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Estimation of Genetics Variance Components from Composite and Hybrid Maize (*Zea mays* L) Hybridization

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Abstract Hybridization is one of strategy to get potential maize that can grow in dry condition and produce high yield. This research was aimed to examine the changes in genetic variance as a result of the hybridization process and to evaluate genetic parameters of F_1Pioneer 21xPHRKL population. The NC I mating design was used to develop the half-sib and the full-sib families in each population. The Randomized Complete Block Design, with sets nested within blocks, was used to examine hybridization result from both families. This research was used two blocks with 15 sets in each block. The data were analyzed by ANOVA, followed by estimation of genetic variance components; and their differences between two populations were analyzed by using F test. The result indicated that hybridization increased the additive variance of grain yield per plant by15.756 g. The variance was only 4.530±0.382 g.plant^{-1} in PHRKL, but increase until 20.286±1.426g.plant^{-1} in F_1Pioneer 21xPHRKL population. Its dominance variance remained the same. Additive variance of grain yield per plant of F_1Pioneer 21xPHRKL population was higher than its dominance variance. Heritability of grain yield was high; genotypic correlation with ear weight per plant at harvest was positive and significant. Therefore, grain yield improvement of the F_1Pioneer 21xPHRKL population can be done directly or indirectly by selection on ear weight.

Keywords Maize, Hybridization, Yield, Additive variance, Dominance variance

1. Introduction

The population resulted from assembled local cultivars (PHRKL) is a composite maize population that could be expected to be excellent varieties of maize for dry land. This population is obtained from exploration and selection of local cultivars that suitable growing at dry land. The PHRKL population is adaptable to dry land and categorized as early maturing population (around 79 days to maturity). On the other hand, its yield potential and genetic variance are low. Improving the yield is necessary by manipulating the genetic variance of the population. Increasing genetic variance of a population could be achieved through mutation, introduction, collection and hybridization. Hybridization could be done within a population or between populations [1]. We used the hybrid maize because of its higher yield up to 50-100% [2]. Composite and hybrid maize combination is the perfect strategy in hybridization. The maize will resistant in dry condition and can produce high yield. This study aim is to examine the changes in genetic variance as a result of the hybridization process and to evaluate genetic parameters of F_1Pioneer 21xPHRKL population.

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2. Materials and Methods

This research was used two populations; PHRKL and F_1Pioneer 21xPHRKL. PHRKL is a composite population while F_1Pioneer 21xPHRKL is from hybridization between PHRKL and Pioneer 21 hybrid. Establishment of half-sib and full-sib families was conducted from July to October 2014 using North Caroline Mating Design I. Testing of half-sib and full-sib families was carried out on dry land using a pump well from November 2014 to February 2015. The characteristics of the dry land include altitude of ± 50 m above sea level, air temperature of 20 – 39° C, and relative humidity during the test ranged from 45 to 100%. The soil type is regosol with silty loam texture, soil pH 6.23, C-organic 0.55%, N-total 12.08%, available-P 16.04 ppm and exchangeable K 1.55 meq%. The number of progeny tested were 225 full-sib for every population. The experimental design for testing the hybridization result of each population was Randomized Complete Block Design with sets nested within the blocks; in which there were two blocks and 15 sets tested in each block. In each set, there were 15 treatments. Each treatment was planted in one row, as many as 20 plants with space 70 x 20 cm; two seeds per hole. Natural crossing between individuals in F_1Pioneer 21xPHRKL population with individuals in PHRKL population was avoided by time insulation method, i.e.

PHRKL was planted 2 weeks earlier before F_1Pioneer 21xPHRKL. Plant thinning was carried out 2 weeks after by letting grow the one of plant which has better growth of each hole. The plants were fertilized by dibbling Urea and Phonska fertilizers with a dose of 100 and 300 kg per hectare, respectively. The following fertilization was done at 21 days after planting with Urea at 100 kg per hectare. Weeding and piling were done once, i.e. at 21 days after planting. Watering was done by flooding one day before planting and at 2 weeks after planting, and afterwards there was no watering because water from the rain was sufficient.

The observed characters were plant height, number of leaves per plant, days to anthesis, days to silking, anthesis-silking interval (ASI), days to harvest, ear length, ear diameter, ear weight at harvest, and grain yield per plant. The data were analyzed using analysis of variance (ANOVA) based on the NC I mating design. Based on the expected values in the ANOVA, the values of variances for the male parental and female parental of each male parental were obtained. Estimation of genetic variance components (additive and dominance) for each population was obtained from variances of male parental and female parental [3]. Standard deviations for estimators of genetic variance components were calculated according to the formula below [4] (1).

$$SD\ \sigma^2_A/\sigma^2_D=\sqrt{(2)/c^2}\ x\{\sum M_i^2/(df_i+2\} \quad (1)$$

Where M_1 and df_1 are mean square and degree of freedom for calculating additive variance and dominance variance, and c is coefficient of expected mean square value.

