Crop Breeding and Applied Biotechnology 10: 312-320, 2010
Brazilian Society of Plant Breeding. Printed in Brazil

Evaluation of maize core collection for drought tolerance

Flavia França Teixeira[1*], Reinaldo Lúcio Gomide[1], Paulo Emílio Pereira de Albuquerque[1], Camilo Lélis Teixeira de Andrade[1], Carlos Eduardo Prado Leite[1], Sidney Netto Parentoni[1], Paulo Evaristo de Oliveira Guimarães[1], Lauro José Moreira Guimarães[1], Adelmo Resende Silva[1], Edson Alves Bastos[2] and Milton José Cardoso[2]

Received 19 January 2010

Accepted 10 June 2010

ABSTRACT - *The maize genebank (GBmaize) preserves nearly 4,000 accessions for conservation and use. The use is however restricted because the accessions do not perform as well as the elite genotypes. This problem can be reduced by pre-breeding, i.e., by extending the information on germplasm and introgressing useful alleles. Since irregular rainfall distribution and drought induce maize yield losses, drought tolerance is a main breeding target. In this study, the GBmaize accessions were evaluated for drought tolerance. Environmental factors, genotypes and the respective interactions influence the phenotypic expression. There was however no interaction genotype - irrigation level, so no accessions with different performance under the two water regimes could be identified. The performance of the following accessions was promising for a number of traits: SP154, BA166, MG099, CE002, SE025, BA154, BA194, BA085, MG076, PR053, Roxo Macapá, SE016, and AL018.*

Key words: Zea mays L., *genebank, non-biotic stresses, pre-breeding.*

INTRODUCTION

Genebanks aim to maintain the genetic diversity and are sources of genetic variability for research. The maize genebank (GBmaize) of Brazil preserves nearly 4000 accessions from national collections, breeding programs and of exotic varieties. The maintenance of the GBmaize involves several activities, including agronomic evaluations (Teixeira et al. 2005). Core collections are representative germplasm samples preserved to maintain the genetic variability with a minimum of repetitiveness. Their main advantage is the fast evaluation and revaluation of the germplasm. The maize core collection in Brazil was established in 1997 using the maize collection maintained at Embrapa Maize and Sorghum and Embrapa Genetic Resources and Biotechnology, which at the time comprised 2280 accessions. This collection contains 300 accessions and was preliminarily classified into four strata: landraces, compounds derived from landraces, improved genotypes and introductions. The landrace stratum was divided into 27 groups, according to the geographical origin and grain type. The groups improved genotypes and introductions are further subdivided (Abadie et al. 2000.)

Despite their importance, breeding programs made little use of the genebanks. Only 14% of the maize breeders regularly use genebanks and one of the reasons is the scarce amount of data on the collections. Besides, especially in the case of maize, breeders have established work collections with exceptional performance, discouraging the search for variation in the GBmaize genotypes (Nass and Paterniani 2000). This situation leads to the gap between the areas of genetic resources and breeding, which

[1] Embrapa Milho e Sorgo, C.P. 151, 35701-970, Sete Lagoas, MG, Brazil. *E-mail: flavia@cnpms.embrapa.br
[2] Embrapa Meio-Norte, C.P. 01, 64006-220, Teresina, PI, Brazil.

consequently prevents the genetic diversity preserved in BGmilho from reaching the elite collection of the breeder and the producer. Pre-breeding involves the identification of special traits in genotypes considered unimproved and the availability of such genotypes to plant breeding ((Nass and Paterniani 2000, Nass et al. 2007). Several studies have been conducted to expand the knowledge about maize germplasm (Teixeira et al. 2002, Miranda Filho and Gorgulho 2003). However, the use of GBmaize is still limited, because according to Nass and Paterniani (2000), the performance of the genotypes used in breeding programs is already much better than of those of the GBmaize, which makes the elite collections far more attractive for breeding.

Among the environmental stresses that lead to yield losses, drought causes most damage in temperate regions, although the detrimental effects of water stress are more pronounced in tropical or subtropical regions than in temperate climates (Ramalho et al. 2009). Irregular rainfall distribution and drought lead to maize yield losses, indicating drought tolerance as a priority for breeding. Due to the great influence of drought on flowering, the gap between male and female flowering is a variable used in the selection of drought-tolerant genotypes (Bruce et al. 2002).

The aim of this study was to evaluate accessions of maize core collection for drought-tolerance deficit aiming at the use in breeding programs.

