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DROUGHT TOLERANCE PHENOTYPING IN CEREALS AND LEGUMES AT TERESINA, PI, SPECIFIC SITE

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INTRODUCTION

The water deficit is a common condition in several parts of the Brazilian territory, and is responsible for the decline in production among various cultures of economic interest (BERGAMASCHI et al, 2004).

In the case of maize, observations in commercial and experimental production areas results, show that when the water stress occurs during flowering, the losses in grain yields can be above 50% DURÃES et al. (2001, 2002, 2003).

The sorghum adapts to a range of environments, particularly under conditions of water deficit, which is unfavorable for the majority of other crop plants. This feature allows the crop to develop and to expand not only in cultivation areas that exhibit an uneven distribution of rainfall and but also in succession of summer cultivations (Santos et al, 1996). However, water stress is the main factor of reduction in the sorghum production worldwide (ROSENOW et al, 1996; NGUYEN et al, 1996; TUINSTRA et al, 1998).

With respect to the cowpea bean, researches report very low grain yields on dry periods, ranging from 300 to 400 kg ha^{-1} (FREIRE FILHO et al., 2005), while the productivity potential of this culture reaches over 2,000 kg/ha.

Considering the territorial extension of the Mid-North Brazilian territory, and that most growers in this region practice rain fed agriculture and, therefore, are subject to droughts, the implementation of a program dedicated to an evaluation and identification of genotypes that are drought tolerant is fundamentally important.

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Thus, the goal of this research is to select maize, sorghum and cowpea genotypes that exhibit drought tolerance. These genotypes, in a later stage, will be used in genetic improvement programs for rain fed plants, with the aim to achieve varieties which are more adapted to the conditions of water stress and, therefore, enable the achievement of higher grain yields and a better life quality for growers in these regions.

MATERIAL AND METHODS

The experiments were set up in the period between September and December of 2007 at Embrapa Mid-North, in Teresina, PI, (latitude 05° 05' S, longitude 42° 48' W, and altitude 74.4 m). The annual average air relative humidity was 75%, the average air temperature was 29.6ºC and rainfall was 1,200 mm (BASTOS et al., 2002). Figure 1 illustrates the distribution of rainfall that occurred during the period of the experiment, where it is possible to notice that the biggest rainfalls occurred in December, which thus didn't disrupt the water deficit imposed to crops during the critical phase (end of October to the beginning of November).

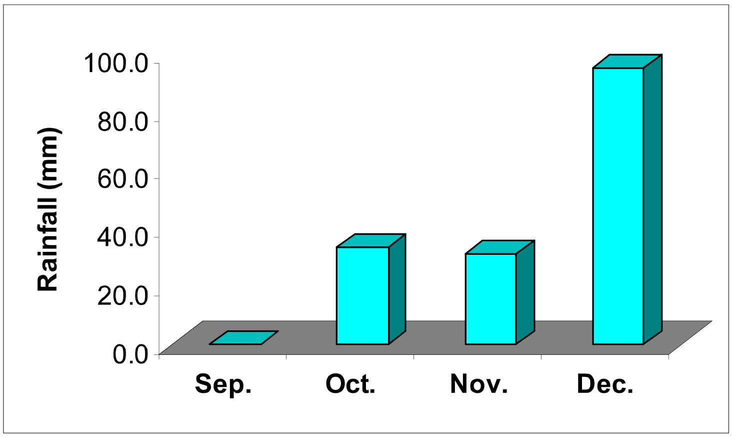


Figure 1. Change of rainfall from September to December 2007 at Teresina site.

The average maximum, medium and minimum air temperatures of the Teresina site is presented in Figure 2. It can be observed that the minimum and maximum air temperature values varying from 20.1°C to 37.9°C, respectively.

The soil from the experimental area (Figure 3) is a Yellow Clay soil of a loam sandy texture with the physical and chemical characteristics presented in Tables 1e 2.

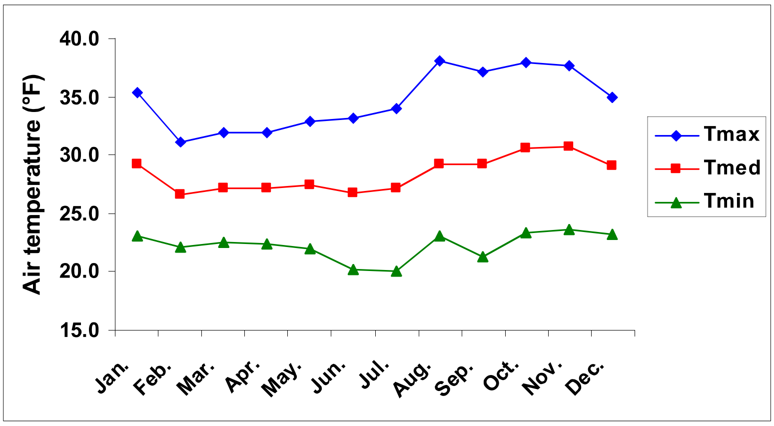


Figure 2. Change of temperature monthly in the year 2007, Teresina, PI.

