Comparing the Genetic Parameters of Three Rice Varieties on Suboptimal Land Using the SRI Method

Nalwida Rozen*, Musliar Kasim, Indra Dwipa, Dini Hervani

Faculty of Agriculture, Universitas Andalas. Kampus Unand Limau Manis, Padang 25163, West Sumatra, Indonesia.

*Corresponding author; email: nalwida_rozen@yahoo.co.id

Abstract

The conversion of fertile land into industrial areas and construction development has contributed to the decline of rice production in Indonesia. Therefore, it is necessary to expand the rice fields to the sub-optimal land, i.e. lands with high levels of Fe and Al and the low soil pH. One of the solutions that can potentially solve the problem is choosing varieties of rice that can adapt to the suboptimal land environment; the rice varieties can be obtained by estimating rice genetic parameters and selection of the optimal planting methods. One method that can potentially improve rice yield is "System of Rice Intensification", or SRI method. Our study was conducted in the rice fields on suboptimal land at Pasar Ambacang, Kuranji District, Padang, Sumatra, from December 2019 to April 2020. The aims of the experiment are to determine the genetic parameters and responses of the three rice varieties to suboptimal land using the SRI method. A complete randomized design with four replications was used to set up the experiment using three varieties of rice, i.e. "Batang Piaman", "Bujang Marantau", and "IPB3S". Based on the plant growth measurement and analysis of the genetic parameters, we found that the plant growth characters, particularly height and panicles length, had high heritability and genetic progression values.

Keywords: heritability, genetic expectations, plant character, rice varieties

Introduction

Estimation of genetic parameters is very important in plant breeding to predict the potential of plant genotypes that interact with the environment to develop character's according to human needs. The success of plant breeding programs largely depends on the genetic diversity and inheritable character, also the ability to sort out genotypes excels in the selection process. Genetic diversity, which means there is a difference in the values between genotype individuals in the population, is a condition for successful selection of the desired characters (Baihaki and Wicaksana, 2005).

The yield components which indirectly increase yield has been selected by plant breeders. One of the important trait to determining its response to selection is using Heritability (h^2) value. High heritability can estimate the genetic improvement for quantitative traits (Akinwale et al. 2011). A successful character selection in plants determines and guides plant breeders in choosing the superior genotypes (Kasno et al., 1983) and the optimal planting methods. The "System of Rice Intensification" (SRI) is an agro-ecological methodology for increasing the productivity of irrigated rice by changing the management of plants, soil, water and nutrients, which is one of the methods of growing rice to produce high yields (Uphoof, 2002). In the SRI method, seeds are planted one seed per hole with a wider planting distance on wet land (Rozen et al., 2011). The rice seedlings are transplanted at an early time to increase the number of tillers up to twice, because of the increase formation of phyllochron (Veeramani et al,. 2012).

Rice planted using the SRI method with the addition of organic materials, such as straw compost, can produce yield up to 10 tons per ha; this is a significant increase from 5 to 6 tons per ha without the addition of organic materials (Rozen et al., 2011).

Critical genetic parameters such as genetic variability, heritability, correlation, and influence of characters closely related to crop yields need to be observed carefully in rice plants to achieve effective and efficient selection (Borojevic, 1990). The final characters are the results of genetic and environmental interactions (Rozen et al., 2011). High yield as one of the criteria in the selection of superior rice genotype is a character controlled by many cumulative, duplicate, and/or dominant genes, and strongly influenced by the environment. Information about the predicted value

of genetic parameters such as phenotypic variety, heritability, and selection response, is very useful in plant breeding programs. For rice, heritability of characters including plant height, inflorescence length, the number of inflorescence, amount of grain per inflorescence, weight of 1000-grains, and plant yield, are important characters that can be improved with breeding (Khush, 2000).

Analysis of the diversity component can be used to determine heritability and elder-derived regression techniques. It can also be used to estimate homogeneous population diversity. The predicted value of genetic variation and heritability will be closer to its actual value with more interactions excluded from the genetic variety (Khan et al., 2009).

Suboptimal land is defined as land that is naturally have one or more constraints such as difficulty in providing sufficient water to support productive and profitable farming efforts, or the soil has high levels of Fe and Al and low pH (Benyamin, 2013). High Al and Fe content causes soil reactions to become highly acidic, causing inhibition to rice growth and grain filling. It takes efforts for this type of land before they can be used to grow crops (Benyamin, 2013).