MATERIAL AND METHODS

Accessions of the stratum of autochthonous varieties (subgroups Caatinga and Cerrado) of the core collection were tested and elite genotypes and commercial cultivars used as controls. These genotypes were divided into two groups: test 1 (T1) and test 2 (T2), according to the number of days to flowering, determined in a preliminary assessment, to facilitate the irrigation management. T1 comprised the earlier accessions and T2, the later. Below is the list of accessions in each test:

Accessions in T1: SP181, SP154, BA166 and MG099 of the Cerrado group with semident grain, BA178 and BA083 in the Cerrado group with semi-flint grain; SP015 Cerrado group with flint grain BA019, PB010, PE011, BA028, MG060, CE002, SE025, BA154, AL001, BA194, and PB003 of the Caatinga group, with semident grain, BA003, BA061 and SE014 Caatinga group semi-flint grain; PE002 Caatinga group with flint grain, and Synthetic Elite Flint (SEF), Drought-tolerant Synthetics (STS) and Sertanejo as controls. Accessions in T2: MG090, MS043, SP019, MS007, SP036, BA085, MG076, PR053, Roxo de Macapá, MS030, MT009, and PR050 of the Cerrado group with semident grain; MS019 and MG010 of the Cerrado group with semi-flint grain; SP145 Cerrado group with flint grain, RN003, PE013, SE016 and AL018 Caatinga group, semident grain; BA020 Caatinga group, semi-flint grain, AL009 and PB020 Caatinga group with flint grain, and BR106, SEF and Synthetic Jaíba (SJ) as controls. It should be mentioned that the controls STS and SJ are elite maize genotypes of the Embrapa Maize and Sorghum breeding program, which at some development stage had undergone selection for drought stress.

The following environmental factors were considered: the locations (L) Janaúba-MG and Teresina-PI; years (A), planting in the dry season in 2005 and 2006, and the irrigation regimes (I) with full water supply throughout the cycle (no stress) or cutting of irrigation in the pre-flowering period (under stress). At each location and each year, experiments were implanted with two irrigation regimes. In the tests without stress, sprinkler irrigation was maintained throughout the cycle. In Janaúba, irrigation management was established as recommended by Albuquerque (2007), based on soil and climate data. In Teresina, plants were irrigated daily and the irrigation level was estimated based on crop evapotranspiration of the day before, according to the methodology proposed by Andrade Júnior et al. (1998). In the stress tests, irrigation was interrupted/halted/ at the beginning of tasseling until 20 days after pollination. After this period, irrigation was resumed by returning the soil to predetermined field capacity. The experimental design used in all evaluations was a 5 x 5 triple lattice where plots consisted of two 5 m rows, a sowing density of five plants per meter and 0.90 m spacing. Statistical analyses were performed in each location and combined analysis involving the factors studied. According to the results of analysis, means were compared using the Tukey test at 5% probability. The broad-sense heritability (h^2) was estimated for all traits evaluated and the phenotypic correlation among these.

The following traits were evaluated: number of days to male flowering (MF), number of days to female flowering (FF), both based on the number of days between seedling emergence and flowering of 50% of the plants in the plot; interval (in days), between anthesis and silk interval (ASI), plant height (PH) and ear height (EH), averaging the data of 10 plants per plot (in cm); prolificacy (PROL) obtained by the division between the total number of ears per plot and the plot stand, and grain yield (GY) in ton ha^{-1}.

RESULTS AND DISCUSSION

The overall means of the traits in each experiment (Table 1) showed that the mean variation in GY in the stressed locations was between 35.54% and 78.79% of the unstressed treatments. Thus, irrigation suspension induced GY reductions approaching 50%, as described by Bruce et al. (2002), which is the value recommended for evaluations of drought stress in maize. The mean ASI between tests with and without water stress reached 6.85 days in T1 in Janaúba, in 2005.

It is worth noting that the water stress in T1 and T2 in Janaúba was very severe, leading to a considerable GY reduction, longer ASI due to the delay in FF and not reaching the flowering stage in some plots, i.e., in some plots percentage of flowering plants did not reach 50 %. Therefore, the accessions were classified into two groups: the first contains the accessions that did not reach flowering and the second, those that flowered all locations. Only the accessions: SP154, BA166, MG099, CE002, SE025, BA154, BA194, and BA061, in T1 and SE016, AL018, BA085, MG076, PR053, and Roxo de Macapá, in T2 flowered under all conditions and were considered in the analysis variance for MF, FF and ASI. This result was considered a preliminary indication of superiority of these accessions over others. One should bear in mind that none of the controls flourished under severe water stress, as imposed in 2005 in Janaúba.

Estimates of phenotypic correlations indicated a significant and high correlation between some traits. In T1, the correlations between PH and EH, PH and GY, GY and EH, and MF and FF estimates were high and positive, while GY and ASI high and negative. In T2, the correlations between PH and EH, PH and GY were high and positive. Among these results, the negative correlation between ASI and GY should be emphasized, which indicates a yield reduction with increasing ASI, in agreement with the statement of Bruce et al. (2002), indicating the use of ASI as variable underlying selection of drought-tolerant genotypes.