The differences of both genetic variance components test was done using F test at 5 percent level of significance. Sattertwaite formula approach was used to estimated the degree of freedom for additive and dominance variances [5]. The magnitude of changes in additive variance or dominance variance was obtained using the following formula (2).

$$\Delta\ \sigma^2_A/\ \sigma^2_D = \{(\sigma^2_A/\sigma^2_D\ F_1\text{Pioneer 21xPHRKL} - \sigma^2_A/\sigma^2_D\ \text{PHRKL})/\sigma^2_A/\sigma^2_D\ \text{PHRKL}\}*100\ \% \quad (2)$$

The narrow sense heritability and the expected selection progress were calculated using formulas above [6].

3. Results and Discussion

The hybridization between PHRKL and Pioneer 21 hybrid to develop the population F_1Pioneer 21xPHRKL was performed to increase the genetic variance components of the yield potential. Due to the correlation between yield and another character, there were possibilities of changes in the genetic variances of other characters. Since the increasing of genetic variance of yield potential was important to developed varieties for dry land. Estimation of genetic variances of both populations was also important, which results are presented in Table 1 for additive variance, and Table 2 for dominance variance.

The additive variance in PHRKL was significant for grain yield per plant, leaf number per plant, days to anthesis, days to silking, ASI, ear weight per plant at harvest, ear length, and days to harvest, while for plant height and ear diameter it is not significant (Table 1). In the F_1Pioneer 21xPHRKL population, additive variance of grain yield per plant and other characters was significant, except for ASI and ear diameter. Similar results were obtained that the additive variance grain yield, days to anthesis, days to silking and ear length was not significant except for ear diameter [7]. Similarly, another research also reported significant additive variances for yield, plant height and ear length [8].

Table 1. Additive variance (σ^2_A) and its changes (Δ) for all characters observed on PHRKL and F_1Pioneer 21xPHRKL populations

No.	Characters observed	Additive variance & standard deviation ($\sigma^2_A \pm$ SD)		Sig.	Changes	
		PHRKL	F_1Pioneer 21xPHRKL		Δ	Δ %
1	Plant height (cm)	4.661 ±10.053*	14.963 ± 1.930**	S	10.302	221.03
2	Leaf number per plant	0.110 ± 0.008**	0.038 ± 0.006**	S	-0.072	-65.45
3	Days to anthesis	0.689 ± 0.047**	0.064 ± 0.014**	S	-0.625	-90.71
4	Days to silking	0.694 ± 0.048**	0.099 ± 0.016**	S	-0.595	-85.73
5	ASI (days)	0.047 ± 0.011**	0.002 ± 0.006*	S	-0.045	-95.74
6	Ear weight at harvest (g plant^{-1})	12.585 ± 0.964**	42.273 ± 3.337**	S	29.688	235.90
7	Ear length (cm)	0.024 ± 0.004**	0.126 ± 0.009**	S	0.102	425.00
8	Ear diameter (cm)	0.004 ± 0.0003*	0.003 ± 0.002*	Ns	-0.001	-25.00
9	Grain yield (g plant^{-1})	4.530± 0.382**	20.286 ± 1.426**	S	15.756	347.81
10	Days to harvest	0.231 ± 0.021**	0.261 ± 0.021**	Ns	0.03	12.99

Remarks: ** = significant variance; * = non-significant variance; s = additive variance between PHRKL and F_1Pioneer 21xPHRKL is significant according to $F_{0.05}$, and ns = not significantly different.

Table 2. Dominance variance (σ^2_D) and its changes (Δ) for all characters observed on PHRKL and F_1Pioneer 21xPHRKL populations

