Gene action that controlling some characters on F2 generation derived from the crossing of Silopuk red rice with Fatmawati superior variety

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Abstract. An F2 population is a segregated population where recombinant characters emergence. To selection these recombinant characters, it is important to know their genetic parameters. The purpose of this study was to determine the action of genes controlling the number of productive tillers, the total number of grains per panicle, the percentage of grain-filled per panicle, weight of one thousand filled grains and total grain weight per hill of F2 generations. Silopuk cultivar with red rice characteristic but has weakness such as long harvest age, high plants, and medium grain size, while superior Fatmawati has early maturity, semidwarf plant thickness, big grain size, and white grain color. The character can be improved by the plant breeding method using hybridization. The research method used is the experimental method without replication with the head to row method [clump to row] and analyzed using the analysis of Skewness and Kurtosis. The result of the crossing of these varieties is expected to obtain large and heavy grain size, early age as Fatmawati and red rice as Silopuk. Z skewness test results and Z test kurtosis on F tow generation for all characters observed are controlled by many additive genes. The characters that have additive gene action such as plant height, panicle length and total grain size can be used as selection criteria for generation F three.

Keywords: Additive, heritability, kurtosis, red rice, skewness

1. Introduction

The effort to assembly rice varieties in Indonesia is aimed at getting high yielding varieties that are continuous activities and require a long time for the success of increasing rice production in Indonesia. In connection with the characteristics of superior varieties of red rice, efforts are made to find and develop new types of rice, which are expected to provide a significant increase in rice productivity, except for red rice.

Red rice is rice that is consumed without going through the process of silencing, but it is ground into broken skin. Aside from being a staple food, red rice has also long been known to be beneficial to health and has been popular in the field of research. Red rice is useful for preventing various digestive tract diseases. The red color of rice is formed from anthocyanin pigments which are not only found in the pericarp and tegmen [layers of skin] but can also be used in every part of the grain, even on the petals.

Local red rice is superior in terms of protein, anthocyanin, and fiber than white rice. Exploration results in West Sumatra anthocyanin content in local red rice ranged from 3.03 mg CyE/g to 410.39
mgCyE/g [1] [2]. The density of red indicates the level of anthocyanin content, the more concentrated the red color, that is higher the anthocyanin content [3].

Efforts to increase genetic vulnerability in self-pollinating crops to produce superior varieties of rice can be done through hybridization or crossing. Plant breeding activities have assembled genetic diversity through crossbreeding or hybridization between local varieties that have high protein and red rice such as Silopuk with Fatmawati's new and early-maturing Superior Type [VUTB] Varieties [1].

The pattern of color inheritance of rice in red rice is an observation of qualitative characters that follows the pattern of inheritance of Mendel's Law. The segregation pattern of rice color characters identified that the color character of rice was controlled by one gene with two alleles and was thought to have a dominant allele against white rice color alleles [1] This pattern of segregation can increase genetic diversity in a population. The crosses between the two rice varieties have been obtained as desired, among others, large seeds such as Fatmawati and red rice such as Silopuk [4].

For selection to be efficient, the characters used as selection characters must be chosen based on the value of heritability, genetic diversity, the distribution of population frequencies and the closeness of the relationship with the results. Frequency distribution information is important for breeders to find out the bias or not the estimation of the progress of the selection made to a character. The purpose of this study was to obtain information about the action of genes that controlling some of the quantitative characters of F2 generation from Silopuk red rice with superior varieties of Fatmawati crosses.

2. Material and Methods
This research was carried out from February to June 2014 in the Limau Manis farmers' land with an altitude of +200 meters above sea level. The research method used is the experimental method without replication with the Head to row method [clump to row] and analyzed using the analysis of Skewness and Kurtosis.

The implementation method starts with land preparation, seed selection, seeding, planting, maintenance [irrigation, fertilizing, weeding and controlling pests and diseases] and harvesting. Observations were made where the character of the height plant, the number of productive tillers, panicle length, the total number of grain per panicle, 1000 grain weight and the weight of grain per clump. Data analysis using the Skewness Kurtosis analysis using the SPSS program through this analysis can be seen as the action of genes that control the characters of the results in generations of F2.

