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Agronomic performance of white maize landrace in different environmental conditions

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ABSTRACT

The aim of this study was to evaluate the agronomic performance of the white maize landrace rescued in Barbacena, MG, Brazil in its home country, in southeast Minas Gerais and northern Rio de Janeiro at the altitude of 1,100 m, 650 m and 14 m above sea level, respectively. In Barbacena, the climate is temperate with dry winters (Cwb) and the soil type is a dystrophic red Oxisol. In southeast Minas Gerais, the climate is humid tropical (Cwa) and the soil is a dystrophic red-yellow Argisol stage terrace. In northern Rio de Janeiro, the climate is maritime tropical and the soil is a dystrophic yellow Oxisol. The white maize landrace was selected by farmers in Barbacena for several decades and has no agronomic information. Three experiments were set up with 100 half-sib progeny in the Campos dos Goytacazes, RJ, in Coimbra, MG and in Barbacena, MG. Analysis of variance found significant differences between the progeny average of all characters evaluated in the three environmental conditions. Plant height (PH, 2.39 m – 2.95 m), ear height (EH, 1.49 – 1.95 m) and EH/PH (63% – 69%) were deemed unfit for the production system with high plant density. The average grain yield was 820 kg ha^{-1} in the Campos dos Goytacazes, 631 kg ha^{-1} in Coimbra and 2795 kg ha^{-1} in Barbacena. Yields were considered low in relation to the lack of population response to inputs such as fertilizer and irrigation, plant density and lack of adaptation to the environmental conditions found in Campos dos Goytacazes and Coimbra. It was concluded that the farmers have a production system that is well adapted to local conditions, but with limited grain yield; it is necessary to carry out pre-breeding selection in the population before using it directly in the

RESUMO

Desempenho agronômico de uma população crioula de milho-branco em diferentes condições edafoclimáticas

O objetivo deste trabalho foi avaliar o desempenho agronômico da população crioula de milho-branco resgatada em Barbacena-MG e avaliada em sua origem, no sudeste de Minas Gerais e no norte do Rio de Janeiro, respectivamente nas altitudes de 1100 m, 650 m e 14 m acima do nível do mar. Em Barbacena, o clima é tropical de altitude (Cwb) e o solo do tipo Latossolo Vermelho distrófico. No sudeste de MG, em Coimbra, o clima é do tipo tropical de altitude (Cwa) e o solo é um Argissolo Vermelho-Amarelo distrófico, fase terraço. No norte de Rio de Janeiro, em Campos dos Goytacazes, o clima é tropical marítimo e o solo é Latossolo Amarelo distrófico. A população crioula foi selecionada pelos agricultores de Barbacena durante várias décadas e não possui informação agronômica. Para isso foram instalados três

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experimentos, com 100 progênies de meios-irmãos em Campos dos Goytacazes, RJ, em Coimbra, MG e em Barbacena, MG. Pela análise de variância verificaram-se diferenças significativas entre as médias das progênies para todos os caracteres avaliados nas três condições edafoclimáticas. As alturas de plantas (AP, 2,39 m - 2,95 m) e espigas (AE, 1,49 m - 1,95 m) e a relação AE/AP (63% - 69%) foram consideradas inadequadas para o sistema produtivo com alta densidade de plantas. A média de produtividade de grãos foi de 820 kg ha^{-1} em Campos dos Goytacazes, 631 kg ha^{-1} em Coimbra e 2.795 kg ha^{-1} em Barbacena. Essas produtividades foram consideradas baixas e relacionadas à falta de resposta da população aos insumos como adubação e irrigação, à densidade de plantas e à falta de adaptação aos ambientes de Campos dos Goytacazes e Coimbra. Para a população crioula de milho-branco Barbacena conclui-se que: os agricultores familiares apresentam o sistema produtivo bem adaptado às condições locais, mas com produtividade de grãos limitada; é necessário o pré-melhoramento da população antes dela ser utilizada diretamente em germoplasma elite; as médias das principais 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 plantas das progênies em cada local, e estratégias de seleção diferenciada.