No.	Characters observed	Dominance variance & standard deviation (σ^2_D±SD)		Sig.	Changes	
		PHRKL	F_1Pioneer 21xPHRKL		Δ	%
1	Plant height (cm)	118.41 ± 22.63**	11.91 ± 3.319**	s	-106.50	-89.94
2	Leaf number per plant	0.029 ± 0.010**	0.042 ± 0.012**	ns	0.01	44.83
3	Days to anthesis	0.419 ± 0.058**	0.213 ± 0.026**	ns	-0.21	-49.16
4	Days to silking	0.383 ± 0.060**	0.146 ± 0.029**	ns	-0.24	-61.88
5	ASI (days)	0.036 ± 0.022*	0.048 ± 0.013**	ns	0.01	33.33
6	Ear weight at harvest (g plant^{-1})	2.283 ± 1.306*	12.575 ± 4.578**	s	10.29	450.81
7	Ear length (cm)	0.072 ± 0.007**	0.015 ± 0.011*	ns	-0.06	-79.17
8	Ear diameter (cm)	0.0001 ± 0.0005*	0.017 ± 0.006**	s	0.02	16900.0
9	Grain yield (g plant^{-1})	2.172 ± 0.542**	2.463 ± 1.837*	ns	0.29	13.40
10	Days to harvest	0.206 ± 0.031**	0.019 ± 0.027*	ns	-0.19	-90.78

Remarks: ** = significant variance; * = non-significant variance; s = dominance variance between PHRKL and F_1Pioneer 21xPHRKL is significant according to $F_{0.05}$, and ns = not significantly different.

Hybridization could increase the additive variance of grain yield by up to 15.756 g plant^{-1} (347.81 percent), which led to significant differences between the two populations, i.e. between 4.530 ± 0.382 g plant^{-1} on PHRKL and 20.286 ± 1,426 g plant^{-1} on the F_1Pioneer 21xPHRKL population (Table 1). Large increases in additive variances also occur in other characters, so that additive variances in F_1Pioneer 21xPHRKL population are greater than those in PHRKL population, such as for plant height, ear weight per plant at harvest, and ear length, with increase of 221.03%, 235.9%, and 425.0%, respectively. The highest additive variance was obtained on the ear weight in both populations, i.e. 42.273±3.337 g plant^{-1} on F_1Pioneer 21xPHRKL, and 12.585±0.964 g plant^{-1} on PHRKL. On the other hand, additive variance for some characters significantly decreased due to hybridization, so that it was significantly smaller in F_1Pioneer 21xPHRKL than in PHRKL, such as occurred in leaf number per plant, days to anthesis, days to silking and ASI. However, 25.00 percent decrease of additive variance for ear diameter and 12.99 percent increase in the days to harvest of did not cause significant difference in additive variance between both populations.

The dominance variance was significant for plant height, leaf number, days to anthesis, days to silking, ear length, grain yield per plant and days to harvest in the PHRKL population, while it was non-significant for ear weight per plant when harvest, ASI and ear diameter (Table 2). The dominance variance in the F_1Pioneer 21xPHRKL population was non-significant for ear length, grain yield and days to harvest, whereas for the other characters they were significant. However, 13.40 percent increase in dominance variance for grain yield as a result of hybridization has not led to significant differences between two populations. Large increases in dominance variance are obtained on ear weight per plant at harvest (450.81 percent) and ear diameter (16900 percent), so that the dominance variance in F_1Pioneer 21xPHRKL is significantly greater than in PHRKL for the two characters. Another characters show small changes in dominance variance, so that both populations are still the same, except for plant height, where hybridization caused a decrease in the dominance variance up to 89.94 percent and delivered a significant difference between two populations. The highest dominance variance in the F_1Pioneer 21xPHRKL population was obtained on ear weight per plant at harvest, i.e. 12.575 ± 4.578 g plant^{-1}, but in PHRKL, it was the highest on plant height, i.e. 118.41 ± 22.63.

Based on the above explanation, hybridization of PHRKL with Pioneer 21 hybrid had led to changes in the genetic variance components. Increased additive variances occurred in grain yield per plant, plant height, ear weight per plant at harvest, and ear length. Additive variance is derived from the magnitude of differences between alleles in each locus and between alleles among loci. The greater the differences makes the greater the additive variances of each population. Additive variance for grain yield in the F_1Pioneer 21xPHRKL population is greater than in the PHRKL population, indicated that the magnitude of differences between alleles in each locus and between loci for the characters was greater in F_1Pioneer 21xPHRKL than in PHRKL population. Such differences might occurred due to large differences frequency of alleles that controlled grain yield between PHRKL population and the hybrid. This is in accordance with the opinion that the magnitude of changes in genetic variance due to hybridization depends on differences in the frequency of alleles and level of dominance of the improved character between the two parents [9]. The high number of heterozygous genes in the composite population of PHRKL also provides the opportunities of additive variance increase of grain yield and other characters. This is in accordance with another the opinion that there will be significant differences between offspring (high variances) if the parents have a lot of heterozygous loci; while dominance variance will result in the same population [10]. This means that hybridization did not cause differences of the

interactions between alleles within the locus. Increased dominance variance for ear weight per plant at harvest and for ear diameter could due to greater differences in the interactions between alleles within each locus of the results of the hybridization. This could be caused by different levels of dominance of the two characters between PHRKL and the Pioneer 21 hybrid.