3. Results and discussion

3.1. Parameters of Population

| Table 1. Performance of Elders and Population F2 |
|-----------------------------------------------|
| Characters         | Silopuk Average | Fatmawati Average | Population F2 Average |
| TT                | 148.19          | 87.30             | 133.51                |
| JAP               | 20.88           | 12.15             | 15.91                 |
| PM                | 28.88           | 31.05             | 33.44                 |
| JGT/M             | 200.31          | 340.00            | 325.79                |
| B1000bGB          | 29.69           | 27.41             | 27.00                 |
| BGT/R             | 49.04           | 48.08             | 62.45                 |

Note: TT = Plant Height; JAP = Number of Productive Tillers; PM = Length of Panicle; JGT / M = Total Grain per Panicle; B1000bGB = Weight of one thousand Grain Bernas; BGI / R = Weight of Grain Fill per Clump; BGT / R = Total Grain Weight per Clump.
The characters of elders and population F2 are shown in Table 1. The characters observed in population F2 obtained the mean values of all observed characters are between the values of the two elders except, panicle length and grain weight per clump higher than the best parent, in other words experiencing transgressive segregation. Characters with a middle value greater than the elders still have a chance to do the selection because the range is outside the parent level. This is evidenced that the population occurs in high segregation.

3.1.1. Plant height
Based on the results obtained, 11 genotypes had lower plant height and were relatively similar to Fatmawati elders, namely 87.30 cm [Figure 1.]. It is expected that individual F2 populations that have a lower plant height or are relatively similar to the elders can reduce the risk of falling stems from rice plants. Following the distribution of plant height data F2 population is presented in Figure 1.

![Figure 1. Distribution of F2 plant height](image)

Plant height character is a character that needs to be considered in the plant breeding program because this character is one of the characters that affect the fall of the stem and the potential yield of rice. Plant height is an indicator of growth to measure the effect of the type of treatment that is closely related to photosynthesis. Based on this, plant height character is included in the assembly program of red rice varieties with ideal plant height according to selection criteria.

3.1.2. Number of Productive Tiller

![Figure 2. Distribution of productive tillers of an F2 population](image)
Productive tillers are plants that consist of one stem, roots and leaves and produce flowers [productive]. Rice tillers also produce to panicle and may not reach a certain age. The number of productive tillers depends on the number of tillers produced by the plant. The more the number of tillers produced by plants, the more the number of productive tillers produced.

Based on Figure 2, 93 individuals have several productive tillers ranging from 12.15-20.88 stems. The highest number of individuals is 63 individuals, which are relatively the same and are higher than Fatmawati elders, which is 12.15 plants.

3.1.3. Panicle length
Panicle length is a character that will affect the amount of grain it produces because the longer panicle will potentially produce a lot of grain so it will greatly affect the production of crop yields. Long panicles allow more grain to sit. However, if the number of empty grains per panicle is high, the production weight per unit area will decrease. The amount of grain formed in each panicle is determined by the length of the panicle and also the number of panicle branches, where each will produce grain.

Based on the panicle length character distribution in Figure 3, 33 individuals with a panicle length range of 28.88 - 31.05 cm were obtained. The number of individuals with panicles exceeding Fatmawati's elders, which was 31.05 cm, was found as many as 83 individuals. Long panicles will produce a lot of grain so that it can increase yield potential.

3.1.4. Total Grain Number per Panicle
The amount of total grain per panicle is a very important character in plant breeding, especially in the production of high yields in brown rice. The amount of grain produced per panicle will be different for each individual. The character of the total number of grains per panicle also largely determines the selection criteria in plant breeding.