Heritability compares the magnitude of genotype variety and the total size of phenotype variety of a character (Syukur et al., 2012). "Batang Piaman", "Bujang Marantau" and "IPB3S" are rice varieties that demonstrated abilities to adapt suboptimal land (Rozen et al., 2021). This study aims to determine the genetic parameters of the three rice varieties using SRI method.

Material and Methods

Study Location

The study was conducted at Pasar Ambacang Kuranji District, Padang, Sumatra, Indonesia, from December 2019 to April 2020.

Sampling and Data Analysis

Three varieties of rice ("Batang Piaman", "Bujang Marantau", and "IPB3S") were tested in a completely randomized design with four replication. Three plants from the four replicates per variety were used as samples. Measurements were made on the plant height, total number of tiller, the number of productive tiller, inflorescence length, the weight of 1000-grains, total grain count, total grain weight, grain weight, grain yield per plot, and grain yield per hectare. Estimation of the genetic parameters were calculated according

to Singh and Chaudhary (1979), as presented on Table 1.

Table 1. Analysis variance of rice varieties

Genetic variance	Middle Squared Expectation Value
Genotypic (G)	$\sigma^2 e + rl\ \sigma^2 g$
Replication (L)	$\sigma^2 e + rg\ \sigma^2 l$
G x L	$\sigma^2 e + r\ \sigma^2 gl$
Galat	$\sigma^2 e$

$\sigma^2 g$ = middle square of genotypic – middle square of environment / rl

$\sigma^2 f = \sigma^2 g + \sigma^2 e$

$H^2 = (\sigma^2 g / \sigma^2 f) \times 100\%$

Information:

H^2 = heritability

$\sigma^2 g$ = genotypic variance

$\sigma^2 f$ = phenotypic variance

$\sigma^2 e$ = varians galat.

Heritability value criteria (Syukur et al., 2012):

High   : $h^2 \geq 0.5$

Quite high   : $0{,}2 < h^2 < 0.5$

Low   : $h^2 \leq 0.2$

Coefficient of variation criteria:

Narrow (0 – 10 %)

Keep   (10 – 20 %)

Broad   (> 20%)

Genetic advance criteria:

Low   (0– 7 %)

Keep   (7-14 %)

High   (>14%)

The value of expectation of genetic progress = k. σf . H

Results and Discussion

The three rice cultivars are significantly different in height, total number of tiller, number of productive tiller, and inflorescence length (Table 2), the weight of 1000-grains, total grain count, total grain weight, grain yield per tiller, and grain yield per hectare (Table 3).

Data on Table 2 and Table 3 showed that the three different varieties of rice used in this study have different growth and yield when planted in the same environment. According to Syukur et al. (2012) changes or improvements in the environmental factors will not cause changes in the phenotype, unless there are differences in the plant's genetic makeup. Each rice variety has its superior characters, e.g. "Bujang Marantau" had a high total number of tiller and number of productive tillers. IPB 3S had high values on plant height, inflorescence length, total grain amount per inflorescence, total grain weight per inflorescence, and grain weight. "Batang Piaman" had high values

Nalwida Rozen, Musliar Kasim, Indra Dwipa, Dini Hervani

Table 2. The differences in plant growth characters of the three rice varieties

Rice variety	Height (cm) at 56 days	Total number of tiller	Number of productive tiller	Inflorescence length (cm)
"Bujang Marantau"	101.04 b	33.50 a	25.25 a	27.08 c
"IPB 3S"	118.46 a	17.46 c	12.83 b	32.92 a
"Batang Piaman"	95.09 b	25.04 b	22.67 a	28.78 b
CV (%)	3.26	13.35	16.70	2.62

Note: values followed by different lowercase letters in the same column showed significant differences according to the DMRT at α=0.05.

Table 3. Yield characters of the three rice varieties

Rice variety	1000-grain weight (g)	Total grain per inflorescence	Number of grains per inflorescence	Total grain per inflorescence (g)	Number of grains per inflorescence (g)	Grain yield per tiller (kg)	Grain yield per hectare (ton)
"Bujang Marantau"	21.03 b	199.73 b	175.66 b	199.73 b	3.85 b	4.57 a	7.60 a
"IPB3S"	27.97 a	238.29 a	188.67 a	238.29 a	5.33 a	3.03 b	5.07 b
"Batang Piaman"	28.52 a	176.99 c	149.92 c	176.99 c	4.20 b	4.87 a	8.07 a
CV (%)	4.19	5.21	8.26	5.21	6.80	11.2	11.04

Note: values followed by different lowercase letters in the same column showed significant differences according to the DMRT at α=0.05.

of 1000-grain-weight, grain yield per plot, and grain yield per hectare. Inflorescence and grains from three rice varieties are shown in Figure 2.

