Original Research Article

Evaluation of maize varieties for Grain Yield under Water-Restricted Conditions

---

ABSTRACT

The study sought to evaluate maize germplasm accessions from the Ifes Germplasm Bank (Ifes BAG) to identify promising lines for breeding programs to increase yield under water-restricted conditions. A competition trial was carried in two contrasting environments in the state of Espírito Santo, Brazil: municipality of Alegre and municipality of Colatina. Twenty-one maize accessions were collected and evaluated for agronomic performance in two locations (The municipalities of Alegre and Colatina) in Espírito Santo State, Brazil. Trials were conducted under water-restricted conditions from vegetative to reproductive stage in a randomized block design with five replicates. Data were subjected to analysis of variance by the F Test and to multivariate clustering analysis according to the estimate of genetic distance proposed by Mahalanobis. Genotype by environment interaction identified promising genotypes for each specific environment. Maize germplasm accessions from the Ifes BAG showed genetic variability. Among the germplasm accessions from the Ifes BAG, the populations Padrinho, Piranão 14, Aliança and Palha Roxa are promising for breeding programs with the goal of increasing grain yield under water-restricted conditions in tropical climate regions.

Keywords: *Zea mays*; abiotic stress; genetic resources; plant breeding; population improvement.

1. INTRODUCTION

Brazil has an average yield of 5.4 ha^{-1} of maize, being the third largest producer and exporter of the grain worldwide [1]. When compared to the average yield of other countries, and considering Brazilian soil and climate conditions, the country has a high potential to increase yield. The southeast is one of the regions with the lowest yield states (Espírito Santo and Rio de Janeiro) of [1].

Factors for low yield include out dated and lack of modern technologies, low yielding maize cultivars as well as inherent soil fertility in addition to the lack of crop technification. As a result, farms are more likely to produce low yields on a low yield scale. The southeast region of Brazil has suffered a deficit and erratic rainfall over the last years. There was rainfall deficiency of around 50 % regarding the historical average in the state of Espírito Santo 2013 and 2015 [2].

As a consequence of the negative effects of climate variability on maize yield, the dependence of family farmers on commercial cultivars is increasing. Most of the commercial cultivars available were developed for the mid-west region of the country, they were not widely adapted for cultivation in the southeast region, which represents a risk to the food sovereignty of farmers in this last region [3].

Hence, the need to increase technologies for maize cultivation is evident, especially the ones that enable greater yield under conditions of biotic and abiotic stress. The development of breeding populations can strengthen the seed market in the country and thereby fostering Brazilian agriculture in relation to maize yield.

The challenges facing farmer families in the southeast region is the low potential for maize yield in the state of Espírito Santo, the *Instituto Federal do Espírito Santo* – Ifes. Since 2014, it has been structuring its Active Germplasm Bank (Ifes BAG) and investing in the development of maize breeding programs for the region. Researchers from Ifes have been working in collaboration with small farmers and public institutions aiming at identifying genetic materials with the potential to develop cultivars adapted to the soil and climate conditions of the southeast region. However, no work has yet been implemented under conditions of water restriction to evaluate and identify promising genotypes for the development of adapted cultivars. The identification of more adapted genotypes is of importance not only at a local level but also at a global scale due to the possibility of germplasm exchange between banks and increased in maize productivity.

This study aimed to evaluate the performance of maize genotypes from the Ifes BAG in crops under water restriction to identify promising genotypes, which can be used breeding programs.

2. MATERIAL AND METHODS

A competition trial was carried out to evaluate 21 maize genotypes in two contrasting environments in the state of Espírito Santo, Brazil. The first was conducted in the municipality of Alegre, in the experimental field of Ifes Campus Alegre, the south region of the state (20º45'50" S; 41º28'25" W; 150 m) and the second was carried in the city of Colatina, in the experimental field of Ifes Campus Itapina, the north of Espírito Santo (19° 32' 22' S; 40° 37' 50' W, 71m) respectively.

According to Köeppen classification, the climate in Alegre is Cwa type, with two well-defined seasons: cold and dry winter and hot and humid summer; the average annual temperature is around 23 °C and the average annual precipitation is approximately 1,300 mm [4]. On the other hand, the climate in Colatina, in accordance with Köeppen classification, is defined as "Aw", with an average annual precipitation of 900 mm and an average annual temperature of 25 °C [5]. The region is known for its irregular rainfall and high temperatures. It is observed that the contrast between the above environments is 400 mm of rainfall on average.

The experiment was conducted from November 2016 to April 2017. From the evaluated genotypes, 20 were open-pollinated genotypes (Table 1). 'Biomatrix 2B655PW', (commercial cultivar) was used as a control.

The area used for cultivation was used in the previous crop to plant maize and was rested for 7 months before planting the competition trial. For the experimental planting of competition, the areas were prepared in advance with plowing and soil harrowing. Planting density was 10 seeds linear meter^{-1}, with deposition of two seeds every 0.20 m.

Thinning was carried out 15 days after planting to maintain five linear meter^{-1} plants. Thus, the experimental unit consisted of a 25-plant per row with 0.20 m x 1.0 m spacing, which represents a density of 50,000-plant ha^{-1}. Application of 100 kg of nitrogen ha^{-1}, 80 kg of P_2O_5 ha^{-1}, and 100 kg of K_2O ha^{-1}, distributed between two fertilizations after planting, according to the standard technical recommendation adopted by the maize producers of the region [6] was done.