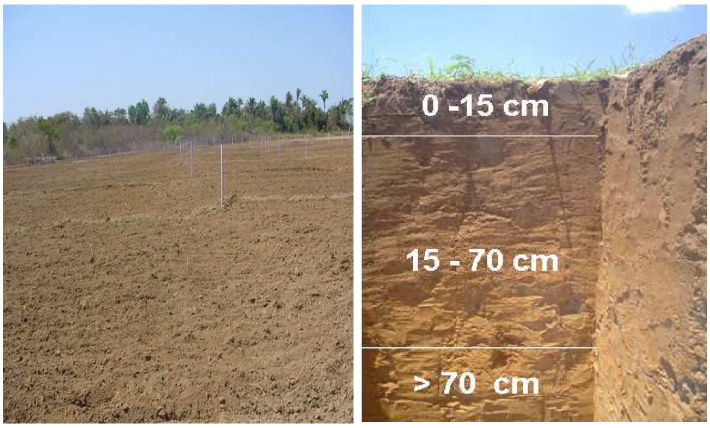


Figure 3. Soil from the Teresina, PI, specific site experimental area.

Table 1. Teresina, PI, specific site soil physics characteristics and textural classification, according to the soil profile horizons.

Soil horizon Depth	Particle size ($g\ kg^{-1}$) Sand	Silt	Clay	Density ($g\ cm^{-3}$)	Textural classification
AP 0 – 0,15m	799,0	85,0	116,0	1,39	Sandy loam
AB 0,15 0,45m	627,0	127,0	246,0	1,33	Clay-sandy loam
Bt 0,45 – 0,70m	627,5	96,5	276,0	1,32	Clay-sandy loam
C > 0,70m	550,0	144,0	306,0	1,27	Clay-sandy loam

Table 2. Teresina, PI, specific site soil chemical characteristics.

Soil horizon Depth	pH	P	K^+	Ca^{2+}	Mg^{2+}	Na^+	$H^+ Al^{3+}$	CTC	V
	(H_2O)	mg dm^{-3}	---------------------	cmol$_c$ dm^{-3}	---------------				%
AP 0–0,15m	5,86	26,40	0,15	2,08	0,86	0,27	2,01	5,37	62,53
AB 0,15–0,45m	4,61	2,20	0,04	1,76	0,71	0,10	4,57	7,18	36,35
Bt 0,45–0,70m	4,30	1,70	0,02	0,45	0,68	0,07	3,91	5,13	23,78
C > 0,70m	4,28	1,10	0,02	0,83	0,72	0,08	2,59	4,24	38,91

The soil moisture retention curve for the Teresina site was determined and adjusted based on VAN GENUCHTEN's (1980) model equation (Figure 4). Considering the 0 to 0.45 m soil layer, the value of the soil field capacity (-10 kPa) was 21,2 % and the permanent wilting point was (-1,500 kPa) 9.05 %.

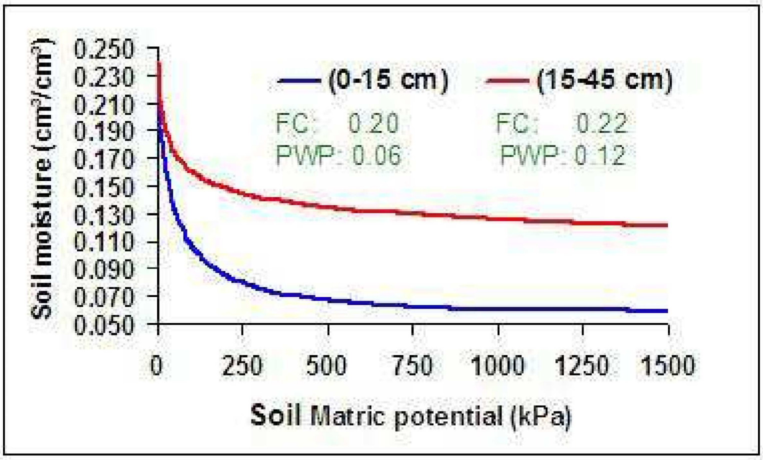


Figure 4. Soil moisture retention curve for the Teresina specific site (FC - Field Capacity; PWP - Permanent Wilting Point).

Irrigation Water Management

The irrigation scheme installed in the Teresina site specific area was a conventional sprinkler irrigation system, with sprinklers spaced 12 m x 12 m, operated with a service pressure of 250 kPa (2.5 atm), which provided a flow rate of 1.07 m3 h^{-1}. The sprinkler nozzles diameter were of 3.4 mm x 2,6 mm. The irrigations were applied according to the soil water balance performed daily. The reference evapotranspiration (ETo) was calculated through the Penman-Monteith equation, based on data collected from the automatic meteorological station of Embrapa Mid-North. The crop coefficients (Kc) values used in this work were obtained by ANDRADE JÚNIOR et al. (1998) for the corn yield; DOORENBOS & KASSAN (1994) for the sorghum yield; and local determined Kc for cowpea beans. The monitoring of soil moisture was carried out through the capacitance probe DIVINER 2000 ®, whose access pipes were installed between the plants, in the soil layers of 0.10 m intervals, up to 0.70 m deep. The soil moisture retention curve was determined (Figure 4) according to VAN GENUCHTEN's (1980) model. The value of field capacity (-10 kPa), considering the 0 to 0.45 m soil layer, was 21.2% and the permanent wilting point was (-1500 kPa) 9.05%.

Two experiments were carried out at Teresina site, one using full irrigation and the other under water deficit induced from the pre-flowering up to the beginning of pod filling crop growing phases.

Maize Cultivation

In both experiments (with and without water deficit) 64 simple hybrids were assessed, at random blocks, through three repetitions. Each parcel consisted of a row of 5.0 m long, spaced 0.80 m between rows x 0.25 m among the plants in the rows. The following fertilizers coumpounds 30-45-20 +2 kg of N, P_2O_5, K_2O + Zn ha^{-1} were applied at the foundation during crop sowing. In coverage, 80 kg of N ha^{-1} were applied, respectively, at the time of the emission of the sixth and eighth leaf.

