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Predicting the genetic gain in the Brazilian white maize landrace

Predição de ganho genético em população crioula de milho branco

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ABSTRACT

The objectives of this research were to evaluate the genetic variability and predict genetic gain in the white maize landrace rescued in Barbacena, Minas Gerais, Brazil. The Brazilian maize landraces have economic and social importance for certain areas in Brazil, and research on this germplasm is very important for local food security. Three experiments were carried out with 100 half-sib progenies, in Campos dos Goytacazes, RJ, Coimbra and Barbacena, Minas Gerais, Brazil. These sites were chosen for their soil and climatic differences. An analysis of variance was significant among the progeny for all characters, indicating the presence of genetic variability between the three populations. In Campos dos Goytacazes and Coimbra, the genetic variation of the white maize landrace was responsible for most of the phenotypic variance in grain yield and can be used in selection cycles. There was no significant genetic variance in grain yield in Barbacena. For the white maize landrace it was concluded that: the characters of the component of productivity such as plant density and number of plants with kernels can produce indirect genetic gain for grain yield and are suitable for breeding; prebreeding of the maize landrace is necessary before being used directly in the elite germplasm; the population contains high genetic variability and opportunities for genetic gain; the average agronomic traits are suitable only for traditional production systems with few inputs, and polyculture; the difference between environments produces specific responses in the progeny i.e. there is a progeny x environment interaction.

Key words: *selection, rescue, breeding.*

RESUMO

Os objetivos deste trabalho foram avaliar a variabilidade genética e predizer os ganhos genéticos de uma população crioula de milho branco resgatada em Barbacena, Minas Gerais (MG), devido à importância social e econômica do milho branco em determinadas localidades brasileiras, à manutenção e ao resgate de populações crioulas e aos poucos trabalhos sobre esse tipo de grão. Para tanto foram instalados três experimentos, com 100 progênies de meios-irmãos, em Campos dos Goytacazes, Rio de Janeiro (RJ), Coimbra e Barbacena (MG), escolhidos pelas diferenças edafoclimáticas. Pela análise de variância foram verificadas diferenças significativas entre as progênies para todos os caracteres, o que indicou a presença de variabilidade genética na população para os três locais. Em Campos dos Goytacazes e Coimbra, a variância genética da população crioula de milho branco foi responsável pela maioria da variância fenotípica para produtividade de grãos, podendo ser explorada em ciclos de seleção. Em Barbacena, não foi detectada variância genética significativa para a produtividade de grãos. Para a população crioula de milho branco Barbacena, conclui-se que caracteres do componente primário de produtividade como estande final e número de plantas com grãos podem apresentar ganhos genéticos direto e indireto com a produtividade e são adequados para o melhoramento. No entanto, é necessário o pré-melhoramento da população antes desta ser utilizada diretamente em germoplasma elite. Além disso, foi observado que a população apresenta variabilidade genética e ganhos genéticos preditos altos; as médias das características agronômicas são adequadas somente para o sistema produtivo tradicional com poucos insumos e policultivo; e a diferença entre os ambientes proporciona resposta específica das progênies, ou seja, interação progênie x ambiente

Palavras-chave: *seleção, resgate, melhoramento.*

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INTRODUCTION

The white maize variety is little known in Brazil and is cultivated mainly by farmers in certain localities of the country, such as the state of Paraná, and may occur in isolated plantations of Minas Gerais and Santa Catarina (WIKIPÉDIA, 2007). In the city of Barbacena, Minas Gerais, it has been the tradition of small farmers to plant white maize, saving their seeds from year to year to be used for planting the following season. In this city, white maize is traditionally used by farmers, either in their own food, or to obtain silage and feed for small animals (chicken and swine). On the other hand, white maize is the main source of income for many small farmers in the region, who live off the products of white maize as well as maize flour and 'canjica' sold in local markets. The maize landrace is less productive than the cultivars, but it is an important source of genetic variability, which can be exploited in the search for genes that are tolerant or resistance to biotic and abiotic factors (SOARES et al., 1998; ARAÚJO & NASS, 2002). The 'Barbacena' white maize landrace evaluated in this work has some undesirable characteristics for the modern production system because the plants are extremely tall, between 3.0m and 4.0m, and it does not support high plant density. The cultivars 'IPR 119' and 'IPR 127' were recommended to provide white maize varieties adapted to modern production systems for small farmers by the Instituto Agronômico do Paraná (IAPAR) (GOVERNO DO PARANÁ, 2007). Such cultivars provide an alternative to traditional yellow maize because the white maize has low seed prices and can be used to produce white 'canjica' and white flour.