INTRODUCTION

Maize is cultivated throughout Brazil with a planted area of 13 million hectares in 2007/8, which makes Brazil the third largest maize grain producer in the world. Meanwhile, the average Brazilian grain yield of 4000 kg ha^{-1} is below the world average of 4500 kg^{-1} (Agrianual, 2007). One of the reasons for low productivity is the diversity of production systems, ranging from subsistence farming, without the use of modern inputs (production oriented to consumption by the farmer and sale of any surplus) to systems that utilize the latest technologies and inputs, achieving productivity equivalent to that obtained in countries with advanced agriculture (Mattoso and Melo Filho, 2007). The family farmers that employ low capital and low technology represent the majority of maize producers in the country, while farmers that are characterized by high business investment in capital and technology for maize production account for the minority of producers in Brazil, but produce a large share of total production (Duarte *et al*, 2007).

Embrapa (2003) demonstrated four types of maize producers irrespective of the planting region: a) “commercial grain producer” who grows maize and soybeans in rotation, specializes in production and the use of the best available technology; b) “grain and livestock producer”, which refers to the average farmer who uses technology in small crops, grows maize as one of the main crops and does not have good management skills; c) “small producer” who uses low technology, involving the use of non-improved seeds and small farms; d) “producer off-season maize”, who produces conventional maize off-season, during the second season, and has a knowledge of the culture to the point at which the technology is adjusted for use depending on the environmental risks, especially the lack of rain. It is clear that there is no single technological standard that suits all production systems used and that adapts to all situations for each crop (Mattoso and Melo Filho, 2007).

In Brazil, white maize is widespread in the states of Parana and São Paulo, and occurs in isolated plantations in Santa Catarina, Minas Gerais and Mato Grosso. In the U.S., production of white maize accounted for 3% of the total in 2004. Though still a minority in recent years, demand for white maize has increased, and the area planted has reflected the growing demand. One reason is that the market recognizes that there are still no transgenic varieties of white maize, which automatically increases its value in specific niches (Wikipedia, 2006).

The white maize landrace is important for technical, environmental and social reasons. Its conservation, characterization and use are linked to local development and the history of a region. Despite the fact that it is the least productive of commercial cultivars, the open-pollinated population is important in plant breeding as a source of genetic variability, which can be exploited in the search for genes resistant or tolerant to biotic and abiotic factors (Araujo and Nass, 2002). An example is the maize landrace grown in the Barbacena region, which has been cultivated for decades and is linked to the local knowledge of family farmers, is adapted to the environment, and meets the food needs of people and animals.

Family farmers in the region of Barbacena have low purchasing power and limited access to technology. These farmers have an old and common habit in the region, which is the cultivation of the white maize landrace whose seeds are kept through the years on their own properties and are used in planting the following season. Even producers who use some input to increase production choose white maize. Among the reasons which led it to be retained by local production systems are the preservation of traditional customs and, degree of autonomy in relation to the seed industry.

The consumption of white maize in Barbacena and surrounding districts is so intense that some farmers do not use yellow maize in food, only in feed for pigs. Farmers use white maize as a base in the daily diet. The dish of the region, called "angu", is eaten every day for lunch and dinner, because the elderly refuse to make their meals without it. Maize is also used in the preparation of cream, cakes, biscuits, local foods such as chicken with brown sauce, and white maize flour, among others. The main source of income for the farmers comes from the sale of white maize flour in markets and shops.

The seeds of the white landrace maize, grown by farmers for at least 50 years, go through a kind of informal selection, in which the ears are hulked manually, the tip seeds are removed and the others are used in the next season. Despite being an open pollinated variety, it is isolated from other populations because hybrids have a longer cycle, there is little interest in planting yellow maize and ease to separate yellow seeds in the ears of white maize.

It is important to emphasize the high quality of the seeds, which can be explained by the selection process in which the plants are harvested at least three months after physiological maturity, and their seed, kept in the ears, is stored at ambient conditions in the bunker for the next planting season. The high quality of the landrace maize seeds was noted by Miranda *et al*, (2003).