Table 1. Maize accessions used during experimentation (Ifes)

Accessions	Origin (farmer/institution)
Aliança	Embrapa/Muqui – ES (Nélio Souza/ Fazenda Aliança
Alto Ribeirão	Conceição de Castelo – ES (Córrego Ribeirão do Meio)
Asa Branca	População de polinização aberta
Caparaó Branco	Pedra Menina - ES (Manoel Protázio)
Cimmyt11	Universidade Estadual do Norte Fluminense
Cimmyt14	Universidade Estadual do Norte Fluminense
Diamantina	Embrapa Milho e Sorgo
Emcapa 203	Incaper
ES 001	Laranja da Terra – ES
Incaper 203	Incaper
MA 008	Embrapa Milho e Sorgo
Milho Gordura	Muniz Freire – ES
Padrinho	Muqui – ES (Renato Bettero/Fazenda Fortaleza)
Palha Roxa	Muniz Freire – ES

Palha Roxa Caparaó	Dores do Rio Preto – ES (Manoel Protázio/C. Forquilha do Rio)
Perim	Embrapa/Muqui – ES (Péricles Bettero/Fazenda Cupido)
Piranão11	Universidade Estadual do Norte Fluminense– RJ
Piranão14	Universidade Estadual do Norte Fluminense– RJ
Pomerano	Nova Venécia – ES (Comunidade Pomerana de Nova Venécia).
Sertanejo	Embrapa Milho e Sorgo

Meteorological data referring to the cultivation period (Figure 1) were collected by automatic meteorological stations of the National Institute of Meteorology. Data recorded by stations A617 and A534 located in the municipalities of Alegre and Colatina, respectively, were accessed.

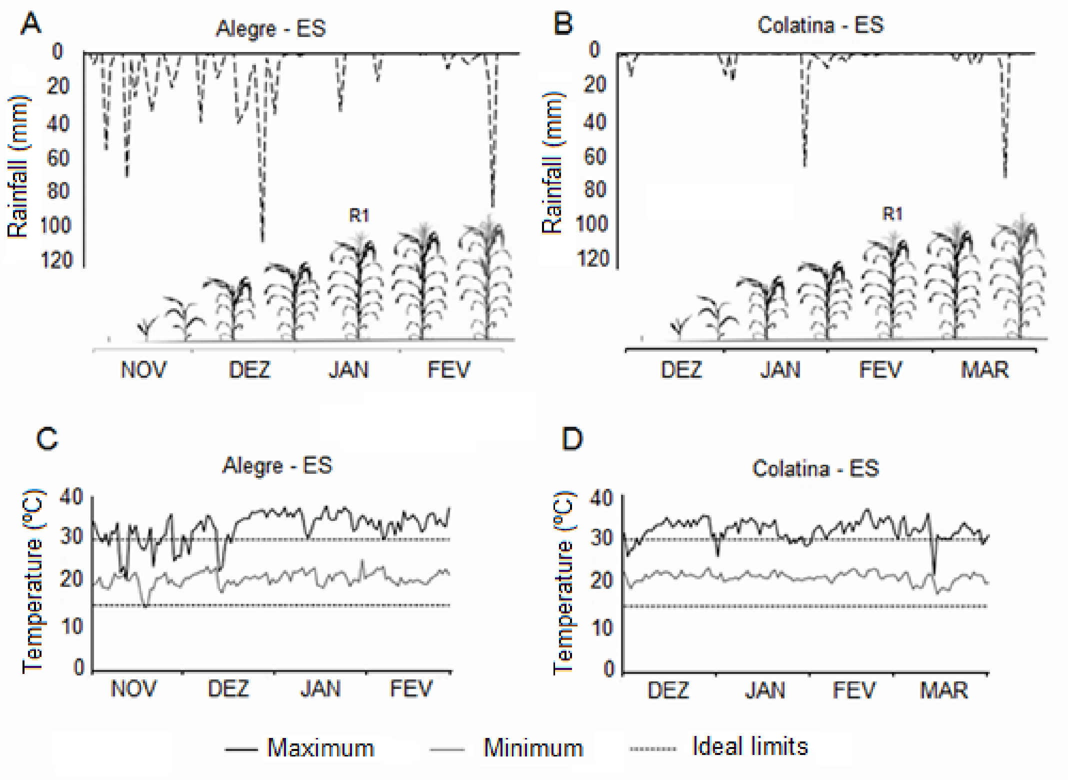

Figure 1. Climatic conditions in the municipalities of Alegre and Colatina, ES, during the 2016/2017 harvest, for maize cultivation.

The temperature requirements of a maize crop for optimal production are between 15 ºC and 30 ºC with water depth of at least 600 mm well distributed throughout the crop cycle [7].

The maximum daily temperature varied between 22ºC and 37ºC approximately, in both environments In Colatina. However, a greater number of days with temperatures above the optimal development range were seen in the initial growth phase of plants. While in Alegre, the average daily temperatures remained above the optimal development range during the entire experimental period [8]. Temperature is one of the abiotic factors that directly affects germination and development of maize plants, mainly influencing their grain yield and nutritional quality [9].

Accumulated water depth was 850.6 mm, in Alegre, and 259.4 mm, in Colatina, during the competition trial. Even though rainfall in Alegre was above crop requirements, it was found to be irregular during the whole period. Rainfall was scarce in both environments during the most critical period for the crop, or rather, from flowering to grain filling [10].

Irrigation was performed with a six-hour weekly irrigation frequency, from planting to the beginning of the reproductive stage of maize, called R1, characterized by the emission of the tassel (male reproductive organ). Once this stage was started, irrigation was stopped, and it was only used as a supplementary measure to ensure minimum yield.

This methodology has been used to conduct experiments aimed at evaluating maize genotypes under water stress in other works [11,12]. The justification for the effectiveness of the method is because, in terms of water demand, the reproductive and grain filling stages are the most critical for grain yield of maize.

Fourteen morpho-agronomic descriptors classified by the International Board of Plant Genetic Resources (IBPGR) were evaluated, namely, days for flowering (DF); plant height (PH); ear height (EH); number of plants at the stand (NPS); number of broken plants (NBrP); number of bedded plants (NBeP); number of ears yielded in the plot (NEP); sick ears (SE); ears attacked by pests (EP); weight of unhusked ears (WHE); grain weight (GW); weight of 100 healthy grains (W100HG); prolificacy, corresponding to the number of ears per plant (PRO); and yield (YIE): estimated yield of 1ha, considering 50.000 plants ha^{-1}.