The presence of the effects of location, year and water regime, as well as most of the respective interactions for most traits showed that the phenotypic expression for different traits was influenced by these environmental factors. The effect of genotypes affected most traits, except

Table 1. General means estimated in the tests 1 and 2, in 2005 and 2006, in Janaúba and Teresina under full irrigation (without drought stress) and irrigation suspension in the pre-flowering period (water stress)

Test 1	Janaúba				Teresina			
	2005		2006		2005		2006	
Trait	Water stress	Without stress	Water stress	Without stress	Water stress	Without stress	Water stress	Without stress
PH	216.00	233.00	308.03	318.73	225.53	243.16	206.30	233.14
EH	144.33	147.13	190.18	187.41	142.87	151.73	135.25	150.30
PROL	0.2844	0.6316	0.8592	1.0143	0.5978	0.7649	0.7384	1.3460
GY	0.74	2.44	3.39	5.28	0.87	1.83	0.49	2.31
MF	65.93	65.89	61.44	60.56	53.85	53.00	54.19	52.96
FF	75.15	68.26	64.07	62.59	60.19	57.96	61.70	57.33
ASI	9.22	2.37	2.63	2.04	6.33	4.96	7.52	4.37
Test 2	**Janaúba**				**Teresina**			
	2005		**2006**		**2005**		**2006**	
Trait	**Water stress**	**Without stress**	**Water stress**	**Without stress**	**Water stress**	**Without stress**	**Water stress**	**Without stress**
PH	226.13	254.66	328.22	337.60	233.37	250.73	219.54	257.03
EH	151.73	157.60	207.61	206.47	147.65	165.51	147.33	169.31
PROL	0.3080	0.6613	0.7960	0.9495	0.6095	0.8300	0.9577	1.1368
GY	0.90	2.43	3.12	4.84	0.88	1.53	0.79	2.18
MF	68.33	68.44	64.56	63.11	57.11	52.11	55.89	53.22
FF	74.89	70.22	68.56	68.22	62.28	60.44	60.06	57.17
ASI	6.56	1.78	4.00	5.11	5.17	8.33	4.17	3.94

PROL in T1, and MF, FF and ASI in T2, indicating that in the latter, the difference observed in ASI between locations with and without water stress was not significant (Table 1). The decomposition of the effects of genotypes within and between the ecogeographic groups showed differences between and within the groups Caatinga, Cerrado, and controls for PH, EH, GY, MF and FF in T1, and only within the Cerrado group for ASI. In T2 however, the effects were observed within and between groups for PH, EH, PROL, and GY. The decomposition of the genotype effect within and between grain type groups in the T1 showed differences for most of the decompositions except: within the flint group for PH, EH, and GY, between the groups for EH and FF and for ASI for any decomposition factor. In T2, the effect of the decomposition of the genotype factor according to the grain type was significant for all traits, except for PH within the flint and PROL within the semiflint group.

The core collection consists of accessions representing the variability of the entire collection with a limited number of entries (Abadie et al. 2000). It was therefore expected that the divergence between these accessions were high. This expectation was confirmed in the differences found between the genotypes and their decompositions. However, the limited number of accessions used in each group must be taken into account, as discussed in the following. In general, higher variability has been reported within groups with flint than within groups with dent grain in the core and base collections (Abadie et al. 2000, Netto et al. 2004), but in this study the variability within the dent group was more pronounced. This may have been caused by the nature of the character, since in most studies aimed at quantifying the genetic divergence neutral characters are considered and in the present study, we focused on agronomically relevant traits. Another noteworthy factor is that the mean squares for the estimated effects between groups were higher, in most cases, than those obtained within groups, which was expected, mainly due to the great phenotypic divergence between the groups formed by GBmaize accessions and the control group, consisting of elite genotypes (Nass et al. 2007, Teixeira et al. 2007). This observation shows the key function of actions of pre-breeding to make GBmaize accessions with valuable variability useful for breeding.

The interactions between genotype and environmental factors were present in some situations. In T1 for GY, there were interactions between locations and genotypes and their decompositions within the Caatinga and semident groups and between grain type and year groups and genotypes. In T2, there were interactions of genotypes by years and the decompositions within the Cerrado, Caatinga, semident and flint groups and between groups of origin and grain type for PH. For EH, the same interactions were present and also the interactions locations by genotypes and of the decompositions within Cerrado and flint groups and between grain type groups. For PROL in T2 interactions between locations and genotypes and the decompositions within Cerrado and semident groups were observed, the interaction between years and genotypes and their decompositions within Cerrado, semident and semiflint groups, and the triple interaction location x year x genotype and their decompositions within the groups Cerrado, Caatinga and semident and between grain type groups; for GY interactions location x genotype were observed and their decompositions within groups Caatinga, control, semident, flint and between grain type groups; genotype x year and the decompositions within the groups Cerrado, control, semident, flint and between groups of geographical origin and grain type; and the triple interaction genotype x location x year and the decompositions within the groups Cerrado, semident, flint and between groups of geographical origin.