Sorghum Cultivation

In both experiments, 49 sorghum genotypes were evaluated, in a randomized blocks layout, with three replications. Each parcel consisted of two rows of 5.0 m long, spaced 0.50 m between each other, with 10 plants per linear meter. The fertilizer 60-60-45 formula kg of N, P_2O_5, K_2O ha^{-1} was applied at the foundation during crop sowing, and 80 kg of N ha^{-1} was added in coverage at the 30 days after the emergence of seedlings.

Cowpea Beans Cultivation

A total of 20 cowpea beans genotypes was used in the trial: Pitiúba (1), Tvu 36 (2), TE-898 (3), Capela (4), Canapuzinho (5), Canapu-BA (6), Canapuzinho-PE (7), CNCx 689-128G (8), BR17-Gurguéia (9), BRS-Paraguaçu (10), Patativa (sempre-verde-PB) (11), TE96-290-12G (12), Pingo-de-ouro-1 (13), Pingo-de-ouro-2 (14), Pingo-de-ouro-1-2 (15), Canapuzinho-2 (16), EPACE-10 (17), IPA-206 (18), Tracuateua-192 (19) e Santo Inácio (20).

In the sowing, four seeds were planted per hole. After 15 days after sowing, some of the young emerged plants were removed from the field, resulting in a final stand of 100,000 plants per hectare. The fertilization utilized during sowing was 20-50-40 $kg.ha^{-1}$ of N, P_2O_5 and K_2O, respectively.

The experimental design layout was based on randomized blocks, with four replications. The plot area consisted of 3.20 m x 5.0 m, totalizing 16 m^2, consisting of four rows of plants, spaced of 0.8 m x 0.25 m. The two central rows were considered as the useful studied area.

It was evaluated in the trials the grain productivity, the production components (length of pods, number of pods per plant, number of seeds per pod and mass of 100 grains), the leaf water potential, the stomatal conductance, the leaf temperature, and leaf gas exchange. The evaluations concerning stomatal conductance, steam dissemination and leaf temperature were performed with a porometer device, manufactured by LI-COR, model 1600 (Steady State Porometer) in leaflets entirely expanded and without signs of senescence or herb ivory in maximum vegetative stadium of the plant (V7 to S9). Schulander pressure chamber equipment (model "Soil Moisture Equipment Corp." Saint Barbara, California) was used in the leaf water potential determination, taking the same leaflets sampled for other measurements.

RESULTS

MAIZE DROUGHT TOLERANCE PHENOTYPING

From the beginning of the 45 days after sowing (DAS), growth period in which starts tillering, it was verified that the maize crop evapotranspiration (ETc) becomes more intense than the reference evapotranspiration (ETo), reaching values around 7 mm.day^{-1} (Figure 5). This means that the maize crop coefficient "Kc" is greater than 1. Figure 5 shows that the water stress occurred starting on 48 DAS. Soil moisture reached minimum values of 15.1% and 10.3% for the experiments with and without water deficit, respectively (Figure 6). This corresponded to an amount of soil water depletion of about 50% (no stress) and 90% (stress), respectively, regarding the total soil water availability (Figure 7).

Table 3 shows the average values of the number of ears (NE), weight of ears (WE), and grain productivity (GY) of 64 maize genotypes accesses phenotyped for drought tolerance under full irrigation (NS=non stressed) and water deficit (WS=water stressed) regimes.

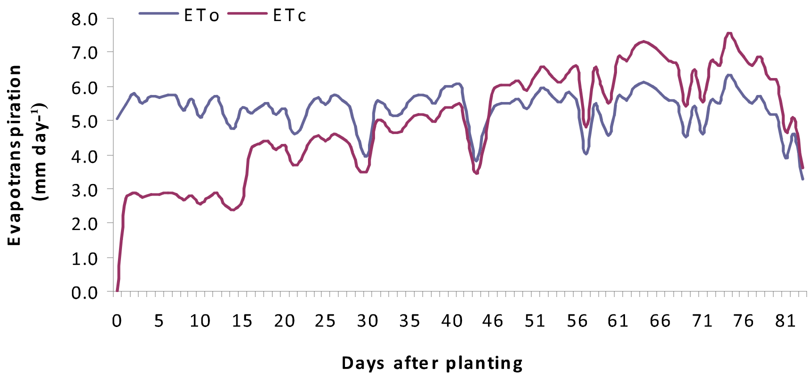


Figure 5. Maize crop evapotranspiration (ETc) and reference evapotranspiration (ETo) variation along the crop growing cycle from September to December 2007, at Teresina, PI.

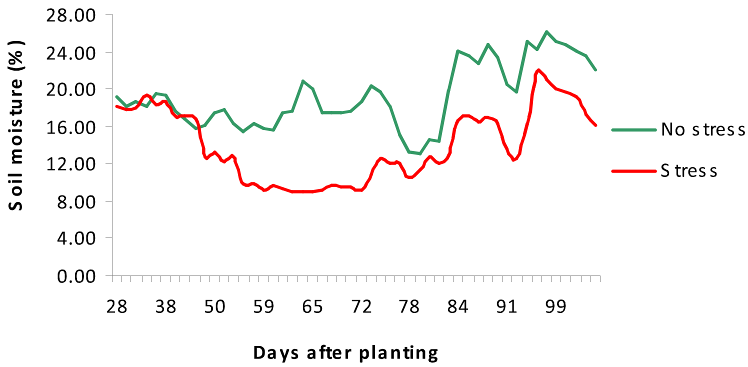


Figure 6. Change of the soil moisture content over the phenological cycle of the maize crop for two water regimes: with and without stress.