In general, farmers in Barbacena, MG, use low-input technologies, the growing season is long and planting takes place in October / November, when the temperature varies between 17 and 25 °C (spring) and 21 and 34 °C (summer) and rain is frequent. The space between plants is 1 m x 0.50 m. Companion cropping with beans and squash is common in the region, with a view to the increased use of the area and diversification of the source of income, as reported by Miranda *et al*. (2005) for other regions of Minas Gerais. Liming is carried out with limestone, which is distributed over the soil surface a few months before planting. The amount used is determined by the farmer himself, as the chemical and physical characteristics of the land are unknown. With regards fertilization, 150 kg of the formulation of 04 (N)-14 (P_2O_5)-08 (K_2O) is applied at planting; side dress fertilizing does not take place. Weed control is performed twice, with a hoe, if necessary. Chemical control of pests and diseases is not done, either due to the limited financial resources or as a result of not recognizing the disease or pest. Manual harvesting starts when all the plants are dry and the ears are suitable for storage.

The objectives of the study were to evaluate the agronomic performance of the white maize landrace rescued in Barbacena, MG, Brazil and to evaluate it in its home country, in southeastern Minas Gerais and northern Rio de Janeiro at the altitude of 1,100 m, 650 m and 14 m above sea level, respectively.

MATERIAL AND METHODS

Experiments were conducted at three locations in 2005/2006: 1) at the "Antonio Sarlo" Agricultural School, located in the city of Campos dos Goytacazes, RJ, 21º45'15''S and 41°19'28''W at an altitude of 14 meters. The climate is maritime tropical with an average annual temperature of 22.7 °C, with moderately warm summers, but diluted by the wind from the sea, and mild winters. The soil is a dystrophic yellow Oxisol; 2) At the Experimental Station of the Universidade Federal de Viçosa, located in the city of Coimbra, MG, 20°50'30"S and 42°48'30"W, at an altitude of 715 meters. The soil is a dystrophic red-yellow Argisol stage terrace. The climate is humid tropical (Cwa), with rain during the hot summer and an annual average temperature around 19 °C, ranging between 14 °C (average minimum) and 26 °C (average maximum); 3) At "Morro Preto" located in the town of Barbacena, MG, 21°13'33"S and 43°46'25"W at an altitude of 1165 meters. The climate is temperate with dry, cold winters (Cwb) and mild summers and an average annual temperature of 17 °C. During growth of the maize crop, the average maximum temperature is 26 °C and the minimum temperature is 14 °C. The soil is a dystrophic red Oxisol.

The seeds of the white maize landrace were obtained from successive crops for several years and have never gone through selection based on the principles of plant breeding methods. One hundred ears were selected based on the absence of pests and a good husk. Each ear is considered a half sib family.

For the evaluation of the half sib families, three experiments were carried out in Barbacena, Viçosa (both in Minas Gerais) and Campos dos Goytacazes (RJ) in November 2005. The experimental design was a triple lattice 10 x 10. The plot contained rows of 3.0 m in length, 1.0 m apart, with a spacing of 0.20 m between the plants within the rows. The initial population was 50,000 plants per hectare.

Fertilization of the plantation was carried out with 300 kg ha^{-1} of N-P_2O_5-K_2O, 8-28-16 formulation. Side dressing was carried out with the application of 60 kg of nitrogen per hectare in the form of ammonium sulfate, when the plant was a sixth fully developed. Weed control was carried out 45 days after emergence. There was no control of pests and diseases.

The following characters were evaluated due to their association with primary and secondary components of production: percentage of broken plants (PBP), final stand (FS), number of plants with ears with grain (NPG), number of plants with ears without grain (EWG), days to male flowering (MF), days to female flowering (FF), plant height (PH), ear height (EH), ratio EH/PH and grain yield (GY), obtained from the weight in kg of kernels per plot, and then transformed to kg ha^{-1} and corrected to 14.5% humidity.

Analysis of variance of the lattice, with adjusted treatments, was carried out according to the statistical model proposed by Cochran and Cox (1957). The joint analysis considered the characteristics for which the ratio between the highest and lowest average square of error was not more than four. Statistical analysis was performed using the software GENES - Genetics and Statistics (Cruz, 1997) and SHEG.