Using the genetic parameters of the three rice varieties grown on suboptimal land, we found that none of the observed plant characters have low heritability values (Table 4). The high heritability indicates that the genetic influences are more significant on phenotypes compared to environmental influences.

Thus, the plant growth character selection can be conducted at the early stage of growth.

Estimation of heritability in populations depends on the partitioning of observed variation into components that reflect unobserved genetic and environmental factors. Heritability has important roles in plant selection and breeding programs, because heritability determines the precision with which the genetic value can be predicted from phenotypic information. A trait
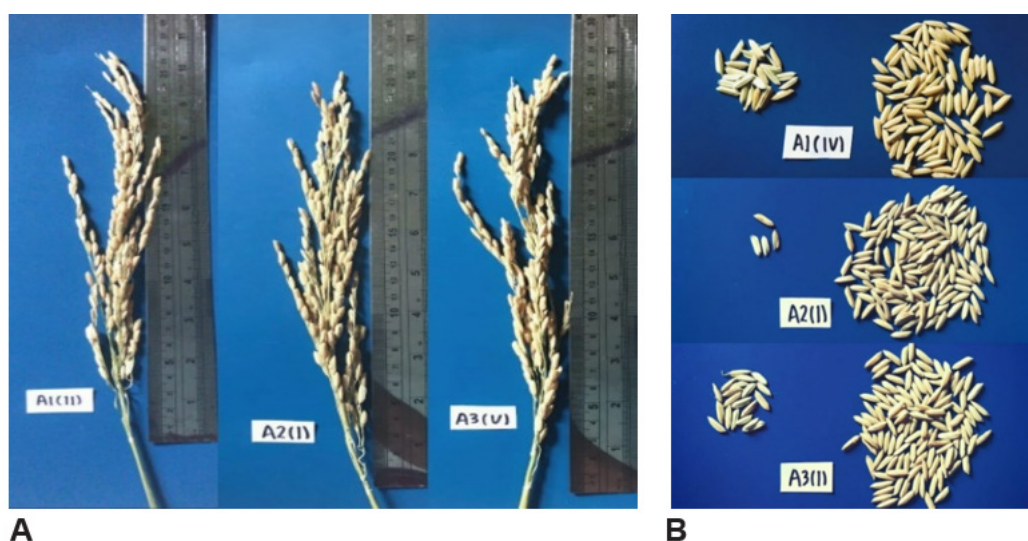

Figure 2. The panicles (A) and grains (B) of "Batang Piaman" (A1), "Bujang Marantau" (A2), and "IPB3S" (A3).

Tabel 4. Genetic parameter analysis of the three rice variety

Characters	Components			Heritability (H²)		Coefficient of variation (%)		Genetic advance (%)	
	Environment	Genetic	Phenotype	Value	Criteria	Value	Criteria	Value	Criteria
Plant height (cm)	11.70	143.64	155.34	0.92	high	11.43	narrow	32.97	high
Total number of tiller	11.14	60.58	72.02	0.84	high	30.73	broad	84.55	high
Number of productive tiller	1.70	42.36	44.06	0.96	high	32.14	broad	94.54	high
Length of inflorescence (cm)	0.60	8.82	9.42	0.94	high	10.03	narrow	29.13	high
Number of productive tillers	113.91	922.51	1036.42	0.89	high	14.82	narrow	41.93	high
Number of pithy grain	200.69	321.93	522.62	0.62	high	10.47	narrow	24.65	high
Total grain weight (g)	0.08	0.83	0.91	0.91	high	19.39	narrow	55.53	high
Weight of pithy grain (g)	0.09	0.57	0.66	0.86	high	16.93	narrow	47.19	high
Plant height (cm)	1.17	17.13	18.30	0.94	high	16.02	narrow	46.49	high
Total number of tiller	0.22	0.89	1.11	0.80	high	22.72	broad	61.06	high
Grain yield per hectare (ton)	0.58	2.41	2.99	0.81	high	22.48	broad	60.56	high

or character with a high heritability value ($h^2 \geq 0.5$) indicates that the phenotype of an individual is informative for its breeding value (Falconer, 1970). Using the average of several measurements of a phenotype can substantially increase heritability. Therefore, for traits with a high heritability value there is a good chance to improve the character through selection. In contrast, with traits with a low heritability, information from many relatives is required to predict breeding values (Visscher et al., 2008). When the value of genetic progress of a character's expectations is low, selection activities is not as important as the expected improvement is relatively low. Data on Table 4 showed that all characters had high values of heritability, so that the characters can be selected effectively in the next generation.

