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Heritability of agronomic characters of Srikandi Putih x local waxy corn

Edy[1], A Takdir[2], S Numba[1], and B Ibrahim[1]

[1]Study Program of Agrotechnology Faculty of Agriculture, University of Muslim Indonesia. Makassar City South Sulawesi Province, Indonesia
[2]Indonesian Cereals Research Institute

Email: *nuhungedy63@yahoo.com*

Abstract. High-protein corn and glutinous already exist, but the unification of these two traits is still temporary we did in a study. The effort to unite the properties of high protein and glutinous (high amylopectin) was started from hybridization between Srikandi Putih Variety corn and Local Waxy Corn followed by a series of crosses and selection. The continuity of a selection in breeding requires the value of heritability as a foundation. The purpose of this study was to determine the level of breeding progress in the corn assembly program with high amylopectin and protein levels based on heritability values. This study was designed in the form of a randomized block design. The treatments are varieties or genotypes which consist of 5 types: G_1 = Srikandi Putih (parent 1♀); G_2 = Local Waxy Corn (parent 2♂); $G_3 = F_1$; $G_4 = F_2$ and $G_5 = F_3$, repeated 3 times. Data for each parameter were analyzed for variance and heritability values. The results showed of Broad-Sense (BS) and Narrow-Sense (NS) heritability of the plant's height 0.75 (BS), 0.61 (NS), number of leaves 0.71 (BS), 0.55 (NS), flowering age ♂ 0.78 (BS), 0.52 (NS), and flowering age ♀ 0.79 (BS), 0.64 (NS), ear length 0.72 (BS), 0.56 (NS), ear diameter 0.77 (BS), 0.54 (NS), weight of 100 seeds 0.73 (BS), 0.60 (NS), seed production per hectare 0.78 (BS), 0.58 (NS), protein content 0.53 (BS), 0.51 (NS), amylopectin content 0.60 (BS), 0.52 (NS). The heritability values of all measured properties parameters are generally included in the rather high category.

1. Introduction

In Indonesia corn is one of the second strategic commodities after rice. In certain regions of Indonesia, corn is still the second staple food after rice. Besides that corn plays an important role in the development of the feed industry and food processing. This is what causes the need for corn to increase. Genetic improvement is very necessary to be done in order to obtain varieties of delicious and nutritious corn as expected. In order for the breeding program to continue, it is necessary to estimate heritability. The purpose of this study was to determine the level of advancement of breeding in the corn assembly program with amylopectin and high protein levels based on heritability.

The advancement of breeding in the process towards the creation of high protein corn varieties and glutinous so that it is delicious to be consumed which in turn is expected to become an alternative staple food. Therefore, efforts are needed to improve the character of corn plants to produce corn with good taste and high protein content. Efforts to improve the character of the traits carried out and while taking place are by crossing the Srikandi Putih Variety corn with Local Waxy Corn which has produced F_1 generation where the content of F_1 protein and amylopectin derivatives has been different from the two parents. Interesting things can be observed between F_1 with both parents (Local Waxy Corn and Srikandi Putih) which shows the value in each production parameter and the quality that tends to be between the values of both parents. This gives an indication that the character of both parents has been passed on to F_1, but the character is still partial and not yet stable so that further research is needed to obtain new varieties [1]. Corn varieties produced through population improvement need to be tested in cropping areas that have different agro-climates to find out their response to the local environment. To ensure the influence of genetic factors on the level of diversity of a character, it can be seen from the heritability value. Estimation of heritability values can illustrate whether inheritance of traits is more controlled by genetic factors or influenced by environmental factors so that it can be known to what extent these traits can be derived in later generations.

According to Poehlman [2], the success of a plant breeding program is essentially dependent on genetic diversity and heritability. If the level of genetic diversity is narrow then this indicates that individuals in the population are relatively uniform resulting in selection for improvement of traits to be less effective. Conversely, the wider the genetic diversity, the greater the chance for successful selection in increasing the frequency of the desired gene. In other words, the opportunity to get a better genotype through greater selection [3, 4].