Data collected were submitted to analysis of variance (ANOVA) by the F test ($p<.01$), followed by clustering of means by the Scott-Knott test ($p>.01$). Given the existence of this interaction, subsequent analyses for each environment were carried out separately, enabling identifying the populations with the best performance for each of the traits in each of the environments.

The genetic distance between the accessions was calculated by Mahalanobis distance, and from the distance matrix, the genotypes were grouped following the neighbor-joining method of Unweighted Pair Group Method with Arithmetic Mean (UPGMA). Analyses were performed separately for each environment because, in a previous analysis of variance, an interaction between genotypes and environment was detected. The Genes software carried out statistical analyses [13].

3. RESULTS AND DISCUSSION

We observed that climatic conditions, during the field competition trial, in both environments, were not ideally suited for maize cultivation, mainly for high temperatures and low and uneven precipitation throughout the period, a typical phenomenon in the past few years.

The differences between the two field environments revealed interactions of among genotypes.

Analysis of variance indicated significant differences among genotypes for 12 descriptors in Alegre and 11 descriptors evaluated in Colatina respectively (Table 2).

Variations were observed with respect to coefficient of variations forplant and ear height, and high or very high for the other traits [14]. These coefficients indicate that there are high variations among the evaluated genotypes, which is of relevant importance for the beginning of improvement programs, considering that it is only possible to select superior genotypes and genetic gains when there is genetic variability [15].

Mean square values (MS) of the residue were important for the traits analyzed, which shows there were high variations between replicates. These variations cannot be regarded as error or improper experimental conduction, since the genotype effect was greater than the random effects, reflecting significant differences in the F test. It should be noted, however, that most of the random effects expressed in the residue may be due to the genetic nature of the material, since these are open-pollinated populations, a greater intrapopulation heterogeneity is expected. This intrapopulation variability indicates the potential to work with these populations in breeding programs aimed at greater intrapopulation homogeneity, which contributes to gains in traits of interest. Classic methods, such as mass selection, stratified mass selection, and recurrent intrapopulation selection, have been used in order to obtain gains in open-pollinated populations [16].

Table 2. Analysis of variance among 21 maize accessions under water stress in two environments, in relation to 14 morpho-agronomic descriptors evaluated: days for flowering (DF), plant height (PH), ear height (EH), number of plants (NP), number of bedded plants (NBeP), broken plants (NBrP), number of ears (NE), sick ears (SE), ears attacked by pests (EP), ear weight (EW), grain weight (GW), weight of 100 healthy grains (W100HG), prolificacy (PRO); and yield (YIE).

Descriptor	Alegre-ES			
	MS Bloco	MS Trat.	MS Res.	VC (%)
DF	13,18	51,28 **	4,44	3,27
PH	1844,69	2032,50 **	262,34	8,57
EH	266,73	1865,28 **	85,57	8,31
NP	3,59	23,09 **	6,83	21,90

NBeP	6,55	2,86 ns	1,89	111,81
NBrP	77,40	32,58 **	12,72	86,08
NE	129,68	58,77 **	20,00	20,80
SE	11,62	28,15 **	10,40	32,84
EP	29,23	24,73 ns	21,85	32,35
EW	1156951,55	261551,55 **	59673,66	39,21
GW	3097280,95	625702,57 **	141204,95	35,64
W100HG	63,27	42,57 **	12,84	13,73
PRO	0,26	012 **	0,03	19,72
YIE	4627804,04	1046206,20 **	238546,64	39,21

Descriptor	**Colatina-ES**			
	MS Bloco	**MS Trat.**	**MS Res.**	**VC (%)**
DF	4,70	40,49 **	3,22	2,97
PH	2628,56	4106,46 **	477,66	8,66
EH	2014,06	4159,16 **	2014,33	9,12
NP	15,25	9,28 **	3,44	13,93
NBeP	0,40	1,07 ns	7,15	177,54
NBrP	5,68	2,44 ns	2,12	154,65
NE	24,89	50,58 **	18,17	28,03
SE	7,82	4,08 ns	5,76	105,96
EP	35,55	81,15 **	42,45	59,03
EW	317802,06	635529,71 **	131199,51	33,01
GW	344690,54	874672,40 **	214910,31	34,14
W100HG	18,37	41,43 **	14,48	14,21
PRO	0,28	0,15 **	0,09	27,35
YIE	1271206,94	2542118,96 **	524798,02	33,01

****** Indicates the presence of significant differences among treatments at a significance level of 1 percent probability (p<.01). ns = not significant.

Genotypes exhibited strong variations for days to flowering (DF), ranging from 60 to 70 days, in Alegre, and from 53 to 63 days in Colatina correspondingtly (Table 3 and Table 4). Moreover, late flowering occurred in the genotypes Milho Gordura and Caparaó Branco, in Alegre, and Cimmyt 11, in Colatina. Flowering in fewer days, in Colatina, can be as a result of temperature effect, since, in such an environment, the average daily temperature remained above the ideal range during the initial period of plant development.

In their evaluation of 4,500 maize genotypes in 13 different locations, Navarro *et al.* [17] confirmed that the days to flowering is determined by different genes, and it is one of the main characteristics for adapting maize plants to different environments. Information on the number of days to flowering of maize genotypes is important in maize breeding program and can be used by breeders in the future.

Table 3. Comparison of means among maize genotypes from the Ifes BAG for days for flowering (DF), plant height (PH), ear height (EH), number of plants (NP), number of bedded plants (NBeP), broken plants (NBrP), number of ears (NE), sick ears (SE), ears attacked by pests (EP), ear weight (EW), grain weight (GW), weight of 100 healthy grains (W100HG), prolificacy (PRO); and yield (YIE) descriptors in Alegre.

