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Genetic Parameters of Yield Character and Yield Components of Pigmented Rice Genotype Grown in Gogo

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Abstract: Increased public interest in red rice and black rice has triggered breeders to develop superior varieties that have high yields and are tolerant of the threat of drought. Genetic parameters are the basis needed for breeding to develop superior varieties. This research aims to examine the genetic parameters of pigmented rice genotypes grown upland. The experiment was carried out in June – September 2024 experimentally in the field using a gogo system, namely in Tampak Siring Village, Batukliang, Central Lombok, NTB. The design used was a Randomized Block Design (RAK) with 21 treatments, 10 red rice lines, 4 black rice lines, 4 parent lines, and 2 comparison varieties. Obtained 63 experimental units by repeating each treatment three times. The data collected was then analyzed using a one-way Analysis of Variance (ANOVA) test with a Randomized Block Design (RAK) model at a confidence level of 95% (α=5%), genetic diversity coefficient (KKG) formula, heritability and genotypic correlation. Referring to the analysis that has been carried out, the findings of the coefficient of genetic diversity and heritability of the number of full grains, weight of 100 grains, yield per plot of red rice and black rice lines are in the high category. The number of productive tillers, weight of 100 grains and weight of grain per hill had a significant positive correlation with the yield per plot, while the number of empty grain parameters had a significant negative correlation with the yield per plot.

Keywords: Black rice; Genetic parameters; Genotype; Pigmented; Red rice.

Introduction

Pigmented rice is a type of rice plant that has pigments or colors. Red and black rice are two types of pigmented rice, and have the potential to be developed into healthy food sources. The advantages of pigmented rice are its high anthocyanin content, amino acids, protein and glucose at low levels (Agustin et al., 2021). The development of information technology has opened people's insights into the importance of consuming nutritious and health-beneficial foods, as a result, many people have started consuming black or red rice which is indeed the result of pigmentation (Kabeakan, 2019). However, the development of pigmented rice production, red and black rice has not been maximized, so far there have not been too many superior varieties of pigmented rice that have high yields and are tolerant to the threat of drought (Andri & Priantoro, 2020).

Efforts that can be made in response to this are assembling new types of superior rice varieties and optimizing the use of dry land for cultivation through the gogo system, utilizing dry land offers many opportunities to produce higher output (Surianti, 2023). The assembly of new superior varieties is based on information on genetic diversity and heritability (Widarsiono et al., 2022). Understanding genetic variation and heritability is needed in determining the selection process (Aryana et al., 2019). Genetic diversity can increase the opportunity to obtain superior genotypes through the selection process (Effendy & Waluyo, 2018). The level of progress in selection is greatly influenced by heritability; the higher the heritability value, the greater the progress that can be

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achieved in selection (Kristamtini et al., 2016). The gogo planting system causes changes in genetic diversity and heritability, this is supported by the opinion of Mustikarini et al. (2022) the gogo planting system can affect genetic variation and heritability in several traits. This may vary depending on the variety and planting location (Marnita et al., 2021).

Hybridization conducted by Aryana et al. (2022) has formed red and black rice lines to obtain F6 in red rice lines and F10 in black rice lines. Red rice lines are obtained from crossing between the promising red rice lines F2BC4P19-36 with IPB 3S and Fatmawati through single and repeated crossings, then pedigree selection is carried out until F3 and the ideal type line is found which has superior properties (Aryana & Santoso, 2017). The black rice parents were created from the local variety Baas Selem which is fragrant, soft, and has a high anthocyanin content, and the dryland rice variety Situ Patenggang which is drought tolerant and has a high yield. Assembly begins with a single crossing then continues with bulk selection until F10, then pedigree selection until F4, so that the promising line of new type black rice with a short maturity and which has a high yield can be found (Aryana et al., 2020). Testing of these lines has never been carried out using the gogo system, so this research aims to examine the genetic parameters of pigmented rice genotypes grown using the gogo system.

