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Estimates of genetic parameters in a maize composite and potential for recurrent selection

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ABSTRACT - *The genetic variability in the maize composite I - Mo, from the improvement program of the Instituto Agronômico de Campinas (IAC), was evaluated. Eight trials of half-sib families with 25 families each, the composite, and a commercial control AL 30 were conducted at the IAC. Individual and combined variance analyses of trials were performed and genetic variance components estimated for ear yield (EY), plant height (PH), and ear height (EH). A high additive variance value was obtained for EY, in contrast to values found in literature, indicating that composites have large variability and are promising for recurrent selection programs. The VC_G/VC_E index of 0.7 for EY indicated suitability for selection. Assuming a 20% selection of best families, an expected selection gain of 7.9% was estimated. Composite I - Mo has great genetic variability and a remarkable potential for breeding via recurrent selection, promising considerable selection gains in yield.*

Key words: maize, composite, additive variance, heritability, selection gain.

INTRODUCTION

Population improvement is an essential aspect in corn breeding programs, since it allows the exploitation of genetic variability and an increased frequency of favorable alleles which determine characters of agronomic interest. The choice of the population to be improved is crucial to obtain selection gains and furthermore a determinant factor for success in recurrent selection programs. The achievement of new maize varieties via recurrent selection aims mainly at attending the needs of small farmers, which is a goal of the IAC maize improvement program. In general, such programs use different population types, including composites, synthetics, F_2 populations, open-pollinated varieties, and intervarietal hybrids. It is important to asses the magnitude of genetic variability of these populations, mainly through estimates of additive variance and the coefficient of heritability, which determine the selection gain.

Estimates of the genetic variance components are obtained by means of an adequate experimental design. The quantity of exploited variance depends on which kind of family is used, which are most frequently half-sib families. The selection method among and within half-sib families (Paterniani 1967) has been broadly applied by maize breeders, owing to its relative simple procedure and satisfactory effect (Paterniani and Campos 1999). These authors present results of recurrent selection with half-sib families in several maize populations.

Composite populations result from crosses in a fixed set of varieties, either by crossing in all possible combinations of parent varieties (diallel cross) followed by recombination and homogenization or simply mixing equal quantities of the parent varieties followed by random mating in an isolated block of open-pollination. In either case, the proportion of participation of each parent variety in the composite is approximately equal and small differences in that proportion are due to variation in sampling gametes in hand pollination or to random distribution of male gametes in an open-pollination scheme (Hallauer and Miranda Filho 1995).

The Composite I - Mo is a result of intercrossing among commercial hybrids with high yield, stability, focusing on the semi-flint and flint endosperm type and orange-yellow color

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of grains. The composite underwent two recombination cycles and mass selection for earliness, disease resistance, and short plants.

The objective of this study was to evaluate the potential of the Composite I – Mo for recurrent selection, by means of estimates of genetic parameters of heritability and additive variance, and a prediction of the gain from selection with half-sib families.

MATERIAL AND METHODS

Two hundred half-sib families of the Composite I - Mo were evaluated in 2000/01, with the objective of estimating genetic parameters and evaluating the genetic variability and selection gain. Eight trials were developed in a randomized complete block design with three replications at the IAC (Campinas), with 25 families, and the Composite (original population), while variety AL 30 was used as commercial control. Each plot consisted of a row of four meters, with spacing of 0.90 m between the rows and 0.20 m between plants. The following characters were evaluated: plant height, ear height, and hulled ear weight. The ear yield was corrected to an ideal stand of 20 plants. Thereafter, the individual and combined variance analyses of trials were carried out to estimate genetic parameters, according to Vencovsky and Barriga (1992).

Expectations of the mean squares were obtained from the combined analysis of variance as follows:

$$E(MS_1) = \sigma^2 + r\,\sigma^2_F \quad \text{and}$$

$$E(MS_2) = \sigma^2$$

where

MS_1 is the mean square of families, MS_2 is the mean square of Error, and r is the number of replications.

Estimates of the variance components were given by:

$$\hat{\sigma}^2 = MS_2$$

$$\hat{\sigma}^2_F = \frac{MS_1 - MS_2}{r}$$

Additive genetic variance was estimated by:

$$\hat{\sigma}^2_A = 4\hat{\sigma}^2_F$$

The heritability coefficient at the level of family means was obtained by:

$$\hat{h}^2_m\% = 100\,\frac{(MS_1 - MS_2)}{MS_1}$$

An expected gain, assuming a selection of 20% of the best half-sib families, was estimated by:

$$\hat{G}_s = k\,\frac{1/4\hat{\sigma}^2_A}{\hat{\sigma}_F}$$

where

k = 1.40 is the selection intensity that corresponds to a selection percentage of 20% of the families and σ_F is the phenotypic standard deviation of family means.