Accessions	DF	PH	EH	NP	NBeP	NBrP	NE	SE	EP	EW	GW	W100HG	PRO	YIE
	Alegre-ES													
Aliança	63 c	195,4 a	109,8 c	22,2 a	0,4	5,6 a	22 a	9,2 b	14,4	1414,0 a	837,0 a	28,9 a	1,0 b	1674 a
Alto Ribeirão	64 c	194,6 a	121,8 b	24,6 a	1,0	2,0 b	22 a	9,0 b	13,0	898,0 b	518,0 b	24,9 b	0,9 b	1036 b
Asa Branca	60 c	163,4 b	87,0 d	23,4 a	1,2	7,6 a	25 a	12,6 a	17,2	1136,0 b	674,0 a	24,9 b	1,1 a	1348 a
‘Biomatrix 2B655PW’	60 c	158,6 b	94,8 d	22,6 a	0,8	3,8 b	21 a	3,6 b	13,0	1462,0 a	932,0 a	26,7 a	0,9 b	1864 a
Caparaó Branco	70 a	221,2 a	140,2 a	24,6 a	1,4	2,0 b	19 b	13,0 a	14,4	642,0 b	344,0 b	29,0 a	0,8 b	688 b
Cimmyt11	67 b	172,2 b	92,4 d	16,4 b	0,2	10,2 a	15 b	7,4 b	10,6	404,0 b	197,0 b	19,6 b	0,9 b	394 a
Cimmyt14	66 b	158,6 b	88,0 d	21,8 a	3,4	3,2 b	22 a	10,4 a	16,8	824,0 b	449,0 b	23,3 b	1,0 b	898 a
Diamantina	62 c	198,2 a	109,0 c	23,6 a	1,2	3,2 b	25 a	10,8 a	15,2	1596,0 a	968,0 a	27,1 a	1,1 a	1936 a
Emcapa 203	61 c	178,8 b	89,0 d	19,4 b	1,4	7,0 a	22 a	8,8 b	14,6	1030,0 b	632,8 a	23,6 b	1,2 a	1265 a
ES 001	60 c	158,2 b	90,6 d	19,8 b	1,0	4,8 a	19 b	10,6 a	13,0	666,0 b	395,0 b	20,9 b	1,0 b	790 a
Incaper 203	60 c	176,2 b	102,8 c	18,4 b	1,2	4,6 a	23 a	7,6 b	14,0	1040,0 b	648,0 a	24,5 b	1,3 a	1296 b
MA 008	65 b	214,8 a	140,0 a	22,6 a	0,4	6,0 a	22 a	10,0 a	15,4	964,0 b	642,0 a	24,9 b	1,0 b	1284 a
Milho Gordura	70 a	206,4 a	141,8 a	22,0 a	0,4	1,0 b	15 b	11,4 a	13,4	542,0 b	245,0 b	24,6 b	0,7 b	490 b
Padrinho	63 c	214,0 a	120,8 b	23,4 a	0,2	1,0 b	23 a	10,6 a	12,6	1352,0 a	802,0 a	28,7 a	1,0 b	1604 a
Palha Roxa	66 b	192,6 a	119,4 b	24,8 a	1,6	1,4 b	24 a	9,8 a	13,4	1472,0 a	848,0 a	31,3 a	0,9 b	1696 a
Palha Roxa Caparaó	65 b	197,8 a	109,2 c	23,6 a	1,0	1,2 b	26 a	9,4 b	13,6	1628,0 a	980,0 a	28,4 a	1,1 a	1960 a
Perim	66 b	203,2 b	122,8 b	19,8 b	1,6	4,0 b	17 b	7,2 b	11,4	992,0 b	610,0 a	28,1 a	0,8 b	1220 a
Piranão11	66 b	185,2 b	104,6 c	21,6 a	2,0	5,8 a	26 a	14,2 a	20,8	802,0 b	445,0 b	26,6 a	1,2 a	890 b
Piranão14	68 a	184,8 b	113,0 c	21,4 a	2,2	2,2 b	27 a	12,6 a	17,0	1374,0 a	781,0 a	28,3 a	1,2 a	1562 a
Pomerano	67 b	218,0 a	148,0 a	22,2 a	1,8	2,8 b	17 b	10,2 a	15,2	826,0 b	484,0 b	29,0 a	0,8 b	968 b
Sertanejo	62 c	178,8 b	93,8 d	21,8 a	1,4	7,6 a	22 a	7,8 b	14,4	1076,0 b	645,0 a	24,3 b	1,1 a	1290 a

Table 4. Comparison of means among maize genotypes from the Ifes BAG for days for flowering (DF), plant height (PH), ear height (EH), number of plants (NP), number of bedded plants (NBeP), broken plants (NBrP), number of ears (NE), sick ears (SE), ears attacked by pests (EP), ear weight (EW), grain weight (GW), weight of 100 healthy grains (W100HG), prolificacy (PRO); and yield (YIE) descriptors in Colatina, ES.