RESULTS AND DISCUSSION

The coefficient of variation (CV) of the lattice for the characters plant height (PH), ear height (EH) and EH/PH was low (15%) and for FS, NPG and PG it was medium. The coefficients of variation found in the agricultural field trials are related to the accuracy of the test and the change in the intrinsic character. This classification is consistent with the proposal of Garcia (1989) that, in general, there is a high CV when the character in question is greatly influenced by the environment.

According to the analysis of variance, there were no significant differences for the progeny x environment interaction of the characters FS, NPG, EH/PH and PBP (Table 1). Therefore, for these characters the progeny maintained the same performance in the three experimental locations, suggesting that these characteristics are inherent in the population. However, the averages for these characters were statistically different for all locations. The characters PH, EH, MF, FF, ASI and PG showed significant progeny x environment interaction, that is, differences among progeny in the three locations. It is likely that different temperatures, precipitation, light and soil fertility affected the population phenotype.

The potential grain yield of the maize population can be predicted by primary components such as the number of plants per area (final stand), the number of ears per plant, the number of kernels per ear and grain weight. Different combinations of these characters can be used to optimize the performance of the cultivars in the production system. For production systems with low inputs, optimum productivity can be achieved by increasing the amount of grain per plant. In production systems with high inputs and monocultures, optimum productivity can be achieved mainly by increasing the number of plants per area. In the white maize landrace, the characters selected by the farmers in productive systems with low inputs were plants with large ears and/or two ears per plant. This system requires wide spacing and low competition among plants to promote the development of a thick stem and the formation of aerial roots. The inoculums are not produced in sufficient quantities to cause foliar disease with high severity. In addition, this population contains plants with a high point of ear insertion, a poor response to increased inputs, excessive broken and lodged plants and foliar diseases only at high planting densities.

The final stand density for the three localities averaged 42,000 plants ha^{-1}, which is below the 55–60,000 plants per hectare that is recommended in the three regions for silage maize production (Miranda and Galvão, 2005), but above recommendations for the maize landrace. The average population for the latter is 27,000 plants per hectare. In this study, the different progeny had different final stands due to the physiological and sanitary qualities inherent in the seeds rather than problems with the experiment. The absence of some plants from the plots, causing variations in the final stand, is a situation that is common in field experiments for different reasons. In this work, the same number of seeds was planted per plot and, therefore, the differences in FS were due to the different capacities for germination, which is an intrinsic characteristic. The Barbacena white maize landrace has the potential to produce 8400 kg ha^{-1}, based on the theoretical production of 200 grams of grain per plant and the current population of 42,000 plants per hectare.

Table 1 - Mean square of analysis of variance for final stand (FS, plants ha^{-1}), number of plants with ears with grain (NPG), plants with ears without grain (EWG), plant height (PH, cm), ear height (EH, cm), ratio EH/PH and grain yield (GY, kg ha^{-1}) for 100 half-sibs of landrace white maize progenies in the experiments carry out in Barbacena-MG, Campos dos Goytacazes-RJ and, Coimbra-MG

SV	DF	Mean Square						
		FS	NPG	EWG	PH	EH	EH/PH	GY
Environments	2	1057.101**	108587.6 **	105788.6**	252811.2**	161989.4**	3169.2**	430508422**
Progenies (adj.)	99	36.979**	969.6**	896.9**	680.8**	650.4**	65.2*	780891**
Progenies x environments	198	7.569 ns	581.8 ns	520.98 ns	489.1**	385.2**	54.7 ns	580328**
Error (intrablock error)	513	7.756	508.3	438.80	444.1	282.1	46.7	484400

**, * significant at 1% and 5% of probability by F test, respectively.

[ns] not significant at 5% of probability by F test.