Conclusion

Using the System of Rice Intensification (SRI) Method, we demonstrated that the three varieties of rice in this study, "Batang Piaman", "Bujang Marantau", and "IPB3S", had different growth responses when growing on the suboptimal land. All plant characters studied, particularly grain weight, number of productive sapds, grain yield per plot, have high heritability and genetic progression values. All genetic parameters of three rice varieties can be used to develop the next rice generation.

Acknowledgement

References

Akinwale, M.G., Gregorio, G., Nwilene, F., Akinyele, B.O., Ogunbayo, S.A. and Odiyi, A.C. (2011). Heritability and correlation coefficient analysis for yield and its components in rice (*Oryza sativa* L.). *African Journal of Plant Science* **5**, 207-212.

Baihaki, A. and Wicaksana, N.(2005). Interaksi genotipe x lingkungan, adaptabilitas dan stabilitas hasil, dalam pengembangan tanaman varietas unggul di Indonesia. *Jurnal Pemuliaan Indonesia* **16**, 1-8

Nalwida Rozen, Musliar Kasim, Indra Dwipa, Dini Hervani

Benyamin (2013). Produktivitas pertanaman jagung di lahan pasang surut Kabupaten Tanjung Jabung Barat, propinsi Jambi *In* "Prosiding Seminar Nasional Serealia 2013". Badan Penelitian dan Pengembangan Pertanian, Kementerian Pertanian.

Borojevic, S. (1990). "Principle and Methods of Plant Breeding". Elsevier, New York.

Falconer, D.S. (1970). "Introduction to Quantitative Genetics". The Ronald Press Company. New York.

Kasno, A., Bari, A., Matjik, A.A., Subandi, and Somaatmadja, S. (1983). Pendugaan parameter genetik sifat-sifat kuantitatif kacang tanah dalam beberapa lingkungan tumbuh dan penggunaannya dalam seleksi. *Balai Penelitian Tropika Bogor* **3**, 44-48.

Khan, A.S., Imran, M., and Asffaq, M. (2009). Estimation of genetic variability and correlation for grain yield component in *Oryza sativa* L. *Journal Agricultural Environment Science* **6**, 585-590.

Khush, G.S.(2000). New plant type of rice for increasing the genetic yield potential. *In* "Rice Breeding and Genetics: Research Priorities and Challenges" (J.S. Nanda, ed.) pp. 99-108. Science Publishers, Enfield, USA.

Rozen, N., Kasim, M., and Dwipa, I.(2021). Response of "Batang Piaman" variety of rice crops to fertilizers in suboptimal rice field. IOP Conference Earth and Environmental Science, pp. 1-6.

Rozen, N., Syafrizal, and Sabrina (2011). Peningkatan potensi hasil tanaman padi melalui alih teknologi SRI di Kota Padang *In* "Laporan Pengabdian kepada Masyarakat". DP2M Dikti. 64 pp.

Singh, R.K. and Chaudhary, B.D. (1979). "Biometrical Methods in Quantitative Genetics Analysis". Kalyani Publication. Ludhiana. New Delhi.

Sirappa, M.P. and Titahena, M.L.(2014). Improvement of suboptimal land productivity approach by land and plant management. *Journal of Tropical Soils* **19**, 109-119

Syukur, M., Sujiprihati, S. and Yunianti, R. (2012). "Teknik Pemuliaan Tanaman". 348 pp. Penebar Swadaya. Jakarta.

Uphoff, N. (2002). "Biophysical Challenges for Technology and Policy: The System of Rice Intensification Developed in Madagascar". Madagascar.

Veeramani, P., Singh, R.D., and Subrahmaniyan, K. (2012). Study of phyllochron system of rice intensification (SRI) technique. *Agricultural Science Research Journal* **2**, 329-334.

Visscher, P.M., Hill, W.G., and Wray, N.R. 2008. Heritability in the genomics era — concepts and misconceptions. *Nature Reviews - Genetics* **9**, 256-266.