correlation between genotype characteristics of Inpari rice varieties Inpari 7, Inpari 11, Inpari 13, Inpari 14, Inpari 15, Inpari 20 and Ciherang.

Genotypic Character	Partial correlation between genotype characters of rice varieties						
	Inpari 7	Inpari 11	Inpari 13	Inpari 14	Inpari 15	Inpari 20	Ciherang
Number of tillers	0.81*	0.67*	0.85*	0.71*	1.00**	1.00**	0.81*
Plant height	0.51*	0.62*	0.87*	0.74*	0.99*	0.68*	0.68*
Length of panicle	0.81*	0.81*	0.68*	0.81*	0.87*	0.87*	0.97*
Number of panicles	0.67*	0.86*	0.60*	0.71*	1.00**	1.00**	0.71*
Productive grain	0.87*	0.62*	1.00**	0.78*	0.76*	0.78*	1.00**
Empty grain	0.95*	0.67*	0.69*	0.67*	0.94*	0.79*	0.91*
Grain weight/tillers (g)	0.91*	0.43^{tn}	0.64*	0.55*	0.43^{tn}	0.34^{tn}	0.44^{tn}
Grain weight/clump (g)	0.82*	0.68*	0.87*	0.58*	0.78*	0.87*	0.81*
Weight of 1000 seeds (g)	0.68*	0.68*	0.79*	0.43^{tn}	0.86*	0.79*	0.46^{tn}
Harvest dry production (ton)	0.85*	0.50^{tn}	0.67*	0.24^{tn}	0.72*	0.76*	0.48^{tn}
Milled dry production (ton)	0.67*	0.56*	0.55*	0.67*	0.72*	0.72*	0.99*

Notes: **: very significant P < 0,01, *: significant P < 0,05, and tn: insignificant.

Direct and indirect effects

Figure 3 shows that the contribution of each characteristic of the Inpari-7, Inpari-11, Inpari-13, Inpari-14, Inpari-15, and Inpari-20 varieties to the production of dry milled grain can be directly or indirectly related. This can be seen that the production of dry milled rice varieties Inpari-7, Inpari-11, Inpari-13, Inpari-14, Inpari-15, and Inpari-20 provides the most significant direct contribution to the production of dry harvested grain (0.72). Then, the weight of 1000 seeds (0.64), the weight of grain per hill (0.57), the weight of grain per panicle (0.78), empty grain (0.59), productive grain (-0.59), the number of panicles (0.75), panicle length (0.85), plant height (0.91), and the number of tillers (0.74). Furthermore, (Sumithra et al., 2019; Kiruthikadevi et al., 2020), the results of the study showed a direct influence between genotypes and a positive (significant) correlation on the characters of the number of tillers per plant, panicle length, number of grains per panicle, weight of 100 grains, and harvest index with grain yield per plant. Character traits such as the number of tillers per plant, the number of grains per panicle, the number of grains, and the L/B ratio of grain had a very high positive direct influence and at 50 percent flowering time showed a negative relationship to grain yield per plant (Sumithra et al., 2019). Furthermore, according to Williams et al. (2021), 29 - 48 rice genotypes tested showed high to moderate values and were positively correlated and had a direct effect on grain yield at the phenotypic level on fresh root weight per plant, number of productive tillers per plant, panicle length, and number of grains per panicle, percentage of harvest index, and weight of 1000 seeds while at the genotypic level on the number of panicles and plant height.

The characteristics of several grain yields of Inpari varieties that provide the smallest direct contribution are the weight of grain per hill (0.57), then empty grain (0.59) and filled grain (-0.59) (Figure 3). However, dry grain production and grain weight per tiller have a real and significant total effect, reaching 0.64 and 0.78, respectively, because dry harvest production has a relatively large indirect effect through the number of panicles (0.88). In contrast, filled grain has a relatively large indirect effect through dry harvest grain production (-0.64) and the number of panicles (-0.55). The results of the above analysis indicate that increasing Inpari rice yield can be demonstrated by selecting characteristics of 1000-seed weight, high grain weight per hill and number of tillers, and low empty grain (Saito et al., 2018), results reported that the number of seeds per panicle and the number of seeds contained in rice plants can provide a very large direct contribution to the harvest yield. Furthermore, (Saikumar et al., 2016), that the number of rice seeds per panicle is one of the important characteristics that affect the harvest yield. Testing 32 rice cultivars of phenotypic expression is very significant compared to the coefficient of genotypic variance for genetic progress in the number of tillers, the number of productive tillers, flag leaf width, grain weight per

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panicle, the number of grains per panicle, showing a direct positive relationship while the number of filled grains per panicle and plant height show a negative relationship with grain yield (Teja et al., 2023).