The number of ears with grain is an important primary component of production. The Barbacena white maize landrace showed an average of only 64% of plants with ears with grain. Therefore, 42,000 plants would produce only 26,880 ears with grain, so the potential grain yield is 5376 kg ha^{-1}, based on the production of 200 grams of grain per plant. This plant population is the same traditionally used in the production system by the family farmers. This level of production was due to the inability of the population to respond to inputs. In Barbacena, 90% of the plants had ears with grain compared to 56.3% in other places. This may be due to the origin of the population and the selection method used by family farmers.

The number and weight of grains of progeny were very low, although not measured directly. It was noted that the population in Campos dos Goytacazes and Coimbra was subjected to periods without rain and high temperatures during most of the cycle, which probably explains the lack of grain in the ear, because in such conditions, pollen grain germination is compromised and grain filling is unsatisfactory (Fancelli and Durval Neto, 2000).

The MF, FF and ASI differed in each location (Table 2). In Barbacena, the average MF was 90 days, in Campos dos Goytacazes it was 74 days and in Coimbra it was 93 days. The FF was 93 days in Barbacena, 77 days in Campos dos Goytacazes and 100 days in Coimbra. The differences between the averages of the three localities were due to the heat supplied by each environment. In addition, there was considerable difference among the ASI of the progeny. This lack of synchrony in the tassel/spike undermines crop production because it prevents fertilization (Magalhães et al., 2002).

The grain yield was 2795 kg ha^{-1} in Barbacena, 820 kg ha^{-1} in Campos dos Goytacazes-RJ and 631 kg ha^{-1} in Coimbra (Table 3). Barbacena is the origin of the population and lies at 1165 meters in altitude with acid soil and low fertility. Coimbra lies at 715 meters in altitude with an Argisol of medium fertility and Campos dos Goytacazes lies at 14 meters in altitude and has medium fertility. The grain yield of 2795 kg ha^{-1} is near the Brazilian average of 3300 kg ha^{-1} (Agrianual, 2007). For the fertilization used, the expected productivity would be 6,000 kg ha^{-1} that was not reached. This can be justified by the history of the use of the white maize landrace, where the selection carried out by family farmers has not increased productivity, because they do not use chemical fertilizers or management to increase soil organic matter. Moreover, the phenotypic selection carried out by farmers is based on the ear size, which is inefficient because it is a quantitative character and has low heritability. For the white maize landrace in the traditional production system, grain yield was adequate. However, for the production system with high inputs, this yield is considered low and is related to the lack of input response and lack of adaptation to increased productivity per area by increasing the number of plants. Machado *et al*. (2003) worked with the maize landrace in soils with low and adequate fertility and obtained 4027 and 5293 kg ha^{-1} in Seropédica-RJ, and 4479 and 4577 kg ha^{-1} in Coimbra-MG. These results showed that depending on the environmental conditions, the maize landrace can respond to increased inputs. Araujo and Nass (2002) obtained 5532 kg ha^{-1} in Londrina, PR, 7004 kg ha^{-1} in Ponta Grossa, PR and 3292 kg ha^{-1} in Anhembi, São Paulo. The low productivity of Anhembi was explained by the fact that the environment was unfavorable to the maize population in relation to climate, soil type and the strong presence of foliar diseases.

Plant height was 2.95 m in Barbacena-MG, 2.54 m in Campos dos Goytacazes and 2.39 m in Coimbra (Table 3). In many plots, the height was about 4.00 m. In the Brazilian maize landrace, plants grow to around 3.00 m. In the work carried out by Araujo and Nass (2002) with the maize landrace, plants grew to 3.20 m, corresponding to 40% more than the control (modern cultivar).

The excessive height of the white maize landrace is due to the methods of plant selection and the traditional production system. The selection of plants available to family farmers in the region is based on the ear size and, therefore, plant height is not considered in the selection

Table 2. Mean square of analysis of variance for male flowering (MF, days), female flowering (FF), Anthesis-Silking Interval (ASI, days) and percentage of broken plants (PBP) for 100 half-sibs of landrace white maize progenies in the experiments carry out in Campos dos Goytacazes-RJ and, Coimbra-MG

SV	DF	Mean Square			
		MF	FF	ASI	NPQ
Environments	1	55161.70**	74259.37**	1416.81**	647736**
Progenies (adj.)	99	28.40**	48.74**	15.92**	266.70 ns
Progenies x environments	99	8.15	19.79**	13.50**	264.86 ns
Error (intrablock error)	342	6.96	9.30	3.86	257.65

** significant at 1% of probability by F test.

ns not significant at 5% of probability by F test.