The mean total number of unhusked rice per panicle of population F2 was 325.79 between the middle values of the two parents. 12 individuals have a total grain number below the Silopuk parent values of 200.31 and 62 individuals who have a total grain number between 200.31-340 and 52 individuals with a total grain number higher than the two elders. It is proven that in population F2 segregation occurs.
3.1.5. Weight of 1000 Grain Seeds

The weight of 1000 grains of pithy grain is a reflection of the grain size and shape of the grain. The higher weight value of 1000 grain means that the grain size is large and the shape is also better and the pan is filled perfectly. The weight of 1000 grains of pithy grain also depends on the results of plant photosynthesis during the reproductive phase, so that during the filling period of the seeds most of the results of the assimilation formed or stored are used to increase the weight of the seeds. Whether or not rice grain is affected by photosynthate originating from the assimilation results before fertilization and cooking seeds.

Based on the explanation, the weight of 1000 grains of pithed grain indicates that the grain size and the success of each genotype must be selected. Thus it can be seen that the pithy grain which has an oval shape and large size has a heavier weight so that it becomes the basis in determining the genotype to be selected based on the character of the 1000 grain weight of the grain.

3.1.6. Total Grain Weight per Clump

The character of total grain weight per clump is a character that is closely related to the yield component and is important in efforts to increase rice production, especially brown rice. So that the weight of the rice grain is used as a selection criterion that determines the high production of brown
rice. The range of grain weight per clump based on PTB criteria is ranging from 36.0 to 62.5 grams per clump. The following is the distribution of total grain weight character data per family presented in Figure 6.

![Figure 6. Distribution of grain per population total weight of F2 population](image)

There are 73 individuals and are the most individuals who have a total grain weight per family between 49.5-206.1 which is above the weight of the two elders. While those who are between the two elders, namely 49.04-48.08 there are 55 individuals. The difference proves that in F2 there is a variation of characters resulting from crossing.

3.2. Genetic Parameters

3.2.1. Estimation of Gene Action that Controls the Characteristics of Population F2 Based on the Distribution of Population F2

The yield character is a quantitative character that is controlled by many additive genes and the phenotype cannot be classified because it follows a continuous distribution. Skewness and curved curves [Kurtosis] can be used to explain the characteristics of a continuous curve so that these values can be predicted by gene action and the number of genes that control a character in a segregated population. Estimation of gene action and the number of genes involved can be estimated from the distribution pattern in a population [5].

Estimation of gene action is usually carried out in F2 populations because segregation occurs maximum or high. The F2 population of each genotype was represented by one individual plant by pedigree selection. Analysis of the distribution patterns of the observed agronomic characters is in Figures 1 to 6 and the observed skewness and kurtosis values are presented in Table 2 and Table 3.

Based on the results of the Z skewness test and Z kurtosis test for all observed characters are significantly different and not significantly different. This shows that the character has an abnormal distribution pattern that is polygenic and few genes thus causing the action of additive and dominant genes. Additive gene action means that the total effect of minor genes is greater than the environment but the effect of gene unity is smaller than the effect of the environment. In dominant genes, it can also be interpreted that the influence of dominant genes is greater than environmental influences.

Table 2. Shows that the characters of plant height and panicle length, as well as the number of grains per panicle, have additive gene action, on the number of productive tillers, 1000 grain weights, and grain weight per clump has the dominant epistasis gene action. The results of plant height and panicle length had additive gene action. Additive gene action on a character indicates that the alleles resulting from genetic contribution between the two elders and the alleles of the parent will be inherited to their offspring [6].
Table 2. Gene Action of Characters on F2 Population

| Characters | Skewness | SE Skewness | Test Z Skewness | Gene Action |
|------------|----------|-------------|-----------------|-------------|
| TT         | -0.79    | 0.21        | -3.76<sup>in</sup> | Additive    |
| JAP        | 0.60     | 0.21        | 2.86*           | Dominant    |
| PM         | 0.32     | 0.21        | 1.52<sup>in</sup> | Additive    |
| JGTM       | 0.26     | 0.21        | 1.24<sup>in</sup> | Additive    |
| B1000GB    | -0.56    | 0.21        | 2.67*           | Dominant    |
| BGTR       | 1.46     | 0.21        | 6.95*           | Dominant    |

Note: TT = Plant Height; JAP = Number of Productive Tiller; PM = Length of Panicle; JGTM = Sum of Grain per Panicle; B1000GB = Weight of 1000 Grain Seeds; BGTR = Total Grain Weight per Clump.