Method

This study was conducted in June - September 2024, experimentally in the field, in Tampak Siring Village. The design applied was a Randomized Block Design (RAK) consisting of 21 treatments, namely 11 red rice lines, 4 black rice lines, 2 red rice line parents, 2 black rice line parents, and 2 comparison varieties. All treatments were repeated three times for a total of 63 experimental units.

Sample plants were determined as many as 10 plants or 6% of the total plant population per treatment plot (160 plants). Determination of sample plants using the screening test method. The parameters observed included plant height (cm), total productive and non-productive tillers per clump, panicle length (cm), total filled grain and grain per panicle, 100-grain weight, weight per clump, blooming age (DAP), harvest age (DAP), and yield per plot are all included.

Data were analyzed using Analysis of Variance (ANOVA) RAK model with a confidence level of 95%. The genetic diversity coefficient (GVC) was evaluated (Singh & Chaudary, 1977).

$$KKG = \frac{\sqrt{\sigma^2 G}}{\bar{x}} \, x \, 100\% \quad (1)$$

$$\sigma^2 G = \frac{(KT_G - KT_E}{r} \quad (2)$$

Information:
$\sigma^2 G$: genetic diversity
$\bar{x}$: average
KT_G : genotype mean square
KT_E : mean square error
r : number of blocks

Genetic diversity categories based on KKG values according to Samudin et al. (2021) are low 0 - 10%; medium 11 - 20%; high 21 - 100%. Genetic diversity differs between red rice and black rice lines if they have different genetic diversity categories.

Broad sense heritability analysis (H2) was measured using the formula from Allard (1960).

Genetic Diversity (σ^2_G) $= \frac{KTG - KTE}{r}$

Phenotype variety (σ^2_P) = $\sigma^2_g + KT_E$ (3)

Estimated value of heritability = $\frac{\sigma^2 G}{\sigma^2 P}$ (4)

Samudin et al. (2021) categorizes heritability as follows, large (H ≥ 0.50); medium (0.20 ≥ H > 0.50); small (H < 0.20). Heritability for a particular character is said to differ between red and black rice lines if the character has a different category.

Genotypic correlation coefficient analysis uses the formula contained in the article by Samudin et al. (2022), namely:

$$(r_G(xy)) = \frac{\text{Cov G(xy)}}{\sqrt{(\sigma^2 gx) - (\sigma^2 gy)}} \quad (5)$$

The covariance components between traits can be determined using the formula

$$Cov_G = (KT_G xy - KT_E xy)/r \quad (6)$$

Based on this formula, the classification of the correlation coefficient in Tanjung & Mulyani (2021) writing is as follows: 0 = no correlation; 0-0.25 = very weak correlation; 0.35-0.5 = sufficient correlation; 0.5-0.75 = strong correlation; 0.75-0.99 = very strong correlation; 1 = perfect correlation.

Result and Discussion

The genetic diversity coefficient in pigmented red rice and black rice was observed in plant height (cm), total productive tillers (tillers) per hill, total unproductive tillers (tillers) per hill, panicle length (cm), flowering age (DAP), harvest age (DAP), total grains per panicle (grains), total empty grain per panicle (grains), 100-grain weight (g), grain weight per hill (g), and yield per plot (kg) were all taken into account. The genetic diversity coefficient (GVC) is an assessor of genetic potential. The value of the genetic diversity coefficient can provide data related to the diversity of its genotypes so that the level of extent of the plant's genotype can be determined (Wicaksono & Martono, 2020). The category of genetic diversity based on the value of the genetic diversity coefficient in the article is low 0 - 10%; medium 11 - 20%; and high 21 - 100%. The genetic diversity coefficient of yield characters and yield components of red rice genotypes showed low, medium and high categories with genetic diversity coefficient values ranging from 0.14% - 61.45% (Table 1). Parameters that have a low category are harvest age (0.14%); flowering age (1.27%); total empty grains per panicle (2.29%); plant height (4.84%) and grain weight per clump (9.37%). Parameters that have a medium category are total non-productive tillers per clump (19.52%) and total productive tillers per clump (22.93%); and parameters that have a high category are total filled grains per panicle (42.43%); weight of 100 grains (43.84); panicle length (53.81%); and yield per plot (61.45%).

