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Heritability, Correlation and Path Analysis of Agronomic Characters in M4 Toraja Local Red Rice Mutants

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ABSTRACT

Local Toraja red rice (Pare lea) has distinctive agronomic characters especially on production and nutritional content which is better than white rice. However, this variety has some weakness that farmers are reluctant to cultivate such as tall posture, long maturing, and low production. Improvement of the local rice characters had been done through mutation breeding. Mutation breeding with ion beam has high mutation rate and cause large variation of mutant. This study aims to obtain information about the relationship between the agronomic components of growth and production. This experiment used nine mutant lines at fourth-generation (M4) as treatment and one non-mutant line as control. This research used Randomized Block design with three repetitions. The parameters observed included plant heigh, panicle number, panicle length, number of grain per panicle, percentage of filled grain per panicle, panicle density, grain yield per plant and grain yield per hectare. The parameters were measured after harvest. The high value of heritability for all the studied traits indicated that those were less influenced by environment and thus help in effective selection of the traits based on phenotypic expression. Grain yield per hectare showed significant and positive correlation with plant heigh, panicle length and grain yield per plant. Plant height, panicle lenght and grain yield per plant had direct positive effect on grain yield per hectare, so it is directly helpful for improvementt of yield. Agronomic characteristics supporting rice production include plant height, panicle length, and grain yield per plant.

Keywords:
Agronomic Character; Correlation; Heritability; Ion Beam Mutation; Mutant; Toraja Local Red Rice

1. Introduction

Rice is the leading staple food with a very high level of consumption in Indonesia. The level of rice consumption is higher than corn and soybeans, with a total of 29,133,510 tons, 5,442,094 tons, and 3,103,475 tons, respectively (BPS, 2019). The high level of rice consumption shows that rice has a vital role as a staple food, hence the necessity to increase production.

There are many constraints in increasing the production of rice. One constraint is the limited land resources due to land conversion. Using new superior varieties can help to increase the grain yield of rice. We can assemble the new superior through breeding. The creation of high yielding varieties accompanied by various intensification programs has succeeded in increasing rice productivity in a sustainable manner (Swastika et al., 2021).

Local rice is a source of germplasm in plant breeding and has been used intensively (Chaniago, 2019). One of the local rice varieties in South Sulawesi is Toraja local red rice (*Pare Lea*). It has a distinctive agronomic character, especially in colour and taste, and it has potentials to be developed. *Pare Lea* has superior number of tillers and high grain yield compared other local rice (Limbongan and Djufry, 2015). *Pare Lea* has red grain colour caused by the anthocyanin content, which is good for health. In addition, red rice also contains carbohydrates, protein, fat, and fiber; hence it is better for health than white rice (Suriany, 2017). The development of local rice as a superior variety can fulfill food and nutritional needs.

However, local rice has several disadvantages including plant height and lower production compared to national rice (Mulyaningsih and Indrayani, 2014). Local varieties generally are taller and have lower production compared to superior national varieties. Therefore, assembly of superior varieties using local rice require character improvement. Improving the character of local rice can be done by mutation breeding. Sjahril et al., (2020) was found that nine line of mutants has dwarf posture caused irradiation ion beam. We can target mutation breeding using ion beams to prevent damage to food reserve cells. In addition, it has shown ion beams to produce a relatively higher mutation percentage so that the variation of mutants is more diverse (Muryono, 2000). This condition is helpful in the line selection process to obtain superior varieties.

Line selection is not only based on high yield characters but also requires information on the relationship between growth and production characters. The relationship between characters can be calculated through correlation analysis (Chandrasari and Nasrullah, 2012). The selection of lines based on surfaces positively correlated to the production will benefit rice breeding (Saleh et al., 2020). However, the correlation value cannot clearly explain the relationship between characters, so path analysis is needed (Safriyani et al., 2018). Path analysis can produce relationships and influences between characters, either directly or indirectly (Chandrasari and Nasrullah, 2012).

Therefore, research on growth and production characteristics was carried out on nine fourth-generation (M4) mutant lines of Toraja local red rice. This study aims to get information about the relationship and direct or indirect influence of growth and production characteristics on yields. This information can help determine selection criteria that support the development of genotypes with high yield ability.

2. Materials and Methods

We conducted this research in an irrigated paddy field in Belajen, Kambiolangi Village, Alla District, Enrekang Regency. The location of this research has an altitude of 600 m above sea level. The research was conducted from March to September 2020. The research was arranged based on Randomized Block Design with three replications. The treatments studied were nine M4 generation mutant lines and one non-mutant line as control. The number of experimental plots was 30 plots with a dimension of 3 m x 3 m and plant spacing of 30 cm x 30 cm, resulting in a total of 121 plants in one plot.