Table 3 - Mean of male flowering (MF, days), female flowering (FF), percentage of broken plants (PBP), final stand (FS, plants ha^{-1}), number of plants with ears with grain (NPG), plant height (PH, cm), ear height (EH, cm), ratio EH/PH and grain yield (GY, kg ha^{-1}) for 100 half-sibs of landrace white maize progenies in the experiments carry out in Barbacena-MG, Campos dos Goytacazes-RJ and, Coimbra-MG

Environments	Mean of traits								
	MF	**FF**	**PBP**	**FS**	**NPG**	**HP**	**EH**	**EH/HP**	**GY**
Barbacena	90.00	93.00	-	13.91	79.20	2.95	1.95	66.00	2795
Campos dos Goytacazes	74.12	77.39	93.38	13.46	53.95	2.54	1.75	69.07	820
Coimbra	93.29	99.64	27.67	10.46	58.71	2.39	1.49	62.58	631

process. However, when selecting ear size, the family farmer indirectly selects plant height because of the high positive genetic correlation between ear size and plant height (Sawasaki, 1996). In addition, there is great interest in plants for silage production. This procedure is incompatible with the modern system of silage production, where the priority is quality over quantity because tall plants are not necessarily good for silage. Working with maize silage hybrids, Miranda *et al*. (2004) obtained plants of 2.06 m and the highest cultivars were 2.36 m. However, the percentage of protein in the silage reached 8.97% which provides high nutritional value for livestock, In national trials of maize silage coordinated by Embrapa in southeastern Brazil, the average plant height was 2.35 m in 2004/2005 and 2.00 m in 2005/2006.

The ear heights (EH) were 1.95 m in Barbacena-MG, 1.75 m in Campos dos Goytacazes and 1.45 m in Coimbra-MG. Despite the excessive plant height, there is no interest in Barbacena in reducing EH because the harvest is manual, family labor is available and there has been a tradition of breaking the plants. However, the maize stalk serves to crops that have a climbing habit, such as beans and cucurbits. Araújo and Nass (2002) found an average EH of 1.67 m, the highest being 2.00 m, which is approximately 50% higher than the maize hybrids used today. Miranda *et al*. (2004) found an average EH of 0.85 m in silage maize hybrids.

The average EH/PH of the three localities was 66%, which is well above the value suggested by Sawazaki and Paterniani (2004) of 50%. Therefore, the white maize landrace is not adequate to support the strong winds that are very common in tropical summers. This, however, is not as detrimental to family farmers, because the harvest is manual, and ears of broken plants can be harvested, unlike when the harvest is mechanized. In addition, there is a tradition for family farmers to put livestock in the harvested fields to eat the dry plants, taking advantage of ears that were not harvested. In the maize landrace characterized by Araujo and Nass (2002), the average EH/PH was 60% and the highest ratio was 62%. Miranda *et al*. (2004) found an average of 45% for this trait in maize hybrids for producing silage.

The average percentage of broken or lodged plants was 61%. The incidence of breakage was high, regardless of the environment in which the crop was grown.

In summary the progeny of the white maize landrace showed similar performance in the region of origin and differences in Campos dos Goytacazes-RJ-MG and Coimbra. It is assumed that plants maintain uniformity in the progeny at Barbacena because the methods of selection have always been the same at that location, and that differences occur at Campos dos Goytacazes and Coimbra due to new selective forces acting on natural selection or performance.

CONCLUSIONS

Family farmers have a production system that is well adapted to local conditions, but produces limited grain yield;

It is necessary to carry out pre-breeding selection before directly using the white maize landrace in the elite germplasm;

The average agronomic characteristics are suitable only for the traditional production system with low inputs;

The differences between the environments lead to a specific response from the progeny of the population at each location, and differentiated strategies of selection.

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