Genotypic correlation between grain yield and other characters could caused changes of variance components in the hybridization results. The closeness of the genetic relationship between the characters could be seen from their genotypic correlation coefficients. This was evident from plant height, ear weight per plant at harvest, and ear length that showed significant and positive genotypic correlation coefficients with grain yield (Table 4), which also resulted in increased additive variance on those characters. The genetic variance increase of grain yield and other characters indicated that the F1Pioneer 21xPHRKL population could be used as the base population and the subsequent studies could be directed to that population. Furthermore, the topics would been studied include the difference in the value of additive and dominance variances, heritability, genotypic correlation, and expected selection progress.

Selection of proper breeding program was determined by the difference in additive and dominance variances of a population. In order to determine the significant differences between the two variances, the F test has been done based on the amount of additive variance in Table 1 and dominance variance in Table 2 for the F_1Pioneer 21xPHRKL population. The amounts of additive variance, dominance variance and F-calc for each character in the F_1Pioneer 21xPHRKL are presented in Table 3.

The additive variance was significantly higher than dominance variance of grain yield in the F_1Pioneer 21xPHRKL population (Table 3) suggested that the variation of alleles for grain yield contributed greater than the variation of interactions between alleles within each locus. The same results were obtained in Mahidhawal maize (open pollinated) by Kumar *et al*. that the additive variance for grain yield was greater than its dominance variance [11]. Wattoo *et al*. also obtained greater additive variances than the non-additive variances in six pure lines [12]. However, some contrary results were obtained by some researchers, i.e. greater dominance variance of grain yield than its additive variance, might be caused by the different populations used. Some of these researchers are used synthetic varieties [13], and Hadini *et al*., who used a population in Hardy-Weinberg equilibrium [3], Wannows *et al.* and Shahrockhi *et al*., who used six generations from crossed-maize of KE72012 (P1) x K1263/1 (P2) [8, 14], and Rezaei and Roohi, who used 60 pure lines of yellow maize [15]. Other characters was showing larger additive variance than its dominance variance in the F_1PHRKLxPioneer 21 population are: ear weight per plant at harvest, ear length, and days to harvest. Chohan *et al*. and Hadini *et al*. obtained the same result for ear length [16, 3]. The characters that has the same additive and dominance variances are: plant height, leaf number, days to silking, ASI, and ear diameter. A similar result was obtained by Wannow *et al*. for days to silking and ear diameter [8]. For the character of days to anthesis, the dominance variance is higher than its additive variance, meaning that the character is controlled by a dominance gene action. A similar result was reported by Silva *et al*. [17].

Since the additive variance of grain yield was higher than its dominance variance, then improvement of the character could been done using selection method. The accuracy of the selection method required other values of genetic parameters, i.e. the narrow sense heritability and genotypic correlation coefficient [8]. In addition, the value of heritability could be used to determine the expected selection progress. The phenotypic variance, heritability, genotypic correlation coefficients and the expected selection progress for the F_1Pioneer 21xPHRKL population are presented in Table 4.

Table 3. F test for the additive variance and dominance variance of all characters observed in the F_1PHRKLxPioneer 21 population

No.	Characters observed	Additive variance	Dominance variance	F-calc.	Sig.
1	Plant height (cm)	14.963	11.91	1.257	Ns
2	Leaf number per plant	0.038	0.042	1.105	Ns
3	Days to anthesis	0.064	0.213	3.328	S
4	Days to silking	0.099	0.146	1.475	Ns
5	ASI (days)	0.002	0.048	24.000	Ns
6	Ear weight at harvest (g plant^{-1})	42.273	12.575	3.362	S
7	Ear length (cm)	0.126	0.015	8.400	S
8	Ear diameter (cm)	0.003	0.017	5.667	Ns
9	Grain yield (g plant^{-1})	20.286	2.463	8.236	S
10	Days to harvest	0.261	0.019	13.737	S

Remarks: s = significant based on F test at 5% level of significance; ns = non-significant.