The agronomic traits of economic importance are quantitative, and are controlled by many genes and environmental interactions. Phenotypic variance of characters is due to genetic and environmental effects, and the interaction of these (HALLAUER & MIRANDA FILHO, 1981). Additive and dominance genetic variance, heritability and genetic correlations are among the genetic parameters, and are the most important for selection of the population base and to define the most appropriate method of selection (COCRHAM & COX, 1957; LORDELO, 1982; BORÉM & MIRANDA, 2005). Knowledge about these genetic parameters is important to estimate the heritability and predict genetic gain with cycle of selection and the relative effectiveness of the methods of breeding (COMSTOCK & ROBINSON, 1948; MARQUEZ-SANCHEZ & HALLAUER, 1970; HALLAUER & MIRANDA FILHO, 1981).

Several studies have been conducted with the aim of understanding the genetic variability and the potential for character selection in the maize population, as well as to provide information on the agronomic characteristics and the potential grain yield of these populations so that they can be used for profit in plant breeding programs (RAMALHO, 1977; LIMA et al., 1988; GAMA et al., 1999). The method of selection among and within half-sib progenies is widely used to improve maize populations. This involves undergoing a few cycles of selection using only 25% of additive genetic variability, and because of its easy implementation, allows faster achievement of genetic gain and the possibility of conducting two cycles of selection in one year (PATERNIANI, 1967; CARVALHO et al., 1998; BORÉM & MIRANDA, 2005). Several studies have demonstrated the efficacy of this method of selection, focusing on aspects of the magnitude of genetic parameters, including the additive genetic variance (RAMALHO, 1977; HALLAUER & MIRANDA FILHO, 1981).

The objectives of the study were to assess the genetic variability and predict the genetic gains, with a cycle of selection of half-sib progenies in the white maize landrace.

MATERIAL AND METHODS

Three experiments were conducted from November 2005 at the following sites: 1) the Agricultural School "Antônio Sarlo," in Campos dos Goytacazes, RJ (21°45'15''S and 41° 19'28''W) at 14m above sea level; 2) the Experimental Station of the Viçosa Federal University in Coimbra-MG (20° 50'30 "S and 42° 48'30" W), at 715m above sea level; and 3) at "Barro Preto" in Barbacena-MG (21°13'33 "S and 43°46'25" W), 1.165m above sea level.

The Barbacena white maize landrace has been structured in half-sib progenies and subjected to selection among and within the half-sib progeny. Thus, we selected 100 cobs stored by a farmer in the region of Barbacena, Minas Gerais, Brazil, which represent 100 half-sib progenies. Subsequently, the 100 progeny were evaluated for agronomic performance, with three replicates. Finally, the ten best progeny were crossed. The criteria for selection of ears were ear size, appropriate husk cover and the absence of pests. A total of 100 ears were separated, identified and stored by the Programa Milho® of Viçosa Federal University. Each ear was a half-sib family.

The experimental design was the triple lattice 10 X 10. The experimental plot consisted of a 3.0m long row (LIMA et al., 2000; RAMALHO et al., 2001), with 1.0m between rows and 0.20m between holes. Six seeds were used per meter to obtain a population equivalent to 50,000 plants per hectare. The plants were not thinned, as we wanted to determine the effect of physiological properties of the seeds on final stand because farmers use low plants densities and this is not associated with the seed germination of the half-sib progenies.

The same fertilizer was used in all experiments, with 300kg ha^{-1} of NPK, 8-28-16 at planting and a further application of 60kg of $nitrogen.ha^{-1}$, in the form of ammonium sulfate, when the plant reached the six-leaf stage. Invasive plants were controlled, but not pests or diseases.