The genetic and environmental variation coefficients were also obtained:

$$\hat{CV}_g = \frac{\hat{\sigma}_p}{\bar{\bar{Y}}}100$$

$$\hat{CV}_e = \frac{\hat{\sigma}_e}{\bar{\bar{Y}}}100$$

where $\bar{Y}$ is the mean of half-sib families.

RESULTS AND DISCUSSION

In general, means of the three characters in the eight trials showed that the half-sib families from the maize composite I – Mo did not perform as well as the commercial control (Table 1). Significance was stated among progenies for all traits, except for ear yield in trial 3 and 7, and plant height and ear height in trial 6 (Table 2). In the combined analysis, the mean square of progenies was significant ($P < 0.01$) for the three traits, giving evidence of the high genetic variability.

Table 1. Means ($\bar{Y}$) of three characters in eight trials with half-sib families of the maize Composite I - Mo and mean percentage ($\bar{Y}$%) in relation to the commercial control

Trials	Ear yield		Plant height		Ear height	
	$\bar{Y}$	$\bar{Y}$ (%)	$\bar{Y}$	$\bar{Y}$ (%)	$\bar{Y}$	$\bar{Y}$ (%)
	g plant^{-1}		cm			
1	185.6	74.2	232.2	93.2	126.8	84.7
2	181.5	80.9	232.4	92.5	127.2	86.5
3	172.7	94.4	224.6	91.4	122.2	81.8
4	169.6	85.6	223.7	90.9	122.1	86.7
5	177.3	73.0	224.0	86.7	122.4	79.6
6	179.0	73.6	220.0	84.3	118.2	74.5
7	194.0	88.3	220.6	91.6	120.1	77.5
8	162.5	76.1	214.8	91.0	113.4	73.6

The experimental variation coefficients (VC_E) (Table 3) of the eight trials varied from 10.5 to 15.8% for ear yield; 4.0 to 5.8% for plant height, and 6.2 to 10.0% for ear height, indicating a high experimental precision. Significance was stated among families for all characters, except for ear yield in trial 3, and plant height and ear height in trial 6. In the combined analysis, the mean square of families was significant ($P < 0.01$) for the three characters, giving evidence of the high genetic variability.

Estimates of additive genetic variance among families ($\hat{\sigma}^2_A$) were expressive (Table 3) for all evaluated characters, suggesting expressive high variability and the possibility of gain with ongoing new selection cycles. The estimate of 821.56 (in g $plant^{-1}$) for ear yield of the genetic additive variance ($\hat{\sigma}^2_A$) was considered high when compared to the values presented by Hallauer and Miranda Filho (1995), based on the average of 99 studies, where $\hat{\sigma}^2_A$ was 469.1. Vencovsky et al. (1988) realized a broad survey of estimates of the additive genetic variances on an intrapopulational level in Brazilian populations for yield. Table 4 shows updated estimates for these populations of different origins (Silva 2001). As shown in Table 4, Paterniani et al. (2000) presented $\hat{\sigma}^2_A$ estimates of 623.3 (in g $plant^{-1}$) for variety IAC V3.

On the other hand, our results were superior to the ones obtained by Nass and Miranda Filho (1999, 2000), who obtained a $\hat{\sigma}^2_A$ of four composites varying from 502 to 762 (in g $plant^{-1}$) and 99.2 to 152.2 (in g $plant^{-1}$), respectively. Thus, there is evidence that composites and synthetics have a great genetic variability and are promising materials for recurrent selection programs. Values of $\hat{\sigma}^2_A$ = 253.19 cm^2 and 199.93 cm^2 were obtained for plant height and ear height, respectively, in line with those reported by Hallauer and Miranda Filho (1995). In a number of Brazilian populations, Santos (1985) verified $\hat{\sigma}^2_A$ estimates for plant height and ear height ranging from 176.56 to 668.0 cm^2.