The genetic diversity coefficient (KKG) of black rice genotypes obtained showed genetic diversity coefficient values ranging from 0.08% - 65.57%; with low, medium, and high categories (Table 2). Parameters that have a low category include total non-productive tillers per hill (0.08%); harvest age (0.22%); flowering age (0.25%); total empty grains per panicle (1.66%) and panicle length (5.39%). Parameters that have a medium category are plant height (17.11%) and grain weight per hill (21.01%). Parameters with a high category in black rice lines are yield per plot (22.04%); total filled grains per panicle (27.35); weight of 100 grains (43.84); and total productive tillers per hill (68.57%).

Table 1. Genetic diversity coefficient of red rice genotypes

Parameter	KKG (%)	Categories
Plant Height	4.84	Low
Number of Productive Tillers per Hill	22.93	Medium
Number of Non-Productive Tillers per Hill	19.52	Medium
Panicle Length	53.81	High
Number of Full Grains per Hill	42.43	High
Number of Empty Grains per Hill	2.29	Low
Weight of 100 grains	43.84	High
Weight of Grains per Hill	9.37	Low
Flowering Age	1.27	Low
Harvest Age	0.14	Low
Yield per Plot	61.45	High

Table 2. Coefficient of genetic diversity of black rice genotypes

Parameters	KKG (%)	Categories
Plant Height	17.11	Medium
Number of Productive Tillers per Hill	68.57	High
Number of Non-Productive Tillers per Hill	0.08	Low
Panicle Length	5.39	Low
Number of Full Grains per Hill	27.35	High
Number of Empty Grains per Hill	1.66	Low
Weight of 100 grains	34.61	high
Weight of Grains per Hill	21.01	Medium
Flowering Age	0.29	Low
Harvest Age	0.22	Low
Yield per Plot	22.04	High

Characters that have low diversity values indicate that these characters have minimal diversity, characters that have minimal variation describe that these characters have similar or uniform diversity (Samudin et al., 2022). Characters with a narrow diversity category require strict selection to obtain the target genotype, selection will be maximized if carried out in the final generation (Kuswantoro, 2017; Mustakim & S., 2019). The genetic diversity coefficient in the medium or low category is interpreted as narrow genetic diversity, as is the low diversity coefficient category (Samudin et al., 2022). Characters that have a narrow diversity category cannot develop genetic progress, which makes the opportunity for improvement in these characters ineffective (Suliartini et al., 2023). High genetic diversity values indicate that the genetic diversity obtained is broad, this is due to the presence of many controlling genes that work and the genotypes have different backgrounds (Wicaksono & Martono, 2020). Large genetic diversity can provide high opportunities in the context of expected character selection, which makes the selection stage more efficient and effective because there is expected genetic progress (Karyawati et al., 2019).

Heritability of pigmented rice genotypes of red rice and black rice

Heritability is a genetic parameter that describes the extent to which a trait is passed down to its generation. The magnitude of the influence on its offspring can be seen through the heritability value obtained (Samudin et al., 2021). The heritability value is a number between 0 and 1. Values around 1 indicate a higher degree of heredity which is mainly determined by genetic factors. Heritability values approaching zero describe a decrease in heritability values which are mostly affected by external aspects (Suliartini et al., 2023). The heritability categories according to Halide & Paserang (2020) are high (H ≥ 0.50); moderate (0.20 ≥ H > 0.50); small (H < 0.20).