Accessions	DF	PH	EH	NP	NBeP	NBrP	NE	SE	EP	EW	GW	W100HG	PRO	YIE
	Colatina, ES													
Aliança	62 a	266,0 b	160,1 b	25,0 a	0,0 b	1,4	26,4 a	6,0	15,0	1864,0 a	1457,0 a	27,8 a	1,1	2934 a
Alto Ribeirão	62 a	263,3 b	172,2 a	25,0 a	0,2 b	0,8	27,6 a	4,6	18,2	1175,0 b	956,0 b	21,8 b	1,2	1912 b
Asa Branca	60 a	214,2 d	124,3 c	23,6 a	0,2 b	1,8	23,6 a	2,8	18,0	1634,0 a	1337,0 a	29,4 a	1,1	2674 a
‘Biomatrix 2B655PW’	58 b	209,9 d	119,8 c	25,0 a	0,0 b	0,0	25,0 a	2,6	16,2	2083,0 a	1751,0 a	29,7 a	1,1	3502 a
Caparaó Branco	62 a	289,7 a	203,7 a	19,8 b	1,0 a	0,8	19,8 b	3,4	11,2	1111,0 b	862,0 b	28,3 a	0,9	1724 b
Cimmyt11	63 a	222,9 d	145,0 b	25,0 a	0,0 b	1,4	25,0 a	6,8	16,4	1155,0 b	799,0 b	22,5 b	1,2	1598 b
Cimmyt14	57 b	221,4 d	133,5 c	25,0 a	0,2 b	0,6	28,0 a	1,2	27,2	1280,0 b	1010,0 b	23,9 b	1,2	2020 b
Diamantina	62 a	249,8 c	159,1 b	20,4 b	0,2 b	2,8	20,4 b	1,6	16,0	1525,0 a	1203,0 a	28,9 a	0,9	2406 a
Emcapa 203	60 a	237,2 c	133,4 c	18,0 b	0,4 b	0,8	18,0 b	2,2	9,0	972,0 b	1011,0 a	28,7 a	1,0	1822 b
ES 001	53 c	203,5 d	123,3 c	20,2 b	0,2 b	1,4	20,2 b	3,8	20,2	757,0 b	539,0 c	26,9 a	1,0	1078 c
Incaper 203	62 a	248,4 c	139,4 c	24,8 a	0,6 b	1,6	26,2 a	3,4	26,2	1397,0 a	1091,0 a	25,9 b	1,2	2182 a
MA 008	62 a	300,2 a	202,3 a	25,0 a	0,8 a	5,2	26,6 a	3,2	17,6	1293,0 b	1119,0 a	21,2 b	1,2	2238 a
Milho Gordura	62 a	258,9 b	198,4 a	10,0 b	0,8 a	1,8	10,0 b	4,8	3,6	413,0 b	290,0 c	26,3 b	0,7	580 c
Padrinho	61 a	256,5 b	163,7 b	25,0 a	1,4 a	2,0	27,4 a	3,6	19,8	2087,0 a	1715,8 a	29,8 a	1,2	3431 a
Palha Roxa	62 a	55,12 b	158,0 b	22,2 b	0,2 b	1,2	22,2 b	4,6	17,2	1569,0 a	1266,0 a	30,3 a	0,9	2532 a
Palha Roxa Caparaó	62 a	273,3 b	188,3 a	25,0 a	0,2 b	0,0	25,8 a	2,8	25,8	1074,0 b	880,0 b	25,6 b	1,2	1760 b
Perim	62 a	291,2 a	184,0 a	21,8 b	0,6 b	0,6	21,8 b	3,2	16,2	1648,0 a	1326,0 a	27,9 a	1,2	2652 a
Piranão11	62 a	244,8 c	154,0 b	25,0 a	0,2 b	2,2	32,8 a	3,2	29,2	1512,0 b	1218,0 a	25,6 b	1,5	2436 a
Piranão14	56 b	237,4 c	147,0 b	25,0 a	1,4 a	2,6	29,8 a	4,8	11,4	1595,0 a	1328,0 a	26,9 a	1,3	2656 a
Pomerano	62 a	302,7 a	216,0 a	17,4 b	1,2 a	2,4	17,4 b	3,0	11,4	795,0 b	664,0 c	23,7 b	0,9	1328 c
Sertanejo	55 c	248,5 c	140,1 c	23,6 a	0,0 b	2,0	23,6 a	5,0	17,4	1441,0 a	1168,0 a	31,5 a	1,0	2336 a

Means followed by the same letter do not differ significantly from each other by Scott-Knott test at a significance level of 1 percent probability (p<.01).

Plant height result ids in conformity with several authors including Alvarez *et al*. [18] they found maize plant height values, close to 3.0 m. They evaluated genotypes of maize with white-colored pericarp in the municipality of Dores do Rio Preto, at the collection site of the Caparaó Branco accession. In Alegre, the accession group with smaller plant sizes gathered the Piranão 14; Cimmyt 14; Cimmyt 11; Perim; Sertanejo; ES 001; Asa Branca; Piranão 11; Emcapa 203; and Incaper 203 genotypes, and the control genotype: CV. Biomatrix 2B655PW.

In Colatina, the group with the smallest plant size was composed of the Cimmyt 14, Cimmyt 11, ES 001, Asa Branca, and Biomatrix 2B655PW genotypes. In both environments, the Cimmyt and Piranão populations reported lower plant height values. This can be attributed to genotypes having carriers of the brachytic gene, which gives a smaller size to the plants [19].

Smaller plants are preferred because they have less space between nodes and lower ear heights, favoring the balance of the plant over the center of gravity, reducing possible losses by bedding or breaking plants [20]. In this way, these smaller genotypes can be used to reduce the size of plants in cultivars, of which the size favors bedding or breaking of the plants. The commercial cultivar evaluated as controldisplayed reduced values for PH, BeP, and BrP in both environments. This is a desirable outcome for commercial material.

The number of plants per stand at harvest were lower for the Cimmyt 11, Perim, ES 001, Emcapa 203, and Incaper 203 genotypes, in Alegre, and for the Perim, Diamantina, Milho Gordura, Pomerano, Caparaó Branco, Palha Roxa, ES 001, and Emcapa 203 genotypes, in Colatina. The accessions with pericarp grains with lighter coloration, such as Caparaó Branco, Milho Gordura, and Pomerano, in both environments, were those that had the lowest stand as a result of the higher number of broken and bedded plants. It should be noted that these genotypes were also those with the highest values for PH, making them susceptible to breakage and bedding. In a study with maize germplasm, Deng *et al*. [21] stated that lighter seeds, when under unfavorable environmental conditions, have a tendency to express less control of the actions of oxidizing substances, in such a way that the germination and initial development of the plant are hampered, generating plants more susceptible to breakage and bedding.

Studies with white corn are at an early stage in Brazil, but the cultivation of this variety of maize is seen as promising for its acceptance on the market in a number of locations all over the country [21]. Furthermore, genetic diversity and the potential of white corn for future breeding programs to strengthen the importance of conserving, characterizing, and evaluating these materials [22]. Hence, even though these populations have not shown superior agronomic performance when cultivated under water deficit, the conservation of this germplasm for breeding programs should be of interest to germplasm banks.