The coefficient of heritability at the level of ear weight means ($h^2 = 0.54$) corroborated the results obtained by Nass and Miranda Filho (1999); for plant height and ear height the values were lower, suggesting a smaller genetic variability

Table 2. Mean squares of the variance analyses of three traits in half-sib progenies of the maize composite IAC Mococa

Trials	Ear weight		Plant height		Ear height	
	Progenies	Error	Progenies	Error	Progenies	Error
1	1811.40**	441.38	366.67**	112.55	381.45**	108.03
2	1281.33**	402.31	256.39**	87.82	234.89**	75.51
3	906.73	640.41	369.83*	181.60	301.50**	109.50
4	946.87**	309.75	416.60**	117.04	290.04*	158.16
5	701.75*	380.66	202.31**	80.03	199.42**	55.76
6	1571.83**	577.18	128.16	126.45	162.52	126.43
7	923.27	657.61	428.64**	113.02	279.41**	132.96
8	1062.65*	607.14	249.65**	80.59	211.78**	95.12
Combined	1143.23**	527.06	302.28**	112.39	257.63**	107.68

*and **: Significant at 5 and 1% by the Test F, respectively.

Table 3. Family means, additive genetic variance ($\hat{\sigma}^2_A$), coefficients of genetic variation (VC_G) and environmental variation (VC_E), and coefficient of heritability at the level of means (h^2_m) of the maize Composite I - Mo, obtained with 200 half-sib families

Estimates	Plant height	Ear height	Ear yield
	cm	cm	g $plant^{-1}$
$\hat{\sigma}^2_A$	253.19	199.93	821.56
h^2_m %	62.80	58.2	53.9
VC_G %	3.52	11.43	7.86
VC_E %	4.70	8.39	12.59
Mean (family)	225.82	123.67	182.40
Mean (Composite I – Mo)	225.62	122.54	186.75
Mean (AL 30)	248.50	151.04	222.70

Table 4. Estimates of additive genetic variance for yield (g $plant^{-1}$) in several Brazilian maize populations

Population	Additive variance	References
CEX-1, CEX-2, CEX-3, CEX-4	146.64 to 970.48	Cunha (1996)
CMS-42	180.97	Pacheco et al. (1998)
CMS-43	486.85	Pacheco et al. (1998)
CMS-453	103.38 to 398.16	Carvalho et al. (2000a)
NPH-PM	91.11	Costa et al. (2000)
IAC V3	623.30	Paterniani et al. (2000)
Caraíba	278.28	Mesquita et al. (2000)
Samambaia	283.58	Mesquita et al. (2000)
BR 5011 Sertanejo	171.80 to 865.00	Carvalho et al. (2000b)
Composite Flintisa	595.92	Anjos and Andrade (2000)
Brazilian pop (s).	41.00 to 753.00	Vencovsky et al. (1988)
Brazilian pop (s).	85.94 to 316.00	Nass (1992)
Brazilian pop (s).	73.40 to 677.38	Cunha (1996)

Source: Silva (2001).

among families for these characters. Estimates of the heritability coefficient obtained by Cunha (1996) and Carvalho et al. (2000a, b) lie in a range of 17.6 to 57.5%.

The VC_G/ VC_E index (from Table 3), a relative measure of the genetic variability, presented a value of 0.7 for ear weight, indicating a favorable situation for selection. For plant height and ear height, estimates of the index close to or above 1.0 also indicated high genetic variability and the possibility of successful selection.

Assuming a 20% selection of the best families, the expected gain in the population mean is estimated at 7.9%. This means, based on the yield of the Composite I - Mo population with 186.75 g $plant^{-1}$, that there is a possibility to attain a yield of around 11.0 ton ha^{-1}. The conclusion was drawn that the Composite I - Mo population has considerable genetic variability and presents a remarkable potential for improvement via recurrent selection, which may give rise to considerable selection gains in ear yield.

Estimativas de parâmetros genéticos em um composto de milho e seu potencial para seleção recorrente

RESUMO - *Investigou-se a variabilidade genética do Composto I - Mo do programa de melhoramento de milho do Instituto Agronômico de Campinas (IAC). Para isso foram instalados oito ensaios com 25 famílias de meios-irmãos cada, mais a população original e a testemunha comercial AL 30. Procederam-se às análises individuais e combinada da variância visando estimar componentes de variância para produtividade de espiga (PE), altura de planta (AP) e de espiga (AE). Obtiveram-se valores altos de variância aditiva para PE, comparativamente aos da literatura, evidenciando que compostos têm elevada variabilidade genética, sendo promissores para seleção recorrente. A razão* CV_G/CV_E,, *apresentou valor de 0,7 para PE, indicando situação favorável para seleção. Com a seleção de 20% das melhores famílias, estima-se um ganho esperado de 7,9%. O composto I-Mo tem grande variabilidade genética, com significativo potencial para melhoramento via seleção recorrente, acenando com ganhos de seleção consideráveis em produtividade.*

Palavras-chave: milho, variedade, variância aditiva, herdabilidade, ganho com seleção.

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