The effect of direct and indirect of several yield characteristics and morphoanatomy on the production of dry milled rice Inpari is presented in Figure 3.

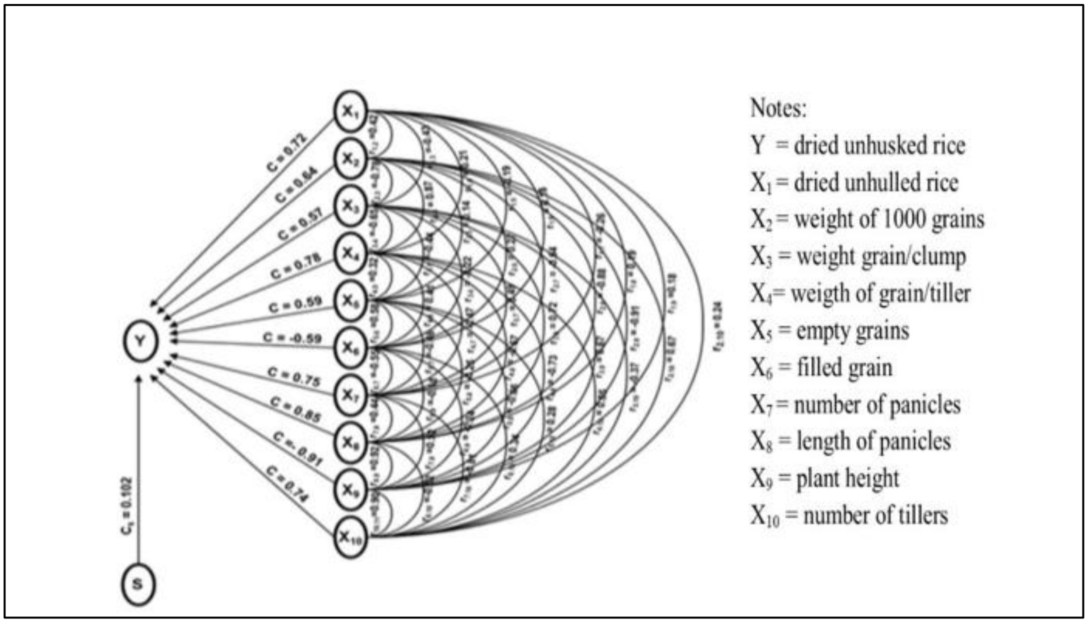

Figure-3. Trajectory of the causal relationship between (Y) fried unhusked rice and (X_1) dried unhulled rice, (X_2) weight of 1000 grains, (X_3) weight grain per clump, (X_4 weight of grain per tiller, (X_5) empty grains, (X_5) filed grain, (X_7) number of panicles, (X_8) length of panicles, (X_9 plant height, (X_{10}) number of tillers.

Genetic diversity and heritability

In Table 5, the analysis of the estimated number and type of gene action that can be used in selecting 11 evaluated quantitative characters shows significant differences among 7 rice genotypes with high coefficients of genotypic diversity and phenotypic diversity coefficients, closely related to the adaptability of the Inpari rice tested. Additive gene action is more dominant than non-additive gene action and was found to control the expression of traits of 45 rice genotypes consisting of 32 hybrids and 12 parents and as many as 13 characters showed significant differences (Vadodariya et al., 2023). The results of the study by Gupta et al. (2023), as many as 25 quantitative traits were evaluated showing significant differences among 48 rice genotypes with high coefficients of genotypic diversity and phenotypic diversity coefficients, in the number of productive tillers, the number of empty grains per panicle, and grain yield per panicle. Testing 25 rice genotypes in three different environments for 11 observed quantitative traits showed genetic character diversity results of 11.98 – 82.72% on grain yield per plant on the number of productive tillers per plant, plant height, panicle length and number of grains per panicle (Chaudhary et al., 2023). The results of research of Praveena et al. (2023), as many as 12 genetic characters quantitatively using 30 and 40 rice varieties showed very real and varied results. The results of the genotypic and phenotypic path coefficient analysis showed a high positive direct effect in testing 9 rice genotypes on the number of tillers, panicle length, number of grains, on rice grain yield, high heritability values in a broad sense and good stability (Abbas, 2024).