No interaction of genotype - irrigation regime was observed, as also reported by Silva et al. (2008), for any characters in the two tests at both locations in two years. The presence of strong interactions between genotypes and other environmental factors should be highlighted. Much of the changes in phenotypic expression are possibly differentiated responses to the environmental effects of locations and years and not to the water regime, principally when taking the influence of the interactions genotype-year and location-genotype into account, as reported in several studies (Welcker et al. 2005, Terasawa Júnior et al. 2008), as well as the great range of climatic conditions in Brazil (Paterniani 1990). The installation costs of experimental evaluations with and without drought stress are high, since this assessment requires rigorous monitoring of irrigation and the decision on the optimum time for irrigation suspension. Moreover, the selection of treatments to be included in this test type is restricted, because genotypes with different cycles can not be evaluated in parallel, since genotypes need to be in the same development phase at the time of stress onset. Regardless of the high costs, the main obstacle is that these tests need to be conducted in the field in the dry season, ie, not in the normal corn season, which can mask the performance of these varieties due to the interactions estimated. The correspondence between the selection performed in environments with and without drought stress is considered controversial by Monneveux et al. (2006). Evaluations including tests with and without water stress are very important for identifying genotypes more and less affected by reduced water availability, in the case of genotype-irrigation regime interaction. Genotypes with coincident performance in the two conditions can also be selected in these tests, both in the presence or absence of interaction. The identification of genotypes with yields less affected by environmental variations is a major breeding target, whereas genotypes strongly influenced by environmental variations are useful in studies on physiological mechanisms related to stress tolerance.

The h^2 estimates obtained for the traits for which significantly different results were obtained in the tests were high, ranging from 53.46% for ASI to 94.10% for EH in T1 and 79.76% for PROL to 93.61% for EH in T2, indicating the possibility of successful phenotypic selection for these traits in breeding programs.

Tables 2, 3 and 4 show the means and test means for the traits evaluated in T1 and T2. For the traits with genotype-year or genotype-location interaction, means were tested based on the averages of each location and year for GY, although in T1, only the assessments of 2006 were used to discriminate accessions for GY, since in the evaluations of 2005 the treatments were similar for GY. In T1 (Table 2), the group means showed that the accessions with semi-flint and flint grain had similar performance to the controls for PH, and that the accessions of the groups Cerrado, Caatinga, semident and semiflint and GY had similar accessions as the group of controls for GY in Janaúba in 2006. In T2, despite the significant differences among genotypes for PROL, the mean tests grouped most accessions on the same level for this trait, which prevented the identification of outstanding genotypes (Table 3). It is also worth mentioning that in the GY evaluations in Teresina, the genotypes did not differ in 2005 and that in 2006, none of the GBmaize accessions reached the same GY level as the control Sintético Jaíba (Table 4). The comparison of the groups formed by the GBmaize accessions and the control group showed that in the mean, PH of the flint group was similar to that of the control group. For GY in Janaúba in 2005, the means of the Caatinga and semident group were similar to the controls.

Some considerations on the estimates of means are appropriate; firstly, the majority of accessions in the T1 and T2 have at least one trait with a similar mean to that of the controls (improved genotypes). Along with the presence of favorable characteristics, there are other unfavorable traits, which disqualifies these accessions for the direct use in breeding. No GBmaize accessions were identified with better performance than the controls for GY or other traits of agronomic performance. But no control flourished under all conditions, while some accessions did not only flourish at all locations, but also had high GY and/or other favorable characters. Thus, the potential for use in pre-breeding programs for the introduction of useful variability sources into elite germplasm was greatest in the accessions SP154, BA166, MG099, CE002, SE025, BA154, and BA194 of T1 and BA085, MG076, PR053, Roxo Macapá, SE016, and AL018 of T2, according to the principles proposed by Nass et al. (2007).

It should also be highlighted that the means of the accessions of the Caatinga and semident groups were similar to the controls for some of the traits. These findings must be interpreted with caution, since the superiority of accessions from the Caatinga may possibly have been caused by adaptation to the regions in which the assessments were conducted, which reinforces the planning of trials on a regional basis. The superiority of the semident group accessions on the other hand is possibly due to the fact that the use of this grain type increased parallel to maize improvement in Brazil (Sawazaki and Paterniani 2004, Teixeira et al. 2007). These accessions may have been modified by a greater breeding effort and consequently have a higher GY.