We evaluated the plant height (PH, m), ear height (EH, m), the relationship EH/PH (EH/PH), number of ears with kernels (EWK, %), stand density (ST, $plant.ha^{-1}$), grain yield (GY, $kg.ha^{-1}$), male flowering (FM, days), female flowering (FF, days), interval between FM and FF (ASI, days) and numbers of broken or lodging plants (NBP, %), as shown in table 1.

An analysis of variance of the lattice, adjusted to the treatment, was carried out in accordance with REGAZZI et al. (1999), using the statistical model proposed by COCHRAN & COX (1957). All effects are random, so the focus was on estimating the components of variance and covariance (REGAZZI et al. 1999). All effects were evaluated by the F test, with a 5% probability of error. The combined analysis of variance was carried out when the ratio between the experiments was lower than four fold (VIANA & REGAZZI, 1999).

RESULTS AND DISCUSSION

According to the pooled analysis of variance, non-significant differences were found for the progeny x environment interaction for the characters ST, EWK, EH/PH and NBP for the half-sib progenies of the 'Barbacena' white maize landrace (data not shown). So, for these characters, the progeny produce the same pattern of performance, regardless of the experimental site, showing that these are inherent characteristics of the population. Moreover, for the characters PH, GY and ASI, there was a progeny x environment interaction, showing that there is variability among the progeny between the three locations. As the population has been structured in half-sib progenies, genetic variability between progeny

Table 1 - Summary of estimates of genotype variance ($\hat{\sigma}^2_g$), additive genetic variance ($\hat{\sigma}^2_A$), environment variance ($\hat{\sigma}^2$) and phenotype variance ($\hat{\sigma}^2_F$), coefficient of genetic variation (CGV), heritability (h^2) and CGV/CV for the characters plant height (PH), ear height (EH), the relationship EH/PH, number of ears with kernels (EWK), stand (ST), grain yield (GY), interval between male flowering and female flowering (ASI) and numbers of broken or lodging plants (NBP)

Traits	$\hat{\sigma}^2_g$	$\hat{\sigma}^2_A$	$\hat{\sigma}^2$	$\hat{\sigma}^2_F$	CGV (%)	h^2 (%)	CGV/CV
				Barbacena, MG			
PH	30.05	120.20	151	181.53	1.9	17	0.26
EH/PH	3.17	1268	3.24	7.54	2.7	42	0.49
ST	3.39	13.56	2.45	5.85	13.0	58	0.68
EWK	12.87	51.48	122	134.97	4.5	9	0.19
GY	3,325	13,300	401,975	405,301	2.1	0	0.05
				Campos dos Goytacazes, RJ			
ASI	0.33	1.32	0.87	1.20	17.46	25	0.352
NBP	2.15	8.60	28.40	30.55	1.57	7	0.159
PH	68.25	273.00	60	128.4	3.25	47	0.61
EH/PH	3.01	12.04	2.47	5.47	2.51	55.5	0.64
ST	4.94	19.76	1.39	6.33	16.51	78	1.09
EWK	111.48	445.92	146	257.5	19.57	42	0.50
GY	66,602	266,408	42,233	108,836	31.44	57.9	0.72
				Coimbra, MG			
ASI	6.91	27.64	1,70	8.61	41.43	80	1.16
NBP	3.27	13.08	143	146.6	6.53	5.03	0.09
PH	10.55	42.20	232.3	243.0	1.36	3.71	0.12
EH/PH	5.33	21.32	39.67	45.2	3.69	10.43	0.21
ST	1.27	5.08	3.91	5.18	10.79	24.35	0.33
EWK	78.44	313.76	240	318.6	21.12	11.42	0.33
GY	92,853	371,412	40,191	133,045	48.22	65.83	0.88

means the existence of additive genetic variation in the population base for these characters, emphasizing the possibility of gain during selection, with a change in the genotype value of these characters.

Because of the environmental heterogeneity, which was established after obtaining the results, we chose to interpret the results of the estimates of genetic parameters for each site. In Barbacena, the highest heritability estimate was 58% for final stand (ST), which is related to the physiological quality of plants and seeds because there was no thinning. This was followed by EH/PH 42% (Table 1). A low CGV indicates the difficulty of achieving selection gain and was observed for most of the characters. The white maize population showed zero heritability for grain yield, because additive genetic variation for this character was not significant, and a low value for EWK, another primary component of production. So the maize population showed insufficient genetic variability from which to obtain genetic gain to increase productivity. This is considered indicative of the low genetic variability available in the white maize population in Barbacena, which as a result will provide only relatively small genetic gains, when using the strategy of half-sib progenies. However, the ST gave a heritability of 58%, which can be considered adequate for selection, so a strategy to increase the number of plants with grain through the selection of progeny with seed with higher physiological and sanitary qualities may indirectly increase grain yield.