The incidence of diseases (IDi) was quite higher in Alegre, with ranges from 4 (Biomatrix 2B655PW) to 14 ears (Piranão 11). In Colatina, a range of 1 (Cimmyt 14) to 7 ears (Cimmyt 11) was achieved with no relevant differences among the genotypes. Pest attack (EP) was relatively high in both environments, from 11 (Perim) to 21 ears (Piranão 11), in Alegre, and between 4 (Milho Gordura) and 29 ears (Piranão 11) in Colatina.

Pest attacks on the ears originated mainly from corn earworms (*Helicoverpa zea*, Boddie, 1850), known for causing high losses to maize yields [23]. Methods in parallel for the selection of genotypes less susceptible to pests should be implemented at all stages of breeding of those populations.

Regarding GW, the following genotypes were highlighted: Palha Roxa Caparaó, Diamantina, Aliança, Palha Roxa, and Biomatrix 2B655PW, which produced grain mass of about 1 kg per plot in the environmental conditions of Alegre. In Colatina, the Padrinho, Aliança, Diamantina, Asa Branca, and Biomatrix 2B655PW genotypes stood out in relation to GW.

With regard to the W100HG, in Alegre, the Piranão 14, Padrinho, Perim, Aliança, Pomerano, Caparaó Branco varietiesmainly the Palha Roxa genotype were principal, while in Colatina, the Piranão 14, Padrinho, Sertanejo, Diamantina, Asa Branca, Emcapa 203, and Palha Roxa showed exceptionally for this trait. W100HG displays the mean grain mass, a direct result of the capacity of plants to incorporate dry matter. Genotypes with greater capacity to add weight to seeds in abiotic stress are preferred as the nutritive potential of grains is directly related to this capacity provided by the plant.

Values for PRO did not surpass 1.5 ears per plant, which showed the water deficit possibly hindered the development of ears in both environments evaluin allogamous crops. In maize, obtaining half-sib and full-sib families, along with pure seeds from the parents within the same generation is significant. The most important steps in many maize breeding methods, can be more efficient in populations with a yield of at least two ears per plant [24]. It should be considered that the PRO trait as a criterion for progeny selection in future generations throughout the stages of breeding.

Biomatrix 2B655PW genotype remained among the highest value cluster for YIE in both environments, with emphasis on the same varieties for GW. Such correlation among variables is expected due to the YIE being estimated based on GW values. The result is in aggrement with Machado *et al.* [24] that investigated the agronomic performance of the Aliança genotype under regular water conditions in 2007 and 2008, in the municipality of Muqui, approximately 40 km away from the municipality of Alegre. They detected differences for YIE, with variations between 4600 and 9650 kg ha^{-1}. When comparing the YIE obtained by the Aliança genotype in this study (1600 to 2900 kg ha^{-1}), it can be seen to what extent YIE can be affected by water-restricted conditions.

It is worth emphasizing that, even though affected by water-restricted conditions in Colatina, the Padrinho and Aliança varieties achieved YIE above the state average, which is 2900 kg ha^{-1} [1]. Aliança genotype is one of the recommended traditional varieties for the south of Espírito Santo state. Being the result of a participatory breeding program developed in the municipality of Muqui [24].The genotype grouping, according to all descriptors examined, enabled their better distinction and helped in the decision making regarding the most promising genotypes for the development of breeding programs (Figure 2).

Four clusters were distinguished in the trial conducted in Alegre. Cluster one brought together ten varieties, which can still be separated into two sub-clusters. The first sub-cluster (SC I) gathered the Diamantina, Palha Roxa Caparaó, Palha Roxa, Padrinho, and Aliança varieties, which displayed high YIE (Figure 2A).

SC I, genotypes tested in Alegre, presented approximately 63 DF, PH around 2.00 m, with high values for NPS, and mean YIE around 1780 kg ha^{-1}. The second sub-cluster (SC II) was composed of the Pomerano, Caparaó Branco, Perim, MA 008, and Alto Ribeirão genotypes, which were less prolific than the genotypes of the first sub-cluster and with YIE mean of 1040 kg ha^{-1}.Cimmyt 11 and Milho Gordura genotypes isolated in different clusters. Clusters III and IV, respectively, and Cimmyt 11 was the one that showed higher NBrP, GW, and YIE. Milho Gordura was the population that showed late flowering and lower values for YIE.

Genotypes were clustered into five clusters in Colatina (Figure 2B), different ones from those in Alegre, a clear result of the existence of genotype x environment interaction. In Colatina, cluster one brought together 12 genotypes, also distinct, into two sub-clusters. The first sub-cluster (SC I) gathered the Piranão 11, Incaper 203, Cimmyt 14, Cimmyt 11, Alto Ribeirão, and Palha Roxa Caparaó genotypes, obtaining higher values for NEP and intermediate values for EW, GW, and YIE.

The second sub-cluster (SC II) brought together the Asa Branca, Biomatrix 2B655PW, Aliança, Sertanejo, Diamantina, and Palha Roxa genotypes, from which the highest values for YIE and intermediate values for PRO were obtained. Cluster II assembled the Piranão 14 and Padrinho populations, obtaining the highest PRO and YIE values.

Cluster III gathered the MA 008, Perim, Emcapa 203, Pomerano, and Caparaó Branco genotypes, of which similar values were found for PH, NPS, WHE, and low YIE values. The ES 001 and Milho Gordura genotypes were isolated and formed clusters IV and V, respectively.