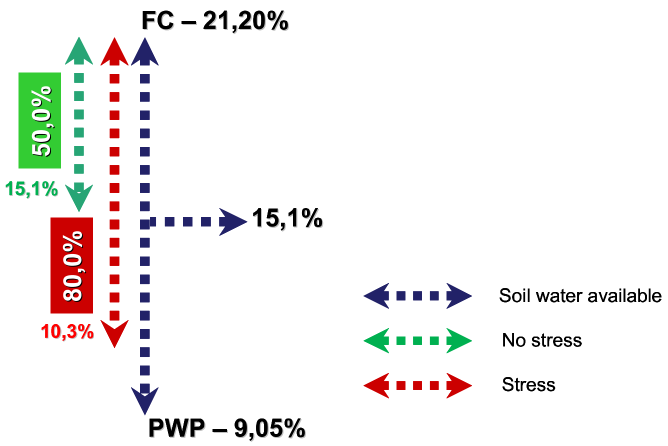


Figure 7. Depletion factor of soil moisture in the depth of 40 cm for two water regimes maize crop: with and without water stress conditions.

With respect to the production components, the number and weight of ears (Table 3) were severely affected by water deficit, reaching values 500% and 1,000% lower than those obtained in experiments under full irrigation, respectively. The average productivity of maize grain under water stress (400 kg/ha) was 11.3 % lower than the maize under full irrigation (4,531 kg/ha). Probably, the increase of the interval between the pendoamento phases and the espigamento and the beginning of ear filling phase favored the pollen abortion, and were also aggravated by climatic factors such as high temperatures and low relative air humidity. Under water deficit condition, 24 maize genotypes stood out with a grain productivity bigger than the experiments' average, and six stood out with a grain productivity greater than 1,200 kg/ha (Table 3).

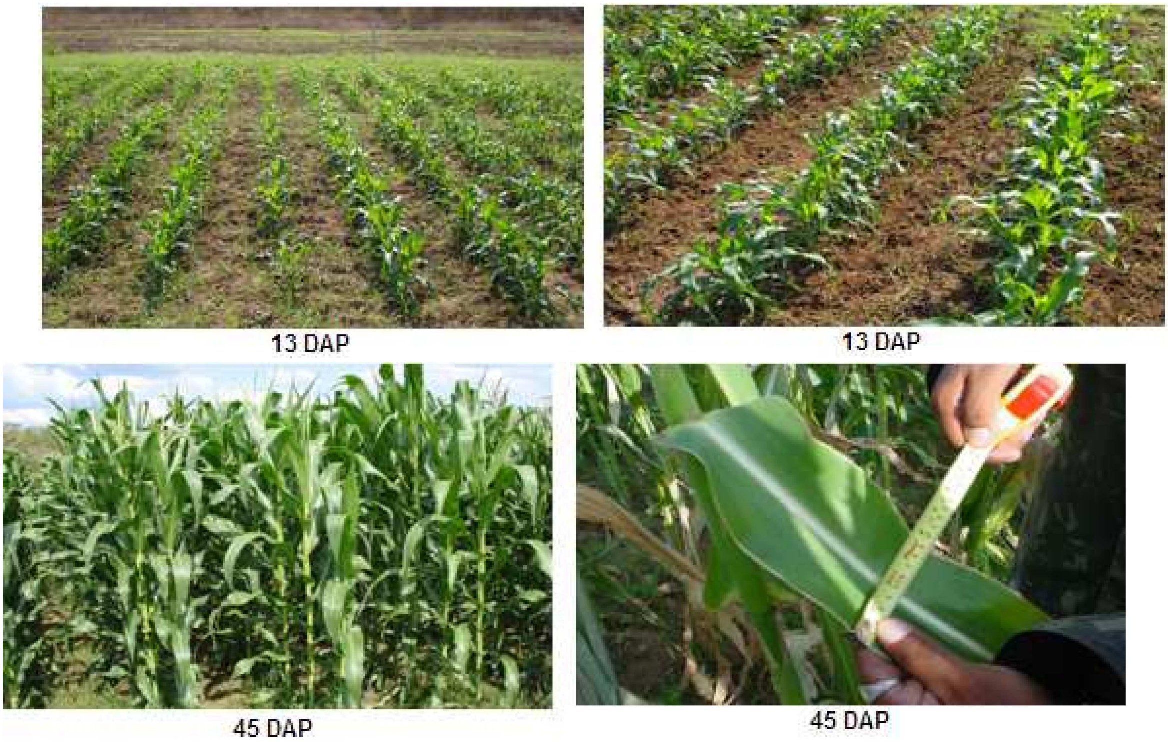
Table 3. Average values of the number of ears (NE), weight of ears (WE), and grain productivity (GY) of 64 maize genotypes accesses phenotyped for drought tolerance under two water regimes (NS=non stressed and WS=water stressed) at Teresina, PI, 2007.