The values of heritability found in Barbacena were much lower than those found by other authors for yellow maize and popcorn (RAMALHO, 1977; SANTOS et al., 1993; GRANATE et al., 2002). Although genetic parameters are exclusive to locality and population, it appears that in breeding program with recurrent cycles of selection, the genetic base is always very broad in order to gradually increase the frequency of favorable alleles without depleting genetic variability. Also, it is usual to only publish articles with positive results, that is, those that show the presence of genetic variability.

In Campos dos Goytacazes, the characters PH and EH/PH showed intermediate heritabilities of 47% and 56%, respectively (Table 1). Only the characters ASI and NBP showed relatively low heritability of 25% and 7% respectively, and therefore would produce little genetic gain. Thus, the characters associated with the secondary components of production can be reduced or increased with recurrent cycles of selection. The three primary components of productivity, ST, EWK and GY, had appropriate heritability values for increasing productivity and the three together can provide even greater benefits for the next generation of the Barbacena white maize landrace. All the characters that showed high heritability had a CGV/CV close or equal to unity, indicating favorable genetic gain. Therefore, in the soil and climatic conditions of Campos dos Goytacazes, the ‘Barbacena’ white maize landrace introduced genetic variability in the characters directly or indirectly related to productivity.

In Coimbra, the characters NBP, PH and EH/PH showed low values of heritability and CGV/CV (Table 1) because the progenies in Coimbra have been subjected to intense environmental stress, and as reported by various authors (PACHECO et al. 1998; CARVALHO et al., 2000; GRANATE et al., 2002), these conditions of stress tend to increase the environmental variance and thus reduce the genetic variance. These situations indicate a disadvantage for genetic gain. The primary components associated with grain yield, such as stand density and ears with kernels (EWK), showed low heritability, so it is preferable to select for GY directly.

As for most crop species, the main interest in the ‘Barbacena’ white maize landrace is in its ability to increase grain yield. According to table 2, the average population-based GY was 2,795kg.ha^{-1} below the average of selected progeny. However, as the heritability of GY is zero, the gain expected for the selection was also zero, which shows that cycles of selection in Barbacena will not result in genetic gains for the population if the selection is made directly for grain yield. However, the principal components of grain yield gains showed genetic heritability intermediaries. In this respect, the average density of selected progeny was 14.43plant.ha^{-1} with a gain selection (GS) of 2%, which means an additional 600 plants in a population of 30,000plants.ha^{-1}. For the character EWK, the average of select progenies was 89.9%, which represents a selection gain of 1.21%. Given the same number of plant.ha^{-1}, the harvest will be 429 more ears in the new cycle. The genetic gains accumulated from these two characters can reach 1.029 plants with the ears with kernels, which is an approximately 3% increase compared with the previous cycle of selection. So, even without direct genetic gain in grain yield, a cycle of selection may lead to indirect increases in GY.

The average PH of selected progeny was 3.00m, with a GS of 0.28%, according to ROMANO et al. (2007), who found similar averages for five maize landraces evaluated in a different production system in Ponta Grossa, Paraná, Brazil. This low gain in plant height is very important, as it contributes to fewer broken plants. As this population is used by small

Table 2 - Estimates of population average ($\bar{X}_O$) and selected progenies ($\bar{X}_S$), heritability (h^2), selection differential (DS), values of genetic gain (GG) and genetic gain in percentage (GG,%) for GY direct selection and indirect gain for plant height (PH), ear height (EH), the relationship EH/PH, number of ears with kernels (EWK), stand (ST), grain yield (GY), interval between male flowering and female flowering (ASI) and numbers of broken or lodging plants (NBP).