Heritability values ranged from 0.11 to 84.31% for Inpari rice varieties Inpari-7, Inpari-11, Inpari-13, Inpari-14, Inpari-15, Inpari-20, and Ciherang as a comparison. Genetic diversity was found in the number of tillers, number of panicles, grain weight per panicle, grain weight per hill, weight per 1000 seeds, dry harvest yield, and dry milling yield. In addition, this rice has moderate and low levels of genetic diversity and heritability (Table 5 and Table 6).

According to the research results of Praveena et al. (2023), moderate to high heritability values, coupled with high genetic progress, were found in fresh root weight per plant, dry root weight per plant, plant height, number of grains per panicle, shoot and root length, biological yield per plant, and grain yield per plant indicating additive gene action. Furthermore, Teja et al. (2023), for genetic progress, high heritability values were in grain weight per panicle and low heritability in the number of productive tillers. According to Mounika et al. (2024), showed "high estimated values of heritability and genetic progress, in the character traits of dry root weight per plant, plant height, number of productive tillers per plant, flag leaf length, number of filled grains per panicle, and grain yield per plant, and provided a high positive direct relationship effect, both at the genotypic and phenotypic levels". The selected Inpari rice variety has high heritability through genetic factors so that in conducting relationship selection, higher productivity can be obtained. The genetic diversity of Inpari rice has low to moderate heritability, but the results of linkage selection provide broad genetic progress. According to Cui et al. (2020), heritability is a measure that can describe the effectiveness of genotype selection based on phenotypic appearance. Complete genetic diversity results in effective selection of each characteristic and increases the genetic potential of the next generation (Ceccarelli, 2015). According to Sahithi et al. (2023), characteristics with high heritability values can acquire more dominant genetic factors or provide a more significant contribution than environmental factors. However, selection can begin in the first generation. The variability, heritability, and genetic progress of rice genotype variants show substantial differences in the number of filled grains per panicle, grain yield per plant and 1000 grain weight, and heritability in the broad sense shows moderate to low genetic progress (Pallavi et al., 2022). This occurs because, cross-breeding of selected genotypes, so that it can produce variability, as a result of segregation selection of superior traits to be achieved in the next generation.

Selection is a method of plant improvement to obtain adaptive advantages in specific areas where varieties can be tested. Heritability determines the character to predict the progress of selection related to genetic and environmental factors because it is the proportion of genetic diversity to its phenotypic variation. The results of the study showed that there were high estimates of heritability and genetic progress in the number of tillers, plant height, number of panicles, 1000 grain weight, and production of Inpari rice which were dominated and influenced by additive gene action. Several Inpari rice varieties were observed to show moderate to high levels of heritability, which means they have characters with a high level of selection progress and both for genetic and environmental factors. According to Ningombam et al. (2022) and Kujur et al. (2023), the results of analysis of variance showed very significant genotype variations in plant height, flag leaf length, number of empty grains per panicle, grain yield per plant, 1000-grain weight and proline content, with high estimates of phenotypic and genotypic heritability coefficients and resulted in genetic improvement. Testing 25 rice genotypes with low estimated heritability values in leaf area index, moderate in harvest index while high heritability values along with high genetic progress were obtained at 50% flowering, and grain yield per plant and dominated by additive gene action (Talekar et al., 2022; Chaudhary et al., 2023). High heritability values along with high genetic progress were obtained in days to 50% flowering in plant height, stem diameter, flag leaf length, panicle length, number of empty grains per plant, number of filled grains per panicle, 1000 grain weight, straw yield per plant, proline content, biological yield, harvest index and grain yield per plant which were influenced by additive gene action (Ningombam et al., 2022; Kujur et al., 2023; Vadodariya et al., 2023). The results of the study by (Shrigovind et al., 2024), revealed that 48 local rice genotypes in India produced high estimates of heritability and genetic progress.