Genetic variation will help in streamlining selection activities. If genetic variation in a large population shows that individuals in the population are diverse, the opportunity to obtain the expected genotype will be large [5]. While the estimation of high heritability values indicates that the genetic influence factor is greater for phenotypes when compared to the environment. For that information, the character is more played by genetic factors or environmental factors, so it can be known to what extent these traits can be passed on to the next generation.

In a crossing with the unification of genes from different parents, and interaction arises between the genes so as to add value to the properties they control. Therefore, the gene is additive, while dominant occurs when the dominant allele at the same locus covers the effect of recessive alleles [6]. Knowledge of the value of heritability is needed in conducting the selection and design of crosses to improve the genetic quality of an organism. This knowledge is useful in estimating the magnitude of progress for different breeding programs. In addition, enabling breeders to make important decisions whether the costs of the breeding program carried out are commensurate with the expected results. The value of heritability is useful in estimating the value of breeding a plant whether the dominant phenotype is influenced by genetics or the environment.

2. Materials and Methods

This research was carried out at Bajeng Experimental Farm, Gowa District from May to September 2018. The materials used in this study were corn Variety Srikandi Putih, Local Waxy Corn, F_1, F_2 and F_3 genotype. This study was designed in a randomized block design. The treatments are varieties or genotype which consist of 5 types, namely: G_1 = Srikandi Putih; G_2 = Local Waxy Corn; $G_3 = F_1$ (Srikandi Putih x Local Waxy Corn); $G_4 = F_2$ (F_1 x F_1), $G_5 = F_3$ (F_2 x F_2), repeated 3 times.

F_1 seeds were obtained from crossing Srikandi Putih Variety (female parent) with Local Waxy Corn (male parent), F_2 seeds were obtained from crossing F_1 with F_1, and F_3 seeds were obtained from crossing F_2 with F_2. Srikandi Putih Variety seeds, Local Waxy Corn, F_1, F_2 and F_3 were planted in the same location with relatively uniform land conditions. Plots between varieties / genotypes are quite far apart to prevent pollination between varieties / genotypes.

The parameters observed were plant height, number of leaves, flowering age ♂, flowering age ♀, ear length, ear diameter, weight of 100 seeds, seed production per hectare, protein content, amylopectin content and heritability. All parameters were analyzed by analysis of variance and further tests with $LSD_{0.05}$. Specifically heritability was analyzed using the formula for broad-sense heritability and narrow- sense heritability.

The heritability value can be expressed in percent (0-100%) or in decimal form (0.0-1.0). A value of 1.0 indicates that all variations are caused by genetic differences, and the value of 0.0 indicates that variations in the population are due to environmental factors. Analysis of variance is used to estimate heritability in a broad sense. The estimated heritability value of a property is calculated by the formula:

$$h^2_{(BS)} = \frac{\sigma^2 G}{(\sigma^2 G + \sigma^2 E)}$$

Where: $h^2_{(BS)}$ = The broad-sense heritability; σ^2G = Variance of genotype; σ^2E = Variance of environment; σ^2G = (MSG-MSE) / r; σ^2E = MSE; MSG=Mean Square Genotype; MSE=Mean Square Environment

In addition, the predictive value of heritability narrow sense is also calculated using the parent-offspring regression [7]. The estimated heritability value of a property is calculated by the formula:

$$\text{Cov (F2 \& F3)} = \frac{\Sigma(F2_i)(F3_i)-(\Sigma F2_i)(\Sigma F3_i)}{n-1}$$

$$\sigma^2 F2 = \frac{\Sigma(F2_i)^2-[(\Sigma F2_i)^2/n}{n-1}$$

$$b = \frac{\text{Cov (F2 \& F3)}}{\sigma^2 F2}$$

$$h^2_{(NS)} = 2b \times 100\%$$

Where: $h^2_{(NS)}$ = The narrow-sense heritability; σ^2F2 = Variance of F2 genotype; σ^2F3 = Variance of F3 genotype; n= number of data; b = The estimated value of comparison between covariant F2 and F3 genotypes with various F2 genotype. Classification of heritability values based on criteria made by Pantalone *et al*. [8]: (1) Low: <0.25; (2) rather low: 0.25-0.50; (3) rather high: 0.51-0.75; (4) High:> 0.75