Traits	$\bar{X}_O$	$\bar{X}_S$	h^2 (%)	DS	GG	GG (%)
			Barbacena, MG			
PH (m)	2.95	3.00	17	0.05	0.008	0.28
EH/PH	66	66	42	0	0	0
ST ($pls.ha^{-1}$)	13.91	14.43	58	0.52	0.29	2.07
EWK (%)	79.2	89.9	9	10.7	0.96	1.21
GY ($kg.ha^{-1}$)	2,795	4,009	0	12.15	0	0
			Campos dos Goytacazes, RJ			
ASI (days)	3.27	2.933	25	-0.33	-0.08	-2.56
NBP (%)	93.38	93.83	7	0.45	0.03	0.03
PH (m)	2.54	2.54	47.0	0	0	0
EH/PH	69.07	68.83	55.5	-0.24	-0.13	-0.19
ST ($pls.ha^{-1}$)	13.46	14.40	78.0	0.94	0.73	5.42
EWK (%)	53.95	68.87	42.0	14.92	6.267	11.62
GY ($kg.ha^{-1}$)	820	1,419	57.9	599	347.29	42.31
			Coimbra, MG			
ASI (days)	6.33	4.83	80	-1.50	-1.87	-29.60
NBP (%)	27.67	20.23	5.03	-7.44	-0.37	-1.35
PH (m)	2.38	2.37	3.71	-0.01	-0.0004	-0.01
EH/PH	62.58	64.37	10.43	1.79	0.19	0.30
ST ($pls.ha^{-1}$)	10.46	10.57	24.35	0.11	0.026	0.25
EWK (%)	58.71	55.77	11.42	-2.94	-0.34	-0.57
GY ($kg.ha^{-1}$)	631	1420	65.83	789	518.90	82.11

farmers, carrying out selection aimed at increasing productivity is always beneficial even when the population characters are inadequate for modern production systems.

In Campos dos Goytacazes-RJ, the average GY was 820kg ha^{-1}, while the average of selected progeny was 1,419kg ha^{-1}. The heritability of this character was 57.9%, with a genetic gain of 42.29%, which justifies the selection cycle. Even ST and EWK can be increased. The average EH / PH for selected progeny was lower than for the population base, so direct selection for GY will be effective in reducing the character EH / PH, and after the cycle of selection the progeny will have a lower insertion point of the ear.

In Coimbra, the direct selection for GY produced an average of 1,420kg ha^{-1} for selected progeny compared to 631kg ha^{-1} for the base population. Heritability was 65.83% with a predicted genetic gain of 82.31%. In this environment, the selection of other primary components of production (EWK) did not increase grain yield. This genetic gain justifies the execution of a cycle of selection in this population in the environment of Coimbra. The progenies had a genetic gain of ASI of -29.60%. Therefore, the number of ears without grain will be significantly reduced, and this in turn will increase grain yield. The genetic gains for the other characters were of low magnitude. However, as the genetic gain for GY was high, the cycle of selection and use of these progeny in the recombination are justified. Among the ten progeny selected for each site, Barbacena/Campos dos Goytacases and Barbacena/ Coimbra, only 27 and 19 progeny were similar, respectively. For Campos dos Goytacazes/ Coimbra only 6 progeny was similar.

CONCLUSION

For the white maize landrace it was concluded that: the characters of the component of productivity such as plant density and number of plants with kernels can produce indirect genetic gain for grain yield and are suitable for breeding; the population contains high genetic variability and opportunities for genetic gain.

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REFERENCES

ARAÚJO, P.M.; NASS. L.L. Caracterização e avaliação de populações de milho crioulo. **Scientia Agricola**, v.59, p.589-593, 2002.

BORÉM, A.; MIRANDA, G.V. **Melhoramento de plantas**. 4.ed. Viçosa: UFV, 2005. 525p.

CARVALHO, H.W.L. et al. Três ciclos de seleção entre e dentro de famílias de meios-irmãos na população de milho BR 5011 no Nordeste brasileiro. **Pesquisa Agropecuária Brasileira**, v.33, n.5, p.713-720, 1998.

CARVALHO, H.W.L. et al. Melhoramento genético da cultivar de milho BR 5033- Asa Branca no Nordeste brasileiro. **Pesquisa Agropecuária Brasileira**, v.35, p.1417-1425, 2000.