Table 2. Means and test of means of the combined evaluation of the treatments in test 1

Accession/ Group	PH	EH	MF	FF	ASI	GY			
						Janaúba/05	Janaúba/06	Teresina/05	Teresina/06
SP181	250.7BCDE*	153.8CDEF	-	-	-	1.43A	4.15 BCDEFGH	1.48A	1.89AB
SP154	261.8ABCDE	171.9ABC	57.67B	63.92A	6.25A	1.80A	3.76 DEFGHI	0.99A	1.41AB
BA166	255.2BCDEF	164.0ABCDE	58.37B	62.67A	4.29AB	1.90A	4.92ABCDE	1.51A	2.00A
MG099	272.7ABC	178.2A	60.75A	65.25A	4.50AB	1.60A	4.50ABCDEFGH	1.29A	1.83AB
BA178	224.2 FGH	133.0GHI	-	-	-	1.03A	4.07 BCDEFGH	1.34A	0.89AB
BA083	293.4 A	173.0ABC	59.79AB	64.62A	4.83AB	2.07A	4.87ABCDEF	1.68A	1.52AB
SP015	248.9BCDEF	157.4BCDEF	-	-	-	0.87A	3.59 EFGHI	1.41A	0.53 B
BA019	224.9FGH	139.9FGH	-	-	-	1.03A	3.43FGHI	1.42A	1.34AB
PB010	236.5DEFGH	147.2EFGH	-	-	-	1.86A	5.37ABC	1.30A	1.63AB
PE011	259.6ABCDE	164.8ABCDE	-	-	-	2.16A	5.51AB	1.49A	1.72AB
BA028	245.4BCDEFG	159.8ABCDEF	-	-	-	1.43A	3.40GHI	0.75A	1.09AB
MG060	250.6BCDEF	159.7ABCDEF	-	-	-	1.19A	4.02 DEFGH	0.95A	1.12AB
CE002	264.7ABCD	167.7ABCD	58.42B	63.87A	5.46AB	2.27A	4.90ABCDE	1.04A	1.45AB
SE025	257.1BCDEF	173.0ABCD	58.00B	62.96A	4.96AB	1.72A	4.91ABCDE	1.13A	2.01A
BA154	265.1ABCD	168.6ABCD	59.12AB	63.83A	4.71AB	1.89A	4.38ABCDEFGH	1.67A	1.08AB
AL001	259.5ABCDE	169.3ABCD	-	-	-	1.52A	4.41ABCDEFGH	1.42A	1.39AB
BA154	274.1AB	176.8AB	59.46AB	65.00A	5.54AB	1.71A	5.07ABCD	1.89A	1.12AB
PB003	259.9ABCDE	168.5ABCD	-	-	-	2.08A	5.37ABC	1.81A	1.68AB
BA003	234.7DEFGH	145.1EFGH	-	-	-	1.06A	3.51 EFGHI	0.94A	1.51AB
SE014	238.7CDEFG	149.2DEFGH	-	-	-	1.13A	3.59 EFGHI	0.93A	1.23AB
BA061	230.2EFGH	144.9EFGH	54.71C	58.54B	3.83B	1.35A	3.25 HI	1.35A	1.02AB
PE002	240.8BCDEFG	150.1 DEFG	-	-	-	1.09A	2.52 I	1.48A	1.06AB
SEF	202.3H	118.3 I	-	-	-	1.67A	4.34ABCDEFGH	1.56A	1.31AB
STS	212.8GH	128.1HI	-	-	-	2.12A	5.76A	1.69A	1.74AB
Sertanejo	236.0DEFGH	140.5FG	-	-	-	1.83A	4.80ABCDEFG	1.24A	1.49AB
Cerrado	258.1BCDE	161.6ABCDE	59.15AB	64.11A	4.97AB	1.53A	4.27BCDEFGH	1.39A	1.44AB
Caatinga	249.4BCDEF	159.0BCDEF	57.94B	62.84A	4.90AB	1.58A	4.24BCDEFGH	1.22A	1.36AB
Semident	255.8BCDEF	164.2ABCDE	58.83B	63.93A	5.10AB	1.71A	4.54ABCDEFG	1.34A	1.52AB
Semiflint	244.2BCDEFG	149.0DEFG	57.25B	61.58A	4.33AB	1.33A	3.86DEFGHI	1.25A	1.23AB
Flint	244.8BCDEFG	153.8CDEF	-	-	-	0.98A	3.06HI	1.45A	0.80AB
Test.	217.1GH	129.0HI	-	-	-	1.87A	4.97ABCD	1.50A	1.51AB

* In each column, means followed by at least one same letter did not differ from each other by the Tukey test at 5 % probability.