3. Results and Discussion

3.1 Vegetative growth and flowering age

Table 1 shows the plant height of the F_1 genotype is not significantly different from Local Waxy Corn as one of its parents, while F_2 is shorter than F_1, Srikandi Putih and Local Waxy Corn, but F_3 genotype is highest and significantly than all of the genotype. The number of leaves of F_1 and F_3 genotypes were not significantly different from the parents, but all were higher and significantly different from F_2. Male flowering and female flowering age of F_1 genotype are longer than F_2 and parents. The F_2 genotype flowered fastest than F_1, F_3 and the parents. Male flowering and female flowering age of F_3 genotype is faster than F_1 and Srikandi Putih Variety but not significantly different from local waxy corn. The variation of stem, leaf and flowering growth shows that F_1, F_2 and F_3 genotypes are unstable because gene segregation still occurs.

Table 1. Parameters of vegetative growth and flowering age of 2 varieties and 3 genotypes tested

Treatment	Plant height (cm)	Number of leaves (sheet)	Flowering of age ♂ (day)	Flowering of age ♀ (day)
Srikandi Putih (G_1)	150.9a	13.0a	51.8b	55.3b
Local Waxy Corn (G_2)	123.2b	12.7b	50.0c	51.0c
F_1	114.9b	13.2ab	56.8a	58.6a
F_2	105.2c	12.1c	47.0d	48.3d
F_3	246.6d	13.2ab	49.2e	50.7c
LSD $_{0.05}$	8.31	0.5	0.8	0.8

Note: The numbers followed by the same letter are not significantly different from the $LSD_{0.05}$ test level

3.2 Production parameters

Table 2 shows the weight of 100 seeds and production per hectare in F_1 is not significantly different from Local Waxy Corn and lower is significantly different than Srikandi Putih and F_2. This indicates that F_1 tends to match Local Waxy Corn as one of its parents. On the contrary, the ear length and ear diameter of F_1 and F_3 were not significantly different from Srikandi Putih but both were higher than Local Waxy Corn and F_2. The weight of 100 seeds F_2 genotype is not significantly different from the Srikandi Putih but both are higher than F_1 and Local Waxy Corn and F_3. The weight of 100 seeds F_3 genotype is higher than F_1 and Local Waxy Corn. The length of ear F_2 is not significantly different from Local Waxy Corn and both are lower and different than F_1 and Srikandi Putih.

Table 2. Production parameters of 2 varieties and 3 genotypes tested

Treatment	100 seeds weight (g)	ear length (cm)	ear diameter (cm))	Production.ha^{-1} (ton)
Srikandi Putih (G_1)	34.6a	16.5a	4.7a	11.9a
Local Waxy Corn (G_2)	25.2b	13.9b	3.3c	4.7c
F_1	23.4b	16.5a	4.5a	4.8c
F_2	32.6a	14.7b	3.9b	6.3b
F_3	29,2c	16.3a	4.5a	6.8b
LSD $_{0.05}$	2.9	1.2	0.2	0.9

Note: The numbers followed by the same letter are not significantly different from the $LSD_{0.05}$ test level

F_2 ear diameter is higher and significantly different from Local Waxy Corn but lower than F_1 and Srikandi Putih. Production per hectare of F_2 and F_3 are higher and significantly different from F_1 and Local Waxy Corn, but F_2 and F_3 production are lower than Srikandi Putih. This indicates that segregation is still occurring, resulting in uncertain or unstable results variations.

3.3 Quality parameters

Table 3 shows the highest protein content of corn seeds and the Srikandi Putih variety is significantly different compared to other varieties or genotypes. Protein levels between genotypes F_1, F_2 and F_3 were not significantly different but all three were higher and significantly different compared to Local Waxy Corn.