Heritability values ranged from 0.11 to 84.31% for the rice varieties Inpari and Ciherang as a comparison. Genetic diversity was found in the number of tillers, number of panicles, grain weight per tiller, grain weight per hill, weight per 1000 seeds, dry harvest yield, and dry milling yield. In addition, this rice had moderate to low levels of genetic diversity and heritability (Table 5). According to the research results of Praveena et al. (2023), moderate to high heritability values, coupled with high genetic progress, were found in fresh root weight per plant, dry root weight per plant, plant height, number of grains per panicle, shoot and root length, biological yield per plant, and grain yield per plant, indicating the presence of additive gene action. Furthermore, Teja et al. (2023), for genetic progress, the heritability value is high in grain weight per panicle and low in the number of productive tillers. According to Mounika et al. (2024), shows the estimated value of heritability and high genetic progress, in the character traits of dry root weight per plant, plant height, number of productive tillers per plant, flag leaf length, number of filled grains per panicle, and grain yield per plant, and provides a high positive direct relationship effect, both at the genotypic and phenotypic levels.

Table-5. Diversity of genetic characteristics and heritability of Inpari rice varieties Inpari 7, Inpari 11, Inpari 13, 14, Inpari 15, Inpari 20 and Ciherang.

Varieties	Morphological Character					
	Number of tillers	Plant height	Length of panicle	Number of panicles	Number of productive grain	Number of empty grain
Inpari-7						
• DGC (%)	1.33	4.22	1.67	5.72	14.74	0.73
• H^2 (%)	3.69*	10.81*	27.32*	25.22*	14.46*	10.73*
Inpari-11						
• DGC (%)	1.11	1.42	0.52	0.62	20.65	0.82
• H^2 (%)	13.81*	12.42*	4.18*	5.62*	17.08*	21.43*
Inpari-13						
• DGC (%)	13.81	12.42	4.18	5.62	17.08	21.43
• H^2 (%)	20.37*	4.98*	47.69*	8.48*	35.21*	2.92*
Inpari-14						
• DGC (%)	8.31	5.43	0.15	3.87	21.92	0.82
• H^2 (%)	82.74*	30.02*	5.14*	69.05*	41.87*	2.44*
Inpari-15						
• DGC (%)	16.78	10.00	1.45	1.47	21.46	3.86
• H^2 (%)	50.49*	14.76*	34.39*	12.78*	18.60	7.11*
Inpari-20						
• DGC (%)	8.31	5.43	0.15	3.87	21.92	0.82
• H^2 (%)	82.74***	30.02**	5.14	69.05***	41.87**	2.44*
Ciherang						
• DGC (%)	16.78	20.00	1.45	1.47	11.46	3.86
• H^2 (%)	50.49***	14.76*	34.39**	12.78*	18.60	7.11*

Notes: *: low, **: middle and ***: high.

The selected Inpari rice variety has high heritability through genetic factors so that in conducting relationship selection, higher productivity can be obtained. The diversity of genetic characteristics of Inpari rice has low to moderate heritability, but the results of relationship selection provide extensive genetic progress. According to Cui et al. (2020) and Fan et al. (2017), heritability is a measuring tool that can describe the effectiveness of genotype selection based on phenotypic appearance. Complete genetic diversity results in effective selection of each characteristic and increases the genetic potential of the next generation (Ceccarelli, 2015). According to Sahithi et al. (2023), characteristics that have high heritability values can acquire more dominant genetic factors or provide a more significant contribution than environmental factors. However, selection can begin in the first generation. Variability, heritability, and genetic progress of rice genotype variants show substantial differences in the number of filled grains per panicle, 1.000 grain weight and grain yield per plant. Heritability in the broad sense shows moderate to low genetic progress (Pallavi et al., 2022). This occurs because cross-breeding of selected genotypes can produce variability, resulting from segregant selection of superior traits to be achieved in the next generation.

Table-6. Diversity of genetic characteristics and heritability of rice varieties Inpari- 7, Inpari- 11, Inpari- 13, Inpari -14, Inpari 15, Inpari -20 and Ciherang.