COCHRAN, W.G.; COX, G.M. **Experimental designs**. 2.ed. New York: John Wiley and Sons, 1957. 611p.

COMSTOCK, R.E.; ROBINSON, H.F. The components of genetic variance in populations of biparental progenies and their use in estimating the average degree of dominance. **Biometrics**, v.4, n.4, p.254-266, 1948.

GAMA, E.E.G. et al. Variabilidade genética em populações de milho de ciclo superprecoce. I. Estimação de parâmetros genéticos. **Ciência e Agrotecnologia**, v.23, p.873-880, 1999.

GOVERNO DO PARANÁ. **Qualidade das sementes do Iapar chama atenção da indústria brasileira**, Curitiba, 06 ago. 2007. Agência Estadual de Notícias. Capturado em 28 jan. 2008. Online. Disponível na internet: http: www.aenoticias.pr.gov.br/modules/news/article.

GRANATE, M.J. et al. Predição de ganhos em famílias de meios-irmãos do milho-pipoca CMS 43. **Ciência e Agrotecnologia**, v.26, p.1228-1235, 2002.

HALLAUER, A.R.; MIRANDA FILHO, J.B. **Quantitative genetics in maize breeding.** Ames: Iowa State University, 1981. 468p.

LIMA, M. et al. Populações de milho: características agronômicas e tecnológicas. **Bragantia**, v.47, n.1, p.55-62, 1988.

LIMA, M.W.P. et al. Procedimentos para escolha de populações de milho promissoras para extração de linhagens. **Bragantia**, v.59, n.2, p.153-158, 2000.

LORDELO, J.A.C. **Parâmetros genéticos nas populações de milho Piranão-VD2 e Piranão-VF1.** Piracicaba: ESALQ/USP, 1982. 73p.

MARQUEZ-SANCHEZ, F.; HALLAUER, A.R. Influence of simple size on de estimation of genetics variances in a synthetic variety of maize. I. grain yield. **Crop Science**, v.10, n.4, p.357-361, 1970.

PACHECO, C.A.P. et al. Estimativas de parâmetros genéticos nas populações CMS-42 e CMS-43 de milho-pipoca. **Pesquisa Agropecuária Brasileira**, v.33, n.12, p.1995-2001, 1998.

PATERNIANI, E. Selection among and within half-sib families in Brazilian population of mayze (***Zea Mays*** L.). **Crop Science**, v.7, n.3, p.212-216, 1967.

RAMALHO, M.A.P. **Eficiência relativa de alguns processos de seleção intrapopulacional no milho baseados em famílias não endógamas.** 1977. 122f. Dissertação (Mestrado em genética e melhoramento de plantas) - Curso de Pós-graduação em Genética e Melhoramento de Plantas, Universidade de São Paulo.

RAMALHO, A.R. et al. Comportamentos de famílias de meios-irmãos em diferentes épocas de semeadura visando à produção de forragem de milho. **Ciência e Agrotecnologia**, v.25, n.3, p.510-518, 2001.

REGAZZI, A.J. et al. Análises de experimentos em látice quadrado com ênfase em componentes de variância. II Análise conjunta. **Pesquisa Agropecuária Brasileira**, v.34, n.11, p.1987-1997, 1999.

ROMANO, M.R. et al. Desempenho de cinco variedades de milho crioulo em diferentes sistema de produção. **Revista Brasileira de Agroecologia**, v.2, n.2, p.808-811, 2007.

SANTOS, N.T. et al. Comparação de ganhos genéticos em populações de milho testadas em dois ambientes e avaliação de um programa de seleção recorrente recíproca. **Revista Ceres**, v.41, n.232, p.543-552, 1993.

SOARES, A.C. et al. **Milho-crioulo: conservação e uso da biodiversidade**. Rio de Janeiro: AS-PTA, 1998. V.1. 185p.

VIANA, J.M.S.; REGAZZI, A.J. Estimação de parâmetros genéticos na análise de grupo de experimentos em látice quadrado. **Bragantia**, v.58, n.1, p.195-208, 1999.

WIKIPÉDIA. Milho Branco. **Wikimédia Foudation**. 5 dez. 2007. Capturado em 5 dez. 2007. Online. Disponível na internet: http://pt.wikipedia.org/wiki/Milho_branco.