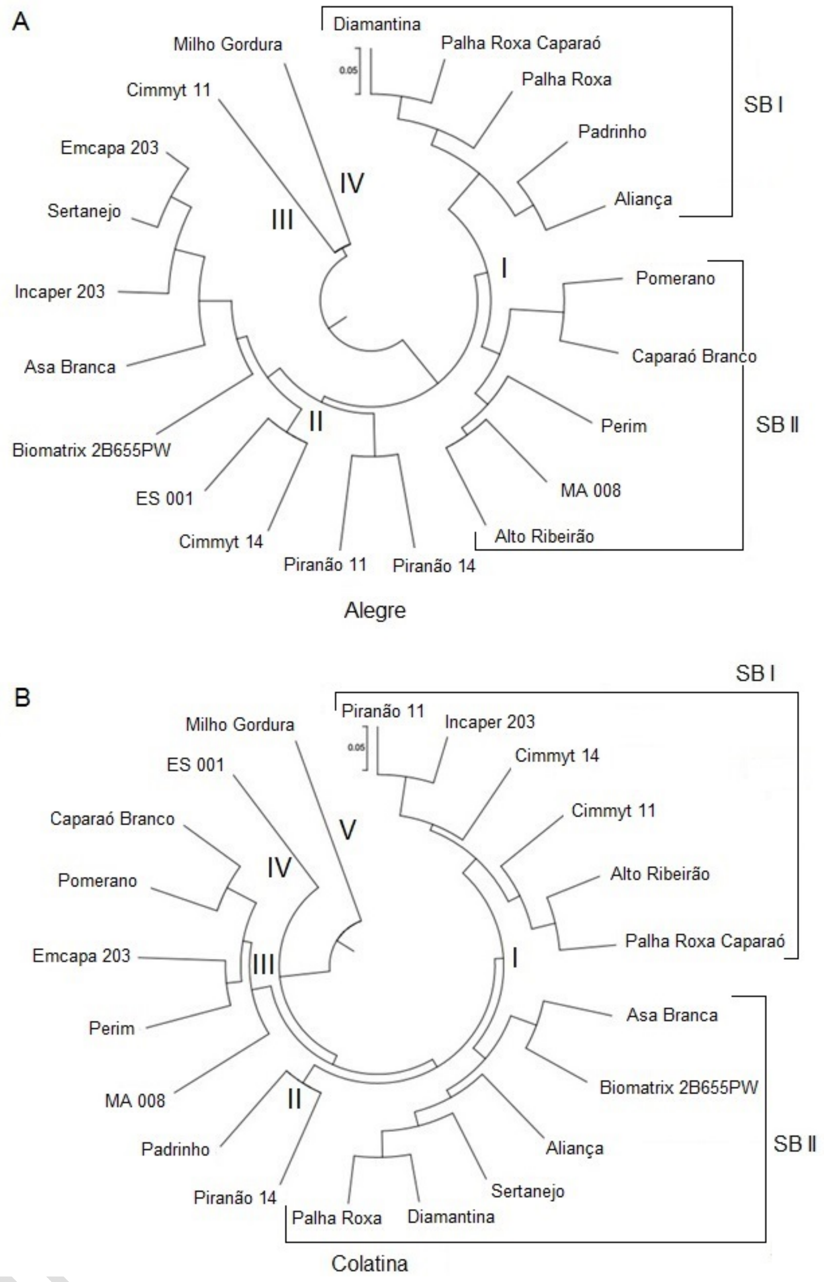

Figure 2. Similarity dendrogram among maize accessions cultivated under water deficit in the municipality of Alegre-ES, according to 14 morpho-agronomic markers.

Different clustering formations in the same environment and the difference in the cluster structure in the environments showed a genetic divergence among the evaluated populations, thereby strengthening the relevance of developing studies in various environments so as to research the most adapted genetic clusters for each environment.

Such work is expected to be used as a source of information for further development of genetic breeding programs, with a view to promoting an increased in the technological level of agriculture, contributing to agricultural development and reducing risks to the food sovereignty of family farmers involved in maize yield.

4. CONCLUSION

Padrinho, Piranão 14, Aliança, and Palha Roxa populations, managed by Ifes BAG, are germplasm accessions of interest for the development of maize breeding programs with the purpose of increasing grain yield for crops under water-restricted conditions in tropical climate regions.
Future research is required to identify genes related to greater tolerance to water stress as well as the best strategy to exploit productivity gains in these populations.