Table 4. Phenotypic variance (σ^2_P), narrow-sense-heritability (h^2), genotypic correlation coefficient (r_g) between grain yield per plant with other characters, and the expected selection progress (Δ_G) for the F_1Pioneer 21xPHRKL population

No	Characters observed	σ^2_P	h^2 (%)	r_g with grain yield	Δ_G [a)]
1	Plant height (cm)	53.256	28.10	0.223 **	4.22 (2.27)
2	Leaf number per plant	0.1847	20.57	0.072 ns	0.18 (1.51)
3	Days to anthesis	0.476	13.45	-0.052 ns	0.19 (0.46)
4	Days to silking	0.482	20.54	-0.017 ns	0.29 (0.57)
5	ASI (days)	0.188	1.06	0.012 ns	0.009 (0.28)
6	Ear weight at harvest (g plant^{-1})	76.832	55.02	0.805 **	9.94 (6.22)
7	Ear length (cm)	0.182	69.23	0.386 **	0.61 (4.51)
8	Ear diameter (cm)	0.08	3.75	0.336 **	0.02 (0.46)
9	Grain yield (g plant^{-1})	30.473	66.16	1.00	7.52 (8.21)
10	Days to harvest	0.526	49.62	-0.023 ns	0.74 (0.87)

Remarks: ** = significant at p-value <0.01; ns = non-significant; [a)] the figures in brackets are indicates the expected selection progress in percent (%)

The narrow sense heritability (h^2) is the ratio of the additive to the phenotypic variances. The heritability could be give an idea for the suitability of the selection methods since it related to the additive gene action [5]. According Stansfield, the classification of heritability are low (<20%), moderate (20 - 50%), and high (> 50%) [18]. The narrow sense heritability of grain yield was high, amounting to 66.16 percent (Table 4). Other characters showed high heritability are ear weight per plant at harvest and ear length, with the values of 55.02 percent and 69.23 percent, respectively. Wannows *et al*. also reported high narrow sense heritability, i.e. 73 percent [8], while Hefny obtained a moderate heritability for yield at 40.65 percent [6]. Chohan *et al*. was also obtained moderate heritability for yield potential [16]. In this research, the heritability for plant height, leaf number, days to silking, and days to harvest were moderate, whereas days to anthesis, ASI and ear diameter were low. High narrow sense heritability indicated that contribution of additive variance effect was greater in the inheritance of these characters. Selection of early generations is more effective to develop these characters [8], and huge progress of selection could be obtained if selection also conducted on that character [5]. Selection process could been done directly or indirectly. Genotypic correlation coefficients are required for indirect selection. This type of selection would be more advantageous if the selected character has high genotypic correlation and greater heritability value than the characters that had been improved. Moreover, genotypic correlation coefficient is important for simultaneous selection, i.e. selection for multiple characters at once, so that the accompanying selection responses (correlated responses) could not been avoided [17].

The ear weight per plant at harvest showed a positive and highly significant genotypic correlation coefficient with grain yield, with a coefficient value of 0.805 (Table 4). Ear length, ear diameter, and plant height also had positive and highly significant genotypic correlation with grain yield but the coefficient values were smaller than the value for ear weight per plant at harvest, while the values for leaf number, days to anthesis, days to silking, ASI and days to harvest were not significant. Similar results were also obtained by Silva *et al.* for plant height and ear length [17], Abdalla *et al*. for plant height and ear weight at harvest [13], and Wannows for ear diameter [8]. Genotypic correlation was caused by pleiotropy and linkage disequilibrium. Pleiotropy is an event when a gene (allele) at one locus or a set of genes at several loci controls two or more different characters, whereas linkage is an event in which two or more genes located on the same chromosome tend to be inherited together [5].

The narrow sense heritability for ear weight per plant at harvest was high (55.02 percent) and the additive variance was higher than its dominance variance (Table 4). The expected selection progress for this character was not much different from grain yield, i.e. 6.22 and 8.21 percent, respectively. Therefore, ear weight per plant at harvest could be considered for character selection in order to yield potential improvement. Plant height, ear length, and ear diameter was also showed significant genotypic correlation with grain yield, but the values of the coefficients were smaller, i.e. 0.223, 0.386 and 0.336 respectively, while leaf number per plant, days to anthesis, days to silking, ASI and days to harvest showed non-significant genotypic correlation coefficients. The expected selection progress for those characters were smaller than that of grain yield, i.e. 2.27, 4.51 and 0.46 percent respectively for plant height, ear length, and ear diameter. Therefore, these characters could not be used as indirect selection criteria for improving yield potential of the F_1Pioneer 21xPHRKL population.

4. Conclusions

Hybridization increased the additive variance of grain yield by 15.756 g plant^{-1}. The variance was only 4.530 g plant^{-1} in PHRKL, increased to 20.286 g plant^{-1} in F_1Pioneer

21xPHRKL population, while their dominance variance remained the same. Additive variance of grain yield in F_1Pioneer 21xPHRKL was greater than its dominance variance. Heritability of grain yield was high; genotypic correlation with ear weight per plant at harvest was significantly positive. Therefore grain yield improvement for this population could be done directly through mass selection or indirectly through ear weight.

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