Genotypes	NE/ha		WE (kg/ha)		GY (kg/ha)	
	WS	NS	WS	NS	WS	NS
30F53	32.500	50.000	2.975	7.946	2.109	6.497
HTMV1	26.667	48.333	2.475	4.808	1.922	3.946
HTMV2	28.333	55.000	1.975	5.858	1.484	4.795
159	25.833	50.833	1.813	4.625	1.358	3.527
155	20.833	62.500	1.600	6.992	1.265	5.575
26	20.833	45.000	1.608	5.583	1.232	4.585
15	15.833	50.000	1.150	5.642	951	4.399
37	16.667	58.333	1.125	5.871	852	5.121
154	10.000	42.500	842	2.779	667	2.323
151	10.833	59.167	863	8.217	645	6.490
BRS 1031	8.333	55.000	854	6.054	642	4.700
35	6.667	51.667	775	5.913	604	4.622
BRS 1010	22.500	50.833	829	7.683	602	5.668
161	15.000	55.000	788	5.683	549	4.526
99	16.667	52.500	754	5.100	549	3.934
BRS 1035	18.333	53.333	829	8.183	540	5.849
63	11.667	54.167	683	5.850	535	4.635
150	7.500	50.833	642	5.479	526	4.442
19	14.167	60.833	850	6.454	512	4.932
162	14.167	47.500	625	4.058	458	3.085
BRS 1001	7.500	15.000	588	2.096	446	1.472
170	18.333	58.333	658	5.613	441	4.118
3	10.833	52.500	646	7.892	427	6.200
25	8.333	54.167	533	5.925	403	4.523
BRS 1015	10.833	49.167	613	7.767	381	5.490
166	8.333	55.833	488	5.963	367	4.533
134	11.667	51.667	492	4.571	328	3.599

118	9.167	55.000	504	5.467	316	4.135
172	6.667	48.333	471	5.192	313	4.058
Maximus	5.000	48.333	383	5.367	294	4.160
62	5.000	45.833	400	5.838	291	3.844
169	4.167	46.667	379	4.213	272	3.270
174	15.833	56.667	417	5.217	269	4.220
147	9.167	53.333	367	7.438	265	5.759
17	9.167	50.000	388	5.921	253	4.646
94	5.833	50.833	313	5.088	240	4.085
145	6.667	53.333	288	4.967	221	4.060
114	10.833	34.167	313	6.996	212	5.409
135	7.500	46.667	271	5.433	192	4.344
124	8.333	49.167	254	5.971	184	4.807
73	9.167	50.000	238	5.767	175	4.435
128	3.333	45.000	213	4.871	171	3.647
112	10.833	47.500	275	6.575	159	4.973
129	11.667	49.167	271	5.646	155	4.459
49	5.833	46.667	192	5.446	139	4.332
113	5.833	54.167	183	4.783	135	3.814
122	5.833	50.000	183	5.425	131	4.276
2B710	6.667	50.833	175	7.071	114	5.362
27	4.167	50.833	146	5.733	102	4.590
65	6.667	53.333	150	6.221	94	4.752
83	3.333	54.167	108	6.975	78	5.446
12	0	55.833	0	6.346	0	4.726
20	0	52.500	0	4.638	0	3.529
33	0	59.167	0	7.629	0	5.937
59	0	53.333	0	5.767	0	4.579
67	0	27.500	0	3.571	0	2.904
80	0	47.500	0	5.938	0	4.649
88	0	50.000	0	4.975	0	3.897
100	0	54.167	0	5.300	0	4.304

101	0	63.333	0	7.117	0	6.431
107	0	56.667	0	6.763	0	5.221
109	0	49.167	0	5.183	0	3.734
119	0	42.500	0	3.946	0	3.165
BRS 1030	0	57.500	0	8.608	0	6.412
Average	**9.310**	**50.000**	**546**	**5.813**	**400**	**4.531**

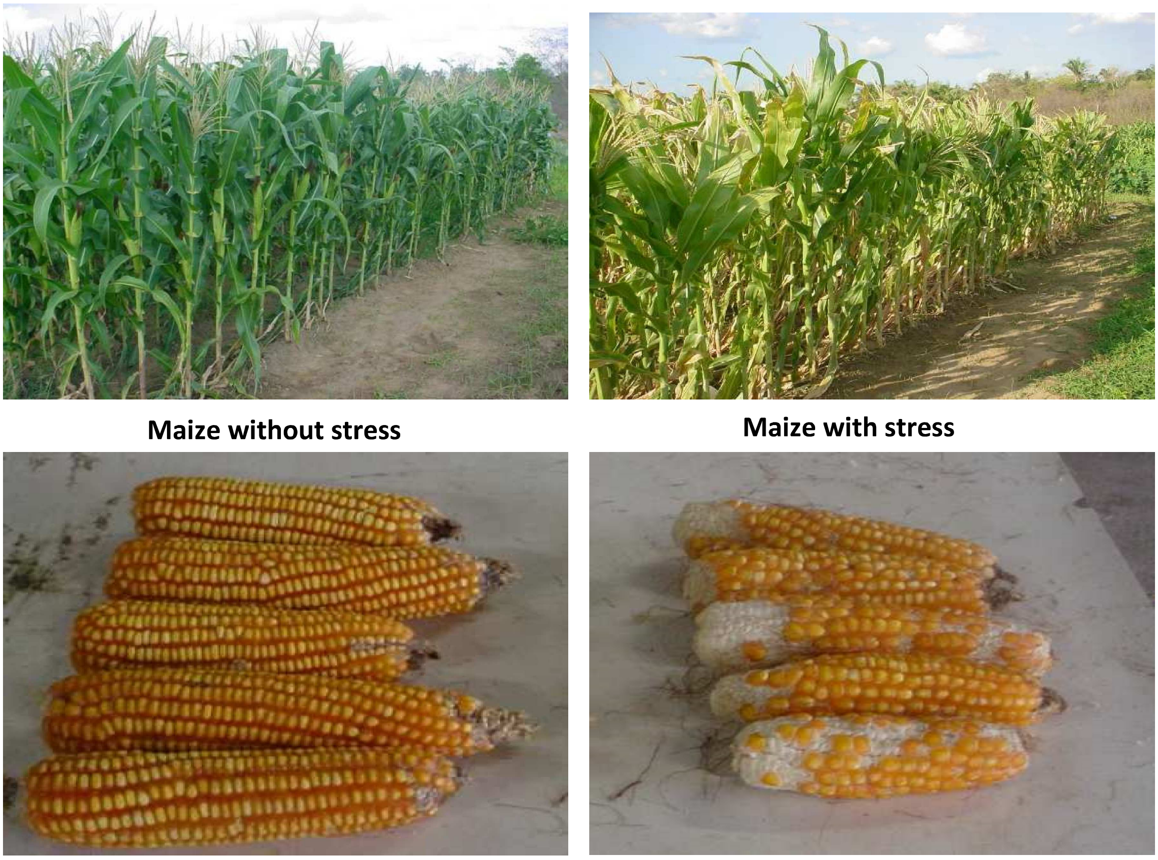
Figures 8 and 9 illustrate of some maize genotypes accesses phenotyped for drought tolerance under two water regimes (full irrigated or NS=non stressed and WS=water stressed) for different phonological stages in the vegetative and reproductive phases at Teresina, PI.