REFERENCES

1. Conab - National Supply Company. Agricultural Observatory. Follow-up of the Brazilian Grain Harvest. v. 6 Safra 2018/19 - Sixth survey, Brasília, 2019. Brazil https://www.conab.gov.br/info-agro/safras/graos. [Accessed 18 March 2019].
2. Ramos HEA, Pontes da Silva BF, Brito TT, Silva JGF, Pantoja PHB, Maia IF, Thomaz LB. The drought in the hydrological year 2014-2015 in Espírito Santo. Incaper in Revista, Vitória, 2016; 6/7 (4): 6-25. Brazil http://biblioteca.incaper.es.go-v.br/digital/bitstream/item/25-38/1/BRT-incaperemrevista-2016.pdf. [Accessed 12 January 2018].
3. Silva KJ. Introduction of transgenic and conventional hybrids in Creole corn: effects on fungi and endophytic bacteria. Santa Catarina: Federal University of Santa Catarina, Center of Agricultural Sciences, 2015. Brazil https://repositorio.ufsc.br/xmlui/ha-ndle/123456789/135157. [Accessed 10 January 2018].
4. Lima JSS, Silva AS, Oliveira RB, Cecílio RA, Xavier AC. Monthly variability of the Alegre-ES monthly precipitation. Revista Agronômica, 2008; 39 (2): 327-332. http://www.ccarevista.ufc.br/seer/index.php/ccarevista/article/view/67. [Accessed 30 Nov. 2018].
5. Busato CCM, Soares AA, Sediyama GC, Motoike SY, Kings EF. Management of irrigation and nitrogen fertigation on the chemical characteristics of 'Rosa Niagara' vine. Rural Science, Santa Maria, 2011; 41 (7): 1183-1188. Brazil. http://dx.doi.org/10.1590/S0103-84782011005000085.
6. Vasconcelos CA, Pereira Filho IA, Cruz JC. Fertilizer for green corn. Technical Circular 17, Embrapa Maize and Sorghum, Sete Lagoas. 2002. Brazil. https://www.agencia.cnptia.embrapa.br/Repository/Circculartecnica17_000fid3mebi02wyiv80z4s473dcbmber.pdf. [Accessed 10 November 2018].
7. Cruz JC, Magalhaes PC, Pereira Filho IA, Moreira JAA. The producer asks Embrapa responds. Brasília, DF, Embrapa Technological Information. 2011. Brazil. http://biblioteca.incaper.es.gov.br/digital-/bitstream/item/78038/1/500P-Milho-ed01-2011.pdf. [Accessed 10 November 2018].
8. Langner JA, Streck NA, Dalmago GA, Reiniger LRS, Durigon A, Silva SD, et al. Estimating the development of landrace and improved maize cultivars as a function of air temperature. Rural Science, 2016; 46 (10): 1737-1742 .. http://dx.doi.org/10.1590/0103-8478cr20151236.
9. Swarts K, Gutaker RM, Benz B, Blake M, Bukowski R, Holland, J, et al. Genomic estimation of complex traits reveals ancient maize adaptation to temperate North America. Science, 2017, 357. http: //dx.doi/10.1126/science.aam9425.
10. Hall, AJ Vilella, F, Trapani N, Chimenti C. The effects of water stress and genotype on the dynamics of pollen-shedding and silking in maize. Field Crops Research, 1982; 5: 349-363. http://dx.doi.org/10.1016/0378-4290(82)90036-3.
11. Magalhães PC, Souza TC, Albuquerque PEP. Research and development 51: effects of water stress on grain production and on the physiology of the corn plant. Embrapa Maize and Sorghum, Sete Lagoas, MG. 2012. http://www.infoteca.cnptia.embrapa.br/infoteca/handle/doc/942408. [Accessed 23 Outcuber 2018].
12. Maheswari M, Tekula VL, Yellisetty V, Sarkar B, Yadav SK, Singh J. et al. Functional mechanisms of drought tolerance in maize through phejotyping and genotyping under well watered and water stressed conditions. Europ. J. Agronomy, 2016; 79: 43-57. https://doi.org/10.1016/j.eja.2016.05.008.
13. Cruz CD. GENES - the software package for analysis in experimental statistics and quantitative genetics. Acta Scientiarum, 2013; 35 (3), 271-276. Brazil http://dx.doi.org/-10.4025/actasciagron.v35i3.21251.

14. Scapim CA, Carvalho CGP, Cross CD. A proposal of classification for the coefficients of variation of corn crop. Pesquisa Agropecuária Brasileira, 1995, 30 (5), 683-686. Brazil. https://seer.sct.embrapa.br/index.php/pab/article/view/4353. [Accessed 20 December 2017].
15. Fernandes EH, Schuster I, Scapim CA, Vieira ES, Coan MM. Genetic diversity in elite inbred lines of maize and its association with heterosis. Genetics and Molecular Research, 2015; 14 (2) 6509-6517. http://dx.doi.org/10.4238/2015.
16. Hallauer AR, Carena MJ, Miranda Filho JB. Handbook of Plant Breeding: Quantitative Genetics in Maize Breedeing. 6th ed. Springer Science: Iowa State University Press; 2010.
17. Navarro RJA, Willcox M, Burgueño J, Romay C, Swarts K, Trachsel S. et al. A study of allelic diversity underlyng flowering-time adaptation in maize landraces. Nature Genetics, 2017; 49 (476). https: //dx.doi/10.1038/ng.3784.
18. Alvarez CRS, Carvalho AHO, Mendonça VQ, Almeida R, Costa AC. Seeds of Hope: the rescue and promotion of creole seeds in the Caparaó Territory, ES, Brazil. Cadernos de Agroecologia, 2016; 11 (2). Brazil. http://revistas.aba-agroecologia.org.br/index.php/cad/article/view/21070. [Accessed 25 November 2017].
19. Entringer, GC, Vettorazzi, JCF, Crevelari, JA, Durães, NNL, Santa Catarina, R, Pereira, MG. Super sweet corn breeding by backcross: a new choice for the brazilian market. Brazilian Journal of Agriculture, 2017; 92 (1): 12-26. http://www.fealq.org.br/ojs/index.php/revistade-agricultura/article/view/3269/pdf_2799. [Accessed 10 January 2018].
20. Gomes LS, Brandão AM, Brito SH, Moraes DF; Lopes MTG. Resistance to the lodging of plants and to the breaking of the stem in tropical corn. Pesq. agropec. Bras., Brasília, 2010; 45 (2): 140-145. Brazil. https://seer.sct.embrapa.br/index.php/pab/article/view/6073. [Accessed 20 Mach 2018].
21. Deng B, Yang K, Zhang Y, Li Z. The effects of temperature on the germination behavior of white, yellow, red and purple maize plant seeds. Acta Physiol Plant, 2015; 37 (174). https: //dx.doi/10.1007/s11738-015-1937-1.
22. Amorim LO, Pereira MCB, Curado FF, Oliveira LCL, Vasconcelos EB. The small farmers' movement and the struggle to protect the native seeds in the Sergipano High Sertão, Brazil. Revista Geografia, Recife, 2017; 34 (1): 71-90. Brazil. https://ainfo.cnptia.embrapa.br/digital/bitstream/item/160624/1/130-3-4332-1-PB.pdf. [Accessed 30 November 2017].
23. Capinera JL. Corn earworm, Helicoverpa (= Heliothis) zea (Boddie) (Lepidoptera: Noctuidae). Department of Entomology and Nematology, Florida University, UF / IFFAS Extension, Gainesville. 2017. http://entnemdept.ifas.ufl.edu/creatures/. [Accessed 20 January 2018].
24. Machado, A. T., Machado, C. T. T, Nass, L. L. Management of genetic diversity and participatory breeding of maize in agroecological systems. Brazilian Journal of Agroecology, 2011; 6 (1): pp 127-136. Brazil. http://revistas.abaagroecologia.org.br/index.php/rb-agroecologia/-article/view/9981. [Accessed 13 December 2018].