Table 3. Seed protein and amylopectin levels of 2 varieties and 3 genotypes are tested

Treatment	Protein (%)	Amylopectin (%)
Srikandi Putih (G_1)	10.4.a	81.9c
Local Waxy Corn (G_2)	8.6c	97.8a
F_1	9.3b	92.5b
F_2	9.4b	91.3b
F3	9.3b	91.6b
$LSD_{0.05}$	0.7	1.5

Note: The numbers followed by the same letter are not significantly different from the $LSD_{0.05}$ test level

Table 3 also shows the highest amylopectin levels in Local Waxy Corn seeds and significantly different compared to other varieties or genotypes. Amylopectin levels between F_1, F_2 and F_3 were not significantly different but all three were higher than the Srikandi Putih variety.

3.4 Heritability

Table 4 also shows the heritability values of some agronomic traits of hybridization between Srikandi Putih Variety and Local Waxy Corn. Heritability values ranging from growth parameters to production and quality all show a rather high to high category. This indicates that the factor of genetic influence is greater towards the appearance of the phenotype when compared to the influence of environmental factors. This condition is very good in the selection process because it gives instructions that the selection can continue.

Table 4. The heritability values of some agronomic traits from the crossing of Srikandi Putih Variety with Local Waxy Corn

No	Parameters of Observable Properties	Value of Heritability (broad-sense)	Value of Heritability (narrow-sense)
1	Plant height	0.75	0.61
2	Number of leave	0.71	0.55
3	Flowering age ♂	0.78	0.52
4	Flowering age ♀	0.79	0.64
5	Ear length	0.72	0.56
6	Ear diameter	0.77	0.54
7	Weight of 100 seeds	0.73	0.60
8	Production per hectare	0.78	0.58
9	Protein content	0.53	0.51
10	Amylopectin content	0.60	0.52

Note: *Data is processed using the formula of the broad-sense heritability based on the value of the mean square of the analysis of variance

*Data is processed using the formula of the narrow-sense heritability is used parent-offspring regression

*Criteria: Low: <0.25, rather low: 0.25-0.50, rather high: 0.51-0.75, High:> 0.75

3.5 Discussion

Plant growth, production and yield quality are strongly influenced by genetic and environmental factors. The occurrence of a cross between corn Srikandi Putih variety and Local Waxy Corn has the consequence of changing the character of the generation or genotype of the next generation.

The character height of plants in F_1 and F_2 genotypes decreased but the F_3 genotype increased from the average of both parents, while the number of leaves increased in F_1 and F_3 genotypes but there was a decrease in F_2 genotype. This indicates the occurrence of gene segregation due to hybridization events, thus giving rise to a new generation with different phenotypes with the two parents. Phenotypes change each generation if continuous hybridization is carried out. This event occurs because of changes in gene pairs as an allele and also the environmental factors it receives. Therefore hybridization can increase genetic diversity. This is in line with the results of Hanafi's research *et al.*[9] where plant height and number of leaves on F_1 and F_2 genotypes were different from one or both of the parents. Flowering age of male and female F_1 genotype is longer but F_2 and F_3 genotype are shorter than the average of both parents. This indicates the flowering age also changes due to hybridization events where each parent's character plays a role. Srikandi Putih Variety tend to provide higher growth ranging from plant height, leaf area, age of male flowering and female flowering longer compared to Local Waxy Corn. Only the number of leaves is relatively the same between the Srikandi Putih Variety and Local Waxy Corn [10].

The flowering age of F_1 genotype tends to be influenced by female parent of Srikandi Putih Variety while genotypes F_2 and F_3 tend to be influenced by male parent of Local Waxy Corn. Unlike the case with the results of Hanafi's research et al. [9] the age of male flowering and female flowering did not affect all offspring genotypes tested. The weight of 100 F_1 and F_3 genotypes seeds decreased compared to the average of both parents, but the F_2 genotype increased again approximately 9%. This indicates that the seed weight characteristic of the Srikandi Putih Variety starts to return even though it is not stable. The results showed that the genotype treatment of parents and filial significantly affected the weight of 25 seeds [9].