Land preparation was conducted twice using a tractor. The first land preparation was carried out 3 weeks before planting. The second land preparation was carried out one day before planting by mixing 5 tons/ha (5 g/m) of manure into the field. Seed preparation was carried out by immersing the seeds in water using a different perforated plastic bag for each strain. The seeds have been soaked for 36 hours, drained, and ripened for 24 hours. Seeds were sown in seedling media made of a mixture of soil and compost with a ratio 2:1 (v/v). Planting is done using rice seedlings aged 15 days after sowing. Planting was done manually with a distance between plants of 30 cm x 30 cm in plots measuring 3 m x 3 m. Fertilization was carried out 2 times, namely 20 days after transplanting (DAT) and 60 DAT. Pest control was carried out by spraying the affected plants according to the type of pest. Harvesting was done manually after the grain meets the harvest criteria.

Observations were made on each of 12 samples from treatment and control plot. The characters observed were plant height, panicle number, panicle length, number of grains per panicle, percentage of filled grain per panicle, panicle density, grain yield per plant and grain yield per hectare. The percentage of filled grain per panicle was obtained by dividing the number of filled grains per panicle with the number of total grains (un-hulled) per panicle multiplied by 100. The panicle density was obtained by dividing the number of grains per panicle and the panicle length. Grain yield per hectare is obtained from the conversion of grain weight per plot. Observational data were analyzed using a correlation coefficients and path coefficients analysis using SPSS. The calculation of heritability was also carried out to determine magnitude of genetic influence on the characters of the mutant lines.

3. Results and Discussion

3.1. Correlation Between Agronomic Characters

The determination of traits used as selection criteria is based on characters related to crop yield (yield per hectare). Based on the results of the correlation analysis in table 1, we found that there were characters that had a significant positive correlation with yield per hectare. The correlation value shows the relationship between yield and other characters. Characters that were positively correlated with yield per hectare were plant height (0.602*), panicle length (0.668*), percentage of filled grain per panicle (0.791**), and grain yield per plant (0.996**). This shows that an increase in plant height, panicle length, percentage of filled grain per panicle, and grain yield per plant will follow an increase in yield per hectare.

The character of plant height was positively and significantly correlated with grain yield per hectare. This is related to plant photosynthesis, where plant height shows the proportion of canopy that affects plant photosynthesis (Kartina et al., 2016). Plants will get more light intensity when plants are taller, which affects photosynthesis (Pennita et al., 2020). In addition, plant height positively correlated with the percentage of filled grain per panicle, so the higher the plant will increase the percentage of filled grain. Wening and Susanto (2014), found that an increase in plant height would increase positive correlation with an increase in panicle fertility and grain production per clump. Panicle fertility is reflected by the character of the high percentage of filled grain per panicle. Increasing the height of a plant will increase plant biomass, which ultimately increases the percentage of filled grain per panicle and grain production. Although plant height supports grain weight, increasing plant height can increase the risk of falling (Li et al., 2014).

Table 1. The correlation coefficient of agronomic character in red rice mutant lines at fourth-generation (M4)

Characters	PH	NP	PL	NGP	PGP	PD	GYP	GYH
PH	1	-0,610 ns	0,489 ns	0,019 ns	0,807**	-0,078 ns	0,596*	0,602*
NP		1	-0,413 ns	-0,049 ns	-0,471 ns	-0,027 ns	-0,364 ns	-0,380 ns
PL			1	0,328 ns	0,502 ns	0,011 ns	0,660*	0,668*
NGP				1	-0,050 ns	0,690**	0,211 ns	0,235 ns
PGP					1	-0,159 ns	0,790**	0,791**
PD						1	-0,202 ns	-0,142 ns
GYP							1	0,996**
GYH								1

Notes: *PH = Plant height; PN = Panicle number; PL = Panicle length; NGP = number of grains per panicle; PGP = Percentage of filled grain per panicle; PD = panicle density; GYP = grain yield per plant; GYH = grain yield per hectare; ns = non significant; *significant at 5% level of probability; ** significant at 1% level of probability*

The character of the percentage of filled grain per panicle also has a very significant positive correlation with grain yield. This shows that higher filled grain per panicle led to higher grain yield. This result is consistent with the findings of Kasim et al. (2020) that the percentage of filled grain per panicle has a positive and very significant correlation with grain yield per hectare. The higher percentage of filled grain will increase grain yield (Okasa et al., 2021). The high and low percentage of filled grain is one of the critical factors for a rice genotype to have high yield potential (Kartina et al., 2016).