Table 3. Means and test of estimated means in Test 2 for each year for plant height (PH, in cm), ear height (EH, in cm), and for each location and year for prolificacy (PROL)

Accession/ Group	PH		EH		PROL			
	2005	2006	2005	2006	Janaúba/05	Janaúba/06	Teresina/05	Teresina/06
MG090	232.7ABC*	286.7ABCDEFG	148.6BCDE	189.8ABCDE	0.5356A	0.7786AB	0.5207ABC	0.7575 C
MS043	233.5ABC	299.6ABCD	147.3BCDE	191.8ABCDE	0.4755A	0.8632AB	0.7492ABC	1.1886 BC
SP019	230.6ABC	273.0 CDEFG	151.2ABCDE	167.6DEFG	0.3746A	0.7758AB	0.4303BC	1.0964 BC
MS007	234.8ABC	297.9ABCDE	157.1ABCD	197.7ABCD	0.4318A	0.8913AB	0.6265ABC	1.0666 BC
SP036	247.7AB	288.8ABCDEFG	160.0ABCD	181.9ABCDE	0.3917A	0.6415B	0.3426 C	0.7562 C
BA085	264.0A	287.6ABCDEFG	180.5A	184.4ABCDE	0.5187A	0.9239AB	0.6035ABC	0.9113 BC
MG076	251.1AB	310.9AB	156.5ABCD	197.3ABCD	0.4587A	0.7389AB	0.9089AB	0.7944 C
PR053	258.3A	300.9ABCD	168.9ABC	193.4ABCDE	0.5248A	0.8697AB	0.8834AB	1.2083 BC
Roxo Macapá	257.2A	287.8ABCDEFG	171.5ABC	194.8ABCDE	0.4332A	0.7730AB	0.9707A	1.0804 BC
MS030	255.0A	308.2ABCD	169.2ABC	211.5A	0.3482A	0.8232AB	0.8122ABC	0.9538 BC
MT009	243.2AB	321.6A	161.2ABCD	204.7AB	0.4084A	0.7718AB	0.7689ABC	2.0410A
PR050	249.2AB	300.2ABCD	164.4ABC	198.0ABCD	0.4342A	0.7468AB	0.7153ABC	1.1110 BC
MS019	235.4ABC	261.3EFG	149.0BCDE	169.3CDEFG	0.5289A	0.8579AB	0.7922ABC	0.9043 BC
MG010	252.7AB	304.2ABCD	163.9ABC	201.5AB	0.4594A	1.0404AB	0.8567ABC	0.8547 C
SP145	233.1ABC	280.7BCDE	143.2CDE	164.8 EFG	0.3397A	0.7336AB	0.5656ABC	0.9263BC
RN003	232.2ABC	272.7CDEFG	145.1CDE	177.9BCDEF	0.5041A	0.8494AB	0.8663ABC	0.9539BC
PE013	245.4AB	291.1ABCDEF	156.2ABCD	183.4ABCDE	0.4935A	0.8393AB	0.7230ABC	1.0990BC
SE016	252.8AB	282.3BCDEFG	163.8ABC	185.4ABCDE	0.5072A	0.8952AB	0.6895ABC	1.4128B
AL018	263.2A	309.8ABC	177.1AB	200.3ABC	0.5563A	0.8329AB	0.5643ABC	1.1554BC
BA020	237.8ABC	283.9BCDEFG	158.8ABCD	181.3ABCDE	0.4817A	0.8563AB	0.6048ABC	0.9120BC
AL009	240.3AB	272.1DEFG	153.5ABCD	169.4 DEFG	0.4879A	0.9717AB	0.7905ABC	0.9862BC
PB020	228.4ABC	301.9ABCD	150.2ABCDE	203.0AB	0.6543A	1.2628A	0.8884AB	1.0359BC
BR106	216.6BC	256.8FG	130.3DE	149.7FGH	0.6368A	1.1174AB	0.9296AB	1.1244BC
SEF	201.5C	215.7H	121.8E	128.7H	0.5707A	0.9612AB	0.5596ABC	0.8520C
Jaíba	233.7A	252.7GH	141.0CDE	139.1GH	0.5595A	1.0033AB	0.8309ABC	0.9994BC
Cerrado	229.9ABC	294.0ABCDEF	159.5ABCD	189.9ABCDE	0.4442A	0.8160AB	0.7031ABC	1.0434BC
Caatinga	209.9C	297.7ABCDE	157.8ABCD	185.8ABCDE	0.5264A	0.9297AB	0.7324ABC	1.0793BC
Semidentado	246.9AB	295.0ABCDEF	161.2ABCD	191.2ABCDE	0.4628A	0.8134AB	0.6984ABC	1.0992BC
Semiflint	242.0AB	283.1BCDEFG	157.2ABCD	184.0ABCDE	0.4900A	0.9182AB	0.7512ABC	0.8903BC
Flint	233.9ABC	284.9BCGEFG	149.0BCDE	179.1ABCDE	0.4930A	0.9694AB	0.7482ABC	0.9828BC
Controls	217.3BC	241.7GH	131.0DE	139.2GH	0.5890A	1.0273AB	0.7734ABC	0.9919BC