The ear length and ear diameter of F_1 genotype increased by 8.6% and 12.5% respectively and F_3 genotype increased too by 7,2% and 12,5% respectively compared to the average of both parents, while the F_2 genotype decreased slightly by 3.3% and 2.5% respectively. The same is true for production per hectare wherein F_1 genotypes there is a quite extreme decrease of about 42.2% compared to the average of both parents but in the F_2 and F_3 genotypes the decline has begun to decrease only about 24.1% and 18,1% respectively. This indicates that the ear size and seed weight of Srikandi Putih Variety affect both the length and diameter of ear and seed production per hectare, although these traits still seem unstable. This is in line with Wijaya et al. [11] stated that corn pollen did not give a significant effect on the characteristics of ear length and ear diameter. It can also be explained that the influence of pollen on quantitative characters is still influenced by a female parent because there are several combinations of crosses that only affect the quantitative character without involving qualitative characters (seed color and seed type).

Protein levels in F_1, F_2 and F_3 genotypes decreased respectively 2.1%, 1.1% and 2.1% compared to both parents. This data shows a decrease in protein levels in the F_2 genotype has begun to decrease. This indicates the character of the parent of female Srikandi Putih Variety that has high protein levels have begun to re-appear in the next generation (F_2 and F_3) but also seems unstable. This indicates that there is still segregation of protein regulating genes (opaque-2) in F_2 and F_3 causing the protein content in F_2 and F_3 to decrease compared to Srikandi Putih Variety. Amylopectin levels in F_1, F_2 and F_3 genotypes increased compared to the average of both parents respectively 2.9%, 1.6% and 1.9%. This shows the existence of hybrid vigor on crossing between species. According to Singh et al. [12], hybrid vigor is a heterosis and heterobiltosis phenomenon. Heterosis is the superiority of F_1 hybrids to the average value of the parent. Heterobiltosis is the superiority of F_1 hybrids to the highest value of their parents. The character of these amylopectin levels also appears to have not been stable in F_1, F_2 and F_3 genotypes. Expression of genes carried pollen can be a direct influence on the phenotype of seeds and fruit produced by the female parent. In inheritance studies, gene expression carried by male parent (xenia) and female parent is expressed in the next generation [13].

In general, all the parameters of the characters observed in heritability values of broad-sense (BS) and narrow-sense (NS) are in the category of rather high to high. The heritability of the plant's height 0.75 (BS), 0.61 (NS), number of leaves 0.71 (BS), 0.55 (NS), flowering age ♂ 0.78 (BS), 0.52 (NS), and flowering age ♀ 0.79 (BS), 0.64 (NS), ear length 0.72 (BS), 0.56 (NS), ear diameter 0.77 (BS), 0.54 (NS), weight of 100 seeds 0.73 (BS), 0.60 (NS), seed production per hectare 0.78 (BS), 0.58 (NS), protein content 0.53 (BS), 0.51 (NS), amylopectin content 0.60 (BS), 0.52 (NS). The heritability value is rather high, indicating the progress of breeding for the formation of corn varieties with high amylopectin and protein content. The rather high to high heritability values indicate that selection can be continued because the dominant plant phenotype is influenced by genetic factors. According to Umaharan et al. [14], the greater the estimated value of heritability, the greater the influence of genetic factors. Conversely, the lower the heritability value, the greater the influence of environmental factors.

4. Conclusions

Based on the results of the study, the following conclusions can be drawn:

1. The heritability value of all characters observed is rather high to high.
2. Heritability for the amylopectin parameters 0.60 (Broad-Sense), 0.52 (Narrow-Sense), and the protein 0.53 (Broad-Sense), 0.51 (Narrow-Sense) are rather high.
3. The heritability value is rather high, indicating the progress of breeding for the formation of corn varieties with high amylopectin and protein content.

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