Figures 8. Some maize genotypes accesses pictures, phenotyped for drought tolerance under two water regimes (full irrigated or NS=non stressed and WS=water stressed) for different phenological stages in the vegetative phase at Teresina, PI.

Sorghum Drought Tolerance Phenotyping

Sorghum crop evapotranspiration (ETc) and reference evapotranspiration (ETo) variation along the crop growing cycle, from September to December 2007, at Teresina, PI, is presented in Figure 10. It can observed that during the most critical period of crop development (flowering to pod filling), ETc ranged from 6 to 7 mm/day. Figure 11 shows the change of the soil moisture content over the phenological cycle of the sorghum crop for the two water regimes studied: with (C/E) and without stress (S/E). Based on Figure 11, it is possible to notice that the water stress occurred starting from day 50 days after planting. Soil moisture reached the minimum values of 16.6% and 11.3% in both experiments - with and without water deficit, respectively. This corresponded to a soil depletion around 40% (no stress) and 80% (stress) of the soil water available in the soil (Figure 12).



Figures 9. Maize genotypes accesses view phenotyped for drought tolerance under two water regimes (full irrigated or NS=non stressed and WS=water stressed) for the reproductive phase phenological stage, at Teresina, PI.

With respect to the sorghum crop production components, the number and weight of panicles, and the weight of a hundred grains were severely affected by water deficit, influencing grain productivity. Without water deficit the overall average productivity (3,411 kg ha^{-1}) indicates that grain yield was 3.63 higher than the average from the experiment with water deficit (938 kg ha^{-1}). Under water deficit 24 genotypes stood out with a grain yield bigger than the experiments' average, and 22 stood out with a grain productivity greater than 1,100 kg ha^{-1} (Table 4).

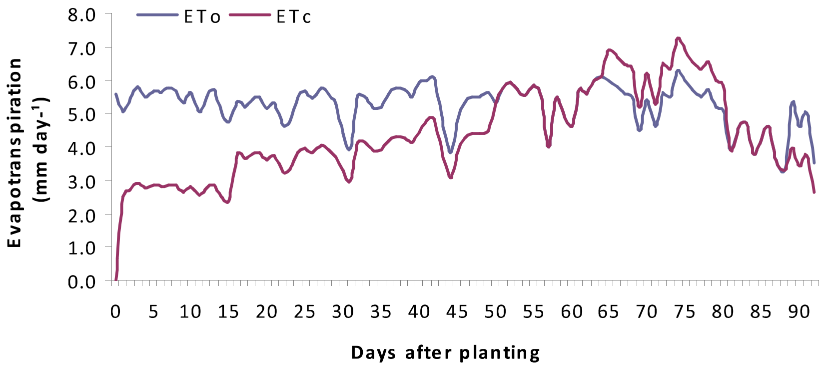


Figure 10. Sorghum crop evapotranspiration (ETc) and reference evapotranspiration (ETo) variation along the crop growing cycle from September to December 2007, at Teresina, PI.

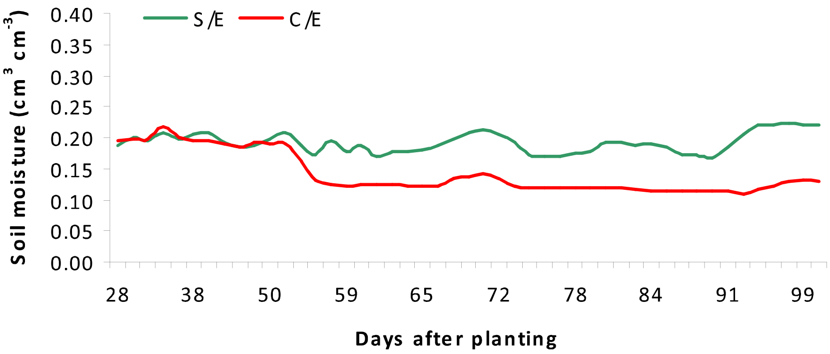


Figure 11. Change of the soil moisture content over the phenological cycle of the sorghum crop for two water regimes: with (C/E) and without stress (S/E).