The broad-sense heritability analysis of red rice that has been conducted obtained heritability values ranging from 0.0157 - 0.9920 with low, medium and high categories (Table 3). Characters that have a low category are the total empty grains per panicle (0.0157) and flowering age (0.1675). Characters that have a medium category are the total non-productive tillers per clump (0.2159); plant height (0.2361); harvest age (0.2949); and total productive tillers per clump (0.4939). The high category of the results of the broad-sense heritability analysis of red rice lines can be seen in the weight of grain per clump (0.5291); total filled grains (0.6770); panicle length (0.9111); weight of 100 grains (0.9582); and yield per plot (0.9911).

Table 3. Heritability of red rice pigmented rice genotypes

Parameters	H^2	Categories
TT	0.2361	Medium
JAP	0.4939	Medium
JANP	0.2159	Medium
PM	0.9111	High
JGB	0.6770	High
JGH	0.0157	Low
Weight 100 grains	0.9582	High
BRMPN	0.5291	High
UB	0.1675	Low
UP	0.2949	Medium
Results per plot	0.9911	High

Description: TT, plant height; JAP, number of productive tillers per hill; JANP, number of non-productive tillers per hill; PM, panicle length; JGB, number of filled grains per hill; JGH, number of empty grains per hill; BRMPN. Weight of grain per hill; UB, flowering age; UP, harvest age.

The broad-sense heritability of black rice produced ranged from 0.0078 to 0.9988 with small, medium, and high categories (Table 4). Characters that have a low category are total empty grains per panicle (0.0078) and total non-productive tillers per clump (0.0108). Harvest age (0.2965); grain weight per clump (0.3517); and flowering age (0.3598) have a medium category. Characters with a high category are panicle length (0.6247); plant height (0.6644); total sided grains per panicle (0.8184); total non-productive tillers per clump (0.7666); weight of 100 grains (0.9980); and yield per plot (0.9961); and weight of 100 grains (0.9980).

Characters with high heritability categories indicate that genetic factors have a more dominant influence, so that in the selection process, characters with high categories have a greater chance of passing on traits to the next generation (Hidayat & Adirejo, 2020). Breeders will find it easier to achieve selection progress with plant traits that have high heritability values because these traits are influenced by genetic factors. This allows selection to be carried out in the early generations (Oktaviani et al., 2018). Characters with moderate heritability categories describe that the visualization of a character is affected by external and genetic factors in equal proportions (Sa'diyah et al., 2022).

Table 4. Heritability of black rice pigmented rice genotypes

Parameters	H^2	Categories
TT	0.6644	High
JAP	0.7666	High
JANP	0.0108	Low
PM	0.6247	High
JGB	0.8184	High
JGH	0.0078	Low
Weight 100 grains	0.9980	High
BRMPN	0.3517	Medium
UB	0.3598	Medium
UP	0.2965	Medium
Results per plot	0.9961	High

Description: TT, plant height; JAP, number of productive tillers per hill; JANP, number of non-productive tillers per hill; PM, panicle length; JGB, number of filled grains per hill; JGH, number of empty grains per hill; BRMPN. Weight of grain per hill; UB, flowering age; UP, harvest age.

The low heritability category in a particular character indicates that this character is more affected by environmental or external aspects than genetic factors, which makes selection tend to be less effective (Samudin et al., 2021). Efforts that can be carried out in characters that have low categories are through the stage of expanding diversity through crossing or mutation. Characters with large genetic variation and heritability indicate that these characters have wide variations and are significantly affected by genetic aspects (Priyanto & Efendi., 2023). High heritability loads explain that genetic factors function as determinants of plant characters (Amzeri et al., 2021). Characters that have high heritability scores can make it easier for breeders to determine the direction of selection (Bartula et al., 2019).

Selection carried out on characters that have high genetic variation values and high broad-sense heritability values will be more effective and efficient, and have a great opportunity for genetic evolution because these characters are controlled by genetic aspects, which can cause traits to be passed on to their offspring (Kartahadimaja et al., 2021; Karyawati et al., 2019). High genetic coefficients and heritability traits can be the basis for selection, which can be carried out on the earliest generation (Meriaty. et al., 2021; Tessema et al., 2022).