High and low grain yield is also related to panicle length. In this study, we found that panicle length significantly correlated with grain yield per plant and grain yield per hectare. This shows that longer the panicle will increase grain yield. The more extended panicle size will provide an excellent opportunity to form large amounts of grain, which can increase grain production (Kartina et al., 2016). We can see a large amount of grain included in the number's character of filled grain per panicle. In this study, we found that the number of filled grains per panicle correlated with grain production, but the correlation was insignificant.

3.2. Direct and Indirect Effect of Agronomic Characters on Grain Yield

The correlation value only shows the pattern of relationships between characters, so it is necessary to look at characters' direct and indirect effects on production to know the characters that support production. We can see the direct and indirect impact from the results of the cross-analysis in table 2. Plant height, panicle length, panicle density, and grain weight per clump have a positive direct influence on grain yield per hectare. This means that the increase in the character directly affects the increase in grain yield per hectare. This finding is supported by the results of Kannapadang et al., (2020) that the panicle length character positively affects grain weight per panicle.

Table 2. Direct, indirect, and total effects of the panicle character's components on the grain yield

Characters	Direct effect	Indirect effect							Total effect
		X1	X2	X3	X4	X5	X6	X7	
X1	0,0106		0,0035	0,0043	-0,0014	-0,0333	-0,0088	0,6272	0,6020
X2	-0,0057	-0,0064		-0,0036	0,0035	0,0194	-0,0031	-0,3835	-0,3795
X3	0,0088	0,0052	0,0024		-0,0233	-0,0207	0,0013	0,6942	0,6678
X4	-0,0710	0,0002	0,0003	0,0029		0,0020	0,0786	0,2222	0,2352
X5	-0,0412	0,0085	0,0027	0,0044	0,0035		-0,0182	0,8313	0,7910
X6	0,1139	-0,0008	0,0002	0,0001	-0,0490	0,0066		-0,2127	-0,1418
X7	1,0525	0,0063	0,0021	0,0058	-0,0150	-0,0326	-0,0230		0,9961

Notes: *X1= plant heigh; X2 = panicle number; X3 = panicle length; X4 = number of grains per panicle; X5 = percentage of filled grain per panicle; X6 = panicle density; X7 = grain yield per plant.*

The highest indirect positive effect was found on the character of grain yield per plant through the percentage of filled grain per panicle. This means that increasing the percentage of filled grain per panicle can increase grain yield per plant so that grain yield per hectare also can increase. However, Kartina et al. (2016) found that the panicle length character and the percentage of grain content had a direct positive effect on production.

3.3. Heritability

Plant phenotypes in the field can be influenced by genetic and non-genetic (environmental) factors (Soeranto, 2003). The magnitude of genetics' role in plant phenotypes can be seen from the value of heritability. This study found that the observed agronomic characters had high heritability values (0.58 - 0.94). The high heritability value reflects that the genetic influence is greater than the environmental influence (Anshori et al., 2018).

Table 3. Genotypic variance, phenotypic variance, and heritability of agronomic characters

Characters	**GV**	**PV**	**H2 (%)**	**Criteria**
PH	344,84	419,81	0,82	High
PN	23,06	39,71	0,58	High
PL	4,36	4,8	0,91	High
NGP	1420,79	1518,74	0,94	High
PGP	845,71	956,02	0,88	High
PD	2,55	3,93	0,65	High
GYP	2,01	2,91	0,69	High
GYH	0,29	0,41	0,71	High

Notes: *PH = Plant heigh; PN = Panicle number; PL = Panicle length; NGP = number of grains per panicle; PGP = Percentage of filled grain per panicle; PD = panicle density; GYP = grain yield per plant; GYH = grain yield per hectare; GV = Genotypic variance; PV = Phenotypic variance.*

The characters that had the highest heritability value were the number of grains per panicle (0.94), followed by panicle length (0.91) and the percentage of filled grain per panicle (0.88). This shows that these characters have a greater genetic influence than other characters. In addition, genetic factors have an important contribution to these characteristics because of their high heritability values (Budi et al., 2019).

4. Conclusion

Based on the results of the heritability, correlation, and path analysis, there were three characters supported the production, namely plant height, panicle length, and grain yield per plant. These characters were necessary to be observe during selection of red rice mutans to increase production.

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