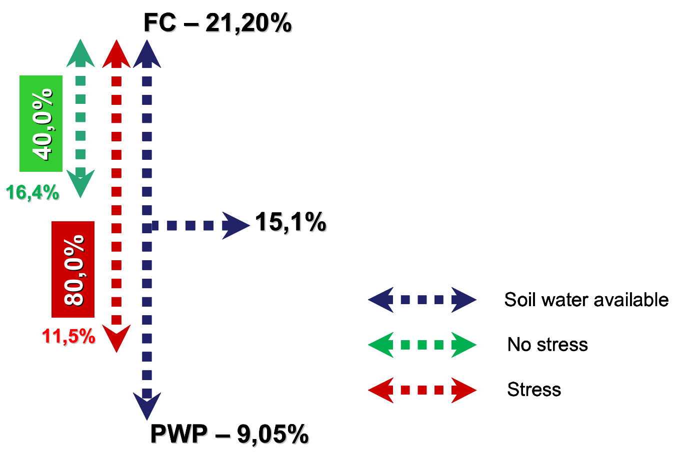


Figure 12. Depletion factor of soil moisture in the depth of 40 cm for two water regimes sorghum crop: with and without water stress conditions.

Table 4. Average values of the number of panicles (NP), weight of panicles (WP), weight of 100 grains (WHG) and grain yield (GY) of 49 sorghum genotypes under full irrigation (NWS=non water stress) and under water deficit (WS=water stress) during post flowering at Teresina, PI, 2007.

Genotypes	NP/ha		WP(kg/ha)		WHG (g)		GY (kg/ha)	
	WS	NWS	WS	NWS	WS	NWS	WS	NWS
9929012	80.000	186.316	3.918	7.864	1,6	2,3	2.671	4.707
9929020	133.333	160.000	3.037	6.876	1,3	2,1	2.558	4.226
ATF 54B	93.069	111.579	3.144	4.244	0,9	1,4	2.550	2.878
9409052	80.882	197.143	3.068	6.957	1,2	1,9	2.513	4.329
ATF 46B	120.000	151.111	3.151	3.821	1,3	1,8	2.429	2.809
9929022	64.220	144.762	2.749	5.433	1,8	2,0	2.306	3.360
9929048	126.923	154.444	3.263	5.059	1,9	2,5	2.279	2.718
BR 007B	110.714	181.538	2.999	3.729	1,2	1,9	2.204	2.510
307091	67.391	227.027	2.511	9.295	0,9	1,8	2.119	6.359
306004	93.976	151.795	2.580	7.069	0,8	1,6	1.945	3.652
307071	108.974	221.687	2.993	9.953	1,7	1,8	1.922	7.444
156-P-5-Ser	73.333	191.795	2.475	9.063	1,8	2,3	1.763	4.817
FBS 8701-9	91.111	122.759	2.490	4.521	1,8	2,3	1.742	3.529
BR 008B	67.742	263.953	2.581	7.556	1,3	2,2	1.697	5.805
Tx 436	73.043	296.410	2.026	8.637	1,0	2,1	1.588	6.175
9929034	70.213	112.195	2.175	3.545	1,8	1,8	1.510	1.926
9920045	45.000	133.846	2.052	5.020	0,8	1,8	1.325	3.549
9409132	98.462	257.000	1.975	4.469	1,2	2,3	1.291	2.988
Tx 2783	48.000	99.355	1.845	4.704	1,9	2,2	1.282	2.453
9409162	91.566	193.103	1.688	4.786	1,2	2,0	1.265	3.179
CMSXS 206B	75.862	214.444	1.606	7.226	0,9	1,9	1.211	5.412
SC 414-12-E	41.818	158.919	1.737	4.421	1,3	1,7	1.169	3.983

BRS 310	61.111	236.000	1.405	8.411	1,2	1,8	973	5.612
9503062	48.718	189.595	1.517	5.381	1,9	2,1	969	2.748
SC 748-5	33.333	124.103	891	4.147	1,4	2,4	797	2.959
9503038	25.000	100.513	677	3.623	1,9	2,3	533	1.720
SC 283	41.176	285.882	870	5.240	0,6	1,8	509	3.514
25162	36.923	108.235	801	3.673	0,6	2,0	473	2.168
9503086	24.419	68.687	573	2.659	1,2	1,6	395	1.577
Tx 7078	0	116.571	0	4.242	0,0	2,3	0,0	2.800
B 35	0	109.474	0	2.952	0,0	2,6	0,0	1.194
IS 5322C	0	124.490	0	1.510	0,0	1,7	0,0	749
Tx 2904	0	178.947	0	7.147	0,0	3,0	0,0	4.891
Tx 2908	0	161.081	0	4.458	0,0	2,7	0,0	5.246
Tx 2907	0	69.268	0	2.101	0,0	2,5	0,0	1.130
Tx 2898	0	89.143	0	3.864	0,0	2,1	0,0	1.867
B 803	0	137.778	0	4.614	0,0	2,4	0,0	2.587
9409094	0	225.641	0	4.915	0,0	1,8	0,0	3.242
BTx 623	0	135.484	0	5.306	0,0	2,3	0,0	3.464
N 122B	0	181.053	0	5.395	0,0	2,2	0,0	4.143
Tx 2896	0	107.778	0	4.430	0,0	1,8	0,0	2.967
Tx 2895	0	52.632	0	3.556	0,0	2,7	0,0	1.795
Tx 2737	0	190.270	0	5.674	0,0	2,2	0,0	3.704
N 95B	0	133.714	0	4.881	0,0	2,5	0,0	2.668
BTx 637	0	214.857	0	7.307	0,0	2,3	0,0	4.769
B 8911	0	142.690	0	5.822	0,0	2,2	0,0	3.580
BTx 636	0	165.556	0	6.879	0,0	2,2	0,0	4.610
Tx 430	0	28.947	0	2.252	0,0	3,4	0,0	1.318

9503083	0	88.889	0	3.443	0,0	2,2	0,0	2.011
Average	**43.394**	**157.111**	**1.282**	**5.315**	**0,8**	**2,1**	**938**	**3.411**

Figures 10 illustrates of some sorghum genotypes accesses phenotyped for drought tolerance under two water regimes (full irrigated or NWS=non water stress and WS=water stress) for different phonological stages (DAP= days after planting) at Teresina, PI.