Varieties	Morphological Character				
	Grain weight per tillers (g)	**Grain weight per clump (g)**	**Weight of 1000 seeds (g)**	**Harvest dry production (t)**	**Milled dry production (t)**
Inpari-7					
• DGC (%)	0.5	23.93	7.25	0.41	0.90
• H^2 (%)	38.84**	11.52*	55.59**	21.15*	3.13*
Inpari-11					
• DGC (%)	0.15	38.77	3.62	0.38	0.24
• H^2 (%)	0.16*	12.97*	1.19*	0.50*	0.11*
Inpari-13					
• DGC (%)	0.16	12.97	1.19	0.50	0.11
• H^2 (%)	38.84*	84.31*	54.48*	39.62*	66.67***
Inpari-14					
• DGC (%)	0.30	13.24	0.63	0.32	0.21
• H^2 (%)	59.26***	24.18**	17.60*	17.23*	17.70*
Inpari-15					
• DGC (%)	0.11	25.33	6.32	0.65	0.44
• H^2 (%)	68.26***	39.86**	68.11***	54.93***	61.04***
Inpari-20					
• DGC (%)	0.30	13.24	0.63	0.32	0.21
• H^2 (%)	59.26***	24.18**	17.60*	17.23*	17.70*
Ciherang					
• DGC (%)	0.11	25.33	6.32	0.65	0.44
• H^2 (%)	68.26***	39.86**	68.11***	54.93***	61.04***

Notes: *: low, **: middle and ***: high.

Selection is a method of plant improvement to obtain adaptive advantages in specific areas where varieties can be tested. “Heritability determines the character to predict the progress of selection related to genetic and environmental factors because it is the proportion of genetic diversity to its phenotypic variation” (Ogunbayo et al., 2014). The results of the study showed that there were high estimates of heritability and genetic progress in the number of tillers, number of panicles, plant height, 1.000 grain weight, and Inpari rice production which were dominated and influenced by additive gene action. Several Inpari rice varieties were observed to show moderate to high levels of heritability, which means they have characters with a high level of selection progress and both for genetic and environmental factors. According to Ningombam et al. (2022); Kujur et al. (2023), the results of the analysis of variance showed very significant genotypic variations in plant height, flag leaf length, grain yield per plant, number of empty grains per panicle, 1.000 grain weight and proline content, with high estimates of phenotypic and genotypic heritability coefficients and resulted in genetic improvement. “Testing of 25 rice genotypes with low estimated heritability values in leaf area index, moderate in harvest index while high heritability values along with high genetic progress were obtained at 50% flowering, and grain yield per plant and dominated by additive gene action" (Talekar et al., 2022; Chaudhary et al., 2023). High heritability values along with high genetic progress were obtained in days to 50% flowering were obtained in plant height, stem diameter, flag leaf length, panicle length, number of empty grains per plant, number of filled grains per panicle, 1000 grain weight, proline content, straw yield per plant, biological yield, harvest index and grain yield per plant which were influenced by additive gene action (Ningombam et al., 2022; Kujur et al., 2023; Vadodariya et al., 2023). The results of the study by Shrigovind et al. (2024), revealed that 48 local rice genotypes in India produced high estimates of heritability and genetic progress.

The rice varieties Inpari showed high phenotypic diversity and environmental suitability, as seen in the characteristics of tiller number, plant height, filled grain number, and grain weight per hill weight (g) (Table 7). According to Muralidharan et al. (2019), genetic progress continues to develop well every year, and variety selection is very important to increase rice production.

Table-7. Diversity of phenotypic and environmental characteristics of rice varieties Inpari 7, Inpari 11, Inpari 13, Inpari 14, Inpari 15, Inpari 20 and Ciherang.

Varieties	Morphological Character					
	Number of tillers	**Plant height**	**Length of panicle**	**Number of panicles**	**Number of productive grain**	**Number of empty grain**
Inpari-7						
• DPC (%)	54.34	39.00	6.10	22.67	99.94	6.83
• L^2 (%)	50.48***	34.78**	4.43*	16.95*	87.20*	6.10*
Inpari-11						
• DPC (%)	6.24	7.40	4.03	7.27	71.08	24.10
• L^2 (%)	5.13*	5.98*	3.52*	6.65*	99.07***	23.28**
Inpari-13						
• DPC (%)	47.46	25.23	5.77	44.69	81.17	92.93
• L^2 (%)	37.79**	26.47**	3.02**	40.90*	76.33**	99.93***
Inpari-14						
• DPC (%)	10.04	18.10	2.92	5.60	52.36	33.53
• L^2 (%)	1.73*	23.53**	2.77	1.73*	30.43**	32.72**
Inpari-15						
• DPC (%)	33.23	67.73	4.22	11.52	61.67	54.34
• L^2 (%)	16.45**	57.73***	2.77*	10.05*	52.20***	50.48*
Inpari-20						
• DPC (%)	40.46	46.81	2.05	51.02	65.10	7.50
• L^2 (%)	27.30**	26.35**	1.17*	27.30*	30.85*	6.77*
Ciherang						
• DPC (%)	39.18	21.83	12.07	12.00	65.60	84.37
• L^2 (%)	25.37**	9.42*	7.88*	6.38*	48.52*	62.93*

Notes: *: low, **: middle and ***: high.