Characters that have a low genetic variation coefficient and high heritability mean that the character has a homogeneous population and is influenced by genetic factors. The description of Jameela et al. (2014) if the genetic diversity is wider, the chances of successful selection in assembling superior varieties will be higher. The total empty grain per panicle and flowering age in red rice lines are categorized as low in the genetic diversity coefficient and heritability; the same is true for the total non-productive tillers per clump and the total empty grain per panicle in black rice lines. Minimal genetic variation and heritability in certain characters indicate that the character is homogeneous and the dominant factor influencing the character is the environment.

Characters that have wide variation and low heritability show large variation and the environment has an influence on the character. The estimated value of genotypic correlation can be used as one of the determinants of selection categories, both directly and indirectly. Plant breeding is highly dependent on information about the close relationship between characters, especially when developing new, better varieties. If it is known that the character and target character have a close correlation, then assembly can be carried out.

Referring to the correlation category, plant height and total infertile tillers per hill are included in the sufficient category. The criteria for tons/ha of yield, flowering age, harvest period, and total grain per panicle are included in the very weak category. Metrics that fall into the "very strong" category include weight of 100 grains, total productive tillers per hill, total empty grains per panicle, and grain weight per hill.

Table 5. Genotypic correlation of pigmented rice

Parameters	R_g	Categories
TT	0.307	Quite
JAP	0.877	Very strong
JANP	-0.412	Quite
PM	0.765	Very weak
JGB	0.290	Very strong
JGH	-0.747	Very strong
Weight 100 grains	0.735	Very strong
BRMPN	0.832	Very weak
UB	-0.025	Very weak
UP	-0.192	Very weak
Result ton/ha	0.205	Categories

Description: TT, plant height; JAP, number of productive tillers per hill; JANP, number of non-productive tillers per hill; PM, panicle length; JGB, number of filled grains per hill; JGH, number of empty grains per hill; BRMPN. Weight of grain per hill; UB, flowering age; UP, harvest age.

The correlation coefficient value on the yield of tons/ha (rG = 0.205); total grain sided per panicle (rG = 0.290); plant height (rG = 0.307) has a positive correlation that is not significantly different, while the weight of 100 grains (rG = 0.735); panicle length (rG = 0.765); grain weight per hill (rG = 0.832); and total productive tillers per hill (rG = 0.877) to the yield per plot describes a significantly different positive correlation. The results of significantly different positive values in the characters of 100 grain weight, panicle length, grain weight per hill, and total productive tillers per hill indicate that if there is an increase in these characters, it can be followed by growth in yield per plot. The value of the significantly different and positive character coefficient can be used as a consideration in the selection category, because the growth in values in positively related characters can increase the value of the yield character (Akbar et al., 2019). These characters need to be prioritized in selection to increase yields. The characters of total non-productive tillers per hill (rG = -0.412); harvest age (rG = -0.192); and flowering age (rG = -0.025) showed negative correlations that were not significantly different, only the total empty grains per panicle (rG = -0.747) showed a significantly different negative correlation to the yield per plot. This shows that the relationship between characters that are negatively correlated with yield per plot is inversely proportional, if there is an increase in the total empty grain character, it will reduce the yield per plot (Muliadi et al., 2018). Information on the correlation between characters is an important part of identifying the best lines. Selection carried out in characters with large genetic variation values and strong correlations with yields will provide a great chance of success for increasing crop yields (Sumanth et al., 2017). The opinion of Badaruddin et al. (2017) namely characters that have a strong correlation with results and have a large heritability value can be used as selection characters, this will be more effective than direct selection.

Conclusion

Coefficient of genetic diversity and heritability of the number of filled grains, weight of 100 grains, yield per plot of red rice and black rice lines in the high category. The number of productive tillers, weight of 100 grains and weight of grain per hill were significantly positively correlated to the yield per plot, while the parameter of the number of empty grains was significantly negatively correlated to the yield per plot..

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Authors Contribution

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Conflicts of Interest

The authors declare no conflict of interest.

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