The action of genes that have dominant epistasis on the character of the number of productive tillers, 1000 grain weight, and grain weight of clumps is the influence of dominant gene factors that cover other dominant genes [not alleles] so that the nature of closed genes does not appear, but also does not disappear. Characters that have dominant epistasis gene action are controlled by few genes except that the weight of 1000 grain is controlled by many genes or polygenic [Table 3].

Table 3. Number of Genes that Controlling some of the Characters on F2 Population

| Characters | Kurtosis | SE Kurtosis | Test Z Kurtosis | Number of Gene |
|------------|----------|-------------|-----------------|----------------|
| TT         | -0.09    | 0.43        | -0.21<sup>in</sup> | Many           |
| JAP        | 0.60     | 0.43        | 1.39*           | Little         |
| PM         | -0.15    | 0.43        | -0.35<sup>in</sup> | Many           |
| JGTM       | -0.16    | 0.43        | -0.37<sup>in</sup> | Many           |
| B1000GB    | -0.36    | 0.43        | 0.84*           | Little         |
| BGTR       | 3.11     | 0.43        | 7.23*           | Little         |

Note: TT = Plant Height; JAP = Number of Productive Tiller; PM = Length of Panicle; JGTM = Sum of Grain per Panicle; B1000GB = Weight of 1000 Grain Seeds; BGTR = Total Grain Weight per Clump.

Based on Table 3. Characters in the F2 population are consistently controlled by many genes found in all characters except in the character of the number of productive tillers, the weight of 1000 grains and the total weight grain per clump are controlled by a few genes. The phenotypic value of potential segregants is better than the parent caused by polygenic additive genes. So, the selection of polygenic characters will be effectively carried out in later generations. The selection in the next generation is done because the additive genes have been fixed properly so that the proportion of homozygosity that makes up the character that has a polygenic character has been high in that generation.

4. Conclusion

F2 population derived from Silopuk cultivar crossing with Fatmawati superior variety shows variability performances in all characters observed. Based on the value of Z Skewness test and Z Kurtosis test, all characters have a normal distribution, polygenic and are affected by additive genes action except in the character of several productive tillers, the weight of 1000 grain seeds and the total grain weight per clump that influenced by the dominant, epistasis gene action which are controlled by a little gene. Z skewness test results and Z test kurtosis on F tow generation for all characters observed are controlled by many additive genes. The characters that have additive gene action such as plant height, panicle length and total grain size can be used as selection criteria for generation F3 to F5.
References

[1] Swasti E and NE Putri 2011 Pengembangan Padi Merah Lokal untuk meningkatkan kesejahteraan petani *Jurnal Embrio* 2 89-96

[2] Swasti E, Syarif A, Suliansyah I, and NE Putri 2007 *Eksplorasi, Identifikasi dan Pemanatan Koleksi Plasma Nutfah Padi Lokal Asal Sumatera Barat* Laporan LPPM Unand

[3] Reza M 2012 Evaluation of Amylose, Anthocyanin and Fiber Content in Some Red Rice (*Oryza sativa* L.) from West Sumatra (Undergraduate Thesis) Andalas University-Padang

[4] Wahyuni H, Swasti E, and Yusniwati 2019 Genetic Diversity of Age, Plant Height, and Number of Grain per Panicle Characters of F3 Generation derived from Crossing Silopuk with Fatmawati Varieties *JERAMI Indonesian Journal Of Crop Science* 1 (2) 36-46

[5] Roy D 2000 *Plant Breeding Analysis and Exploitation of Variation* New Delhi-Narosa Publishing House

[6] Manurung SO and Ismunadj 1998 *Rice Morphology and Physiology. In Book Rice Agricultural Research and Development Agency* Food Crop Research and Development Center-Bogor pp 55-102