In Table 8, it shows that the coefficient of variation of the phenotypic and actual environmental coefficients ranges from 0.11-38.77%, and the highest is found in the characteristics of plant height, number of panicles, filled grain weight, grain weight per hill and 1000 grain weight which are dominated and influenced by adaptive gene action. Thus, 77% in all Inpari and Ciherang rice varieties. According to Shrigovind et al. (2024), a total of 44 genotypes tested had real mean square values for all traits with estimated phenotypic coefficient of variation exceeding the genotypic coefficient of variation, which showed a significant environmental influence on harvest age (93.46), plant height (92.38), 50% flowering age (90.55), grain yield per plant (85.05), number of grains per panicle (81.65), number of fertile grains per panicle (81.48), biological yield per plant (79.42), and 1000 grain weight (75.90).

Table-8. Diversity of phenotypic and environmental characteristics of rice varieties Inpari 7, Inpari 11, Inpari 13, Inpari 14, Inpari 15, Inpari 20 and Ciherang.

Varieties	Morphological Character				
	Grain weight per tillers (g)	**Grain weight per clump (g)**	**Weight of 1000 seeds (g)**	**Harvest dry production (t)**	**Milled dry production (t)**
Inpari-7					
• DPC (%)	0.12	20.84	13.05	0.10	0.09
• L^2 (%)	0.07*	83.81*	5.79*	0.08*	0.08*
Inpari-11					
• DPC (%)	0.18	87.84	11.90	0.09	0.05
• L^2 (%)	0.16*	49.07**	8.29*	0.05*	0.03**
Inpari-13					
• DPC (%)	006	28.42	9.16	0.08	0.09
• L^2 (%)	0.03*	20.16**	4.17*	0.05*	0.03*
Inpari-14					
• DPC (%)	0.16	54.75	3.59	0.19	0.12
• L^2 (%)	0.05*	41.51**	2.96*	0.15*	0.10*
Inpari-15					
• DPC (%)	0.22	38.47	9.28	0.12	0.07
• L^2 (%)	0.15*	23.13*	2.96*	0.05*	0.03*
Inpari-20					
• DPC (%)	0.12	58.53	3.18	0.08	0.06
• L^2 (%)	0.07*	54.07*	2.25*	0.06*	0.04*
Ciherang					
• DPC (%)	0.24	62.47	2.67	0.08	0.04
• L^2 (%)	0.18*	89.57***	1.48*	0.03**	0.02*

Notes: *: low, **: middle and ***: high.

Therefore, phenotypic selection of Inpari varieties can be a good approach to improve the quality of genetic traits to obtain genotypes that can be promising for future rice breeding programs.

Conclusions

Grain yield is influenced by physical characteristics such as the number of panicles per clump, the number of tillers per clump, the nymber of empty grains per clump, the number of grains per clump, and the weight of 1,000 grains.

The dry milled grain yield of the Inpari-7, Inpari-11, Inpari-13, and Inpari-20 varieties correlated significantly to highly significantly with the number of productive tillers per hill, the number of panicles per hill, the number of grains per panicle, the number of grains per hill, the number empty grains per hill, and weight of 1000 grains. The highest genetic variation values were found in the plant height, number of panicles, grain weight per hill, and weight per 1000 grains of Inpari rice varieties compared to Ciherang. Estimates of heritabilityadn genetic progress of Inpari-7, Inpari-11, Inpari-13, Inpari-14, Inpari-15, and Inpari-20 rice varieties showed high numbers of productive tillers per plant, number of panicles, number of grains per hill, weight of grain per hill, weight of 1,000 grains, dry harvest yield, and dry milled yield, caused by the dominance and influence of additive genes.

The highest dry harvest and dry milled grain yields were obtained by Inpari-20, Inpari-13, Inpari-7, and Inpari-11, rice varieties, and the lowest was Ciherang.

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