* In each column, means followed by at least one same letter did not differ from each other by the Tukey test at 5 % probability.

Table 4. Grain yield means of the accessions evaluated in the 2nd test for each location and year

Accession	Janaúba/05	Janaúba/06	Teresina/05	Teresina/06	Ac/Group	Janaúba/05	Janaúba/06	Teresina/05	Teresina/06
MG090	1.71 BCDE*	3.67 DEF	0.82 A	1.49 BCDEF	PE013	1.59 CDEF	4.11 CDE	1.92 A	1.78 BCDEF
MS043	1.35 EF	4.12 CDE	1.80 A	1.37 BCDEF	SE016	2.46 AB	4.48 BCD	1.06 A	1.55 BCDEF
SP019	1.41 DEF	3.18 EFGH	1.00 A	1.15 CDEF	AL018	2.25 ABCD	4.14 CDE	0.54 A	1.51 BCDEF
MS007	1.65 BCDEF	4.52 BCD	0.95 A	1.44 BCDEF	BA020	1.38 EF	3.21 EFGH	0.72 A	1.72 BCDEF
SP036	1.16 EF	2.30 H	0.70 A	0.78 F	AL009	1.30 EF	3.79 CDE	0.77 A	1.33 BCDEF
BA085	1.96 ABCDE	4.35 CD	0.97 A	2.02 BCD	PB020	1.50 DEF	4.10 CDE	1.00 A	1.83 BCDE
MG076	1.68 BCDE	3.88 CDE	1.31 A	1.34 BCDEF	BR106	2.68 A	6.14 A	1.09 A	2.32 AB
PR053	1.92 ABCDE	4.40 CD	1.84 A	1.10 CDEF	SEF	1.81 BCDE	4.09 CDE	0.65 A	1.56 BCDEF
Rio Macapá	1.59 CDEF	2.57 FGH	1.52 A	0.85 EF	Jaíba	2.42 ABC	5.52 AB	1.41 A	3.22 A
MS030	1.39 EF	4.80 BC	1.86 A	0.87 EF	Cerrado	1.51 DEF	3.70 DEF	1.31 A	1.20 CDEF
MT009	1.14 EF	3.42 DEFG	1.56 A	0.98 DEF	Caatinga	1.72 BCDE	4.03 CDE	1.04 A	1.68 CDEF
PR050	1.63 BCDEF	4.01 CDE	1.19 A	1.14 CDEF	Semident	1.65 BCDEF	3.89 CDE	1.27 A	1.34 CDEF
MS019	1.76 BCDE	4.11 CDE	1.91 A	1.50 BCDEF	Semiflint	1.54 DEF	3.68 DEF	1.33 A	1.50 CDEF
MG010	1.47 DEF	3.73 CDE	1.35 A	1.28 BCDEF	Flint	1.21 EF	3.45 DEF	0.90 A	1.30 CEDF
SP145	0.82 F	2.47 GH	0.93 A	0.74 F	Test.	2.30 ABC	5.25 B	1.05 A	2.37 A
RN003	1.56 DEF	4.35 CD	1.30 A	2.06 BC					

* for each combination location/year, means followed by at least one same letter did not differ from each other by the Tukey test at 5 % probability.

Avaliação da coleção núcleo de milho quanto à tolerância à seca

RESUMO - *O banco de germoplasma de milho (BGMilho) preserva quase 4000 acessos visando conservação e uso. Entretanto, esse uso é reduzido, pois seus acessos apresentam desempenho inferior aos genótipos elite. O pré-melhoramento visa contornar esse problema, ampliando a informação sobre o germoplasma e introgredindo alelos úteis. A má distribuição de chuvas e a seca levam a perdas de produção de milho, o que faz com que a tolerância à seca seja uma das prioridades do melhoramento.Neste trabalho, foram avaliados acessos do BGMilho quanto à tolerância à seca. Fatores ambientais, genotípicos e suas interações influenciaram a manifestação fenotípica, entretanto a interação entre genótipos e regimes de irrigação esteve ausente, levando a não identificação de acessos com comportamento diferenciado nas duas condições hídricas. Os seguintes acessos foram destacados devido ao comportamento superior para vários caracteres: SP154, BA166, MG099, CE002, SE025, BA154, BA194, BA085, MG076, PR053, Roxo Macapá, SE016 e AL018.*