NWS 63 DAP

WS 63 DAP

NWS 76 DAP

WS 90 DAP

Figures 10. Some sorghum genotypes accesses pictures phenotyped for drought tolerance under two water regimes (full irrigated or NWS=non water stress and WS=water stress) for different phonological stages (DAP= days after planting) at Teresina, PI.

Cowpea Beans Drought Tolerance Phenotyping

Figure 11 shows the cowpea beans crop evapotranspiration (ETc) and reference evapotranspiration (ETo) variation along the crop growing cycle, from September to November 2007, at Teresina, PI. The average value of ETc during the complete crop cycle was 4.3 $mm.day^{-1}$ and the highest values (5.5 $mm.day^{-1}$) were obtained during the crop reproductive phase. The change of the soil moisture content throughout the phenological cycle of the cowpea beans crop for two water regimes: with (Stress) and without stress (No stress) is presented on Figure 12. It is possible to notice that water stress occurred starting since 33 days after planting. Soil moisture reached the minimum values of 15.1% and 9.7% for both experiments - with and without water deficit, respectively. This corresponded to a soil water depletion around 50% (no stress) and 95% (stress) of the soil water availability, according to the depletion factor of soil moisture in the depth of 40 cm for the two water regimes of the cowpea beans crop studied (Figure 13).

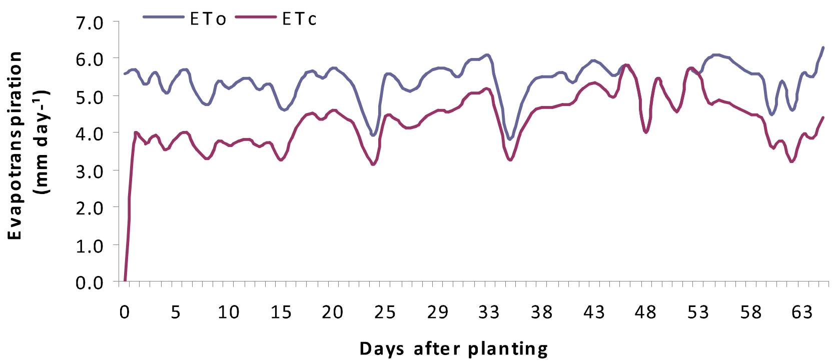


Figure 11. Cowpea beans crop evapotranspiration (ETc) and reference evapotranspiration (ETo) variation along the crop growing cycle, from September to November 2007, at Teresina, PI.

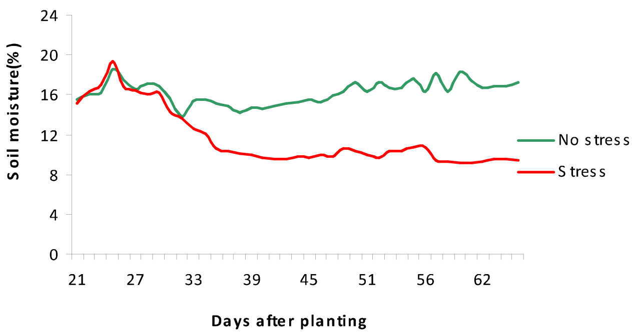


Figure 12. Change of the soil moisture content throughout the phenological cycle of the cowpea beans crop for two water regimes: with (Stress) and without stress (No stress).

With respect to the physiological parameters, Figure 14 presents stomatal conductance values (mmol m^{-2} s^{-1}) results of 20 cowpea bean genotypes accesses for two water regimes conditions. It was found that the genotypes submitted to water deficit indicated lower values of stomatal conductance, characterizing stomatal closing to avoid loss of water through the leaves. Under full irrigation conditions, genotype 17 (EPACE 10) was the one which presented a higher value of stomatal conductance (532.04 mmol m^{-2} s^{-1}), probably due to the better water regime condition of the plants. The genotypes submitted to water deficit indicated low stomatal conductance values, with an overall average of 40.94 mmol m^{-2} s^{-1}; and for this water stress condition, the genotype EPACE 10 presented the lowest stomatal conductance (16.83 mmol m^{-2} s^{-1}).

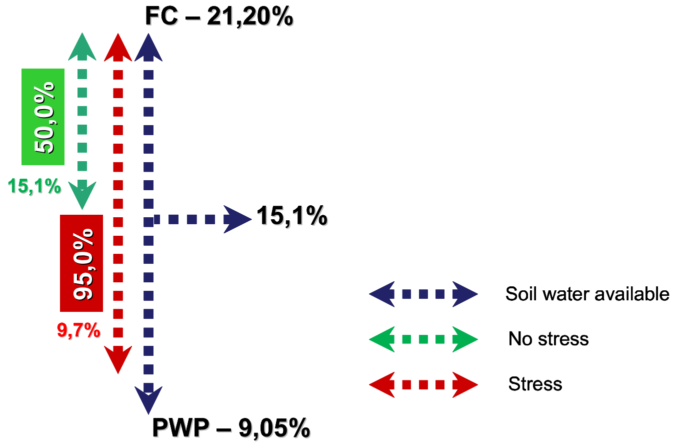


Figure 13. Depletion factor of soil moisture in the depth of 40 cm for two water regimes cowpea beans crop: with and without water stress conditions.

Figure 15 presents leaf temperature values of 20 cowpea bean genotypes for two water regime values