Palavras-chave: Zea mays *L., banco de germoplasma, estresses abióticos, pré-melhoramento.*

REFERENCES

Abadie T, Cordeiro CMT, Andrade RV, Parentoni SN and Magalhães JRA (2000) **Coleção nuclear de milho para o Brasil**. Embrapa Recursos Genéticos e Biotecnologia, Brasília, 37p.

Albuquerque PEP (2007) **Planilha eletrônica para a programação da irrigação em sistemas de aspersão convencional, pivô central e sulcos**. Embrapa Milho e Sorgo, Sete Lagoas, 18p. (Circular Técnica, 97).

Andrade Júnior AS, Cardoso MJ, Melo FB and Bastos EA (1998) Irrigação. In Cardoso MJ (Org.) **A cultura do milho no Piauí**. 2 ed., Embrapa Meio-Norte, Teresina, p. 68-100 (Circular Técnica, 12).

Bruce WB, Edmeades GO and Barker TC (2002) Molecular and physiological approaches to maize improvement for drought tolerance. **Journal of Experimental Botany 53**: 13-25.

Miranda Filho JB and Gorgulho EP (2003) Yield potential and variability of two maize composites. **Revista Brasileira de Milho e Sorgo 2**: 90-98.

Monneveux P, Sánchez C, Beck D and Edmeades GO (2006) Drought tolerance improvement in tropical maize source populations: evidence of progress. **Crop Science 46**: 180-191.

Nass LL and Paterniani E (2000) Pre-breeding: a link between genetic resources and maize breeding. **Scientia Agricola 57**: 581-587.

Nass LL, Nishikawa MAN, Fávero AP and Lopes MA (2007) Pré-melhoramento de germoplasma vegetal. In Nass LL (Ed.) **Recursos genéticos vegetais**. Embrapa Recursos Genéticos e Biotecnologia, Brasília, p. 683-716.

Netto DAM, Souza IRP, Oliveira AC, Pinto CABP and Andrade RV (2004) Avaliação agronômica e molecular de acessos da coleção núcleo de milho, subgrupo endosperma duro. **Revista Brasileira de Milho e Sorgo 3**: 92-107.

Paterniani E (1990) Maize breeding in the tropics. **Critical Reviews in Plant Science 9**: 125-154.

Ramalho MAP, Silva GS and Dias LAS (2009) Genetic plant improvement and climate changes. **Crop Breeding and Applied Biotechnology 9**: 189-195.

Sawazaki E and Paterniani MEAGZ (2004) Evolução dos cultivares de milho no Brasil. In Galvão JCC and Miranda GV (Eds.) **Tecnologias de produção de milho**. UFV, Viçosa, p. 55-83.

Silva RG, Miranda GV, Cruz CD, Galvão JCC and Silva DG (2008) Estimativas de parâmetros genéticos da produção de grãos das populações de milho UVFM 100 e UFVM 200, submetidas a déficit hídrico. **Revista Brasileira de Milho e Sorgo 7**: 57-67.

Teixeira FF, Andrade RV, Oliveira AC, Ferreira AS and Santos MX (2002) Diversidade genética no germoplasma de milho coletado na região Nordeste do Brasil**. Revista Brasileira de Milho e Sorgo 1**: 59-67.

Teixeira FF, Souza BO, Andrade RV and Padilha L (2005) **Boas práticas na manutenção de germoplasma de variedades crioulas de milho**. Embrapa Milho e Sorgo, Sete Lagoas, 8p. (Comunicado Técnico, 113).

Teixeira FF, Vasconcellos JH, Andrade RV, Santos MX, Netto DAM, Novotny EH and Monteiro MAR (2007) Desempenho de variedades de milho quanto a qualidade da palha para artesanato. **Revista Brasileira de Milho e Sorgo 6**: 84-94.

Terasawa Júnior F, Vencovsky R and Koehler H (2008) Location and Genotype-location Interaction in Breeding Maize in Paraná, Brazil. **Crop Breeding and Applied Biotechnology 8**: 17-22.

Welcker C, Thé C, Andréu B, De Leon C, Parentoni SN, Bernal J, Félicité J, Zonkeng C, Salazar F, Narro L, Charcosset A and Horst WJ (2005) Heterosis and combining ability adaptation to tropical acid soils: implications for future breeding strategies. **Crop Science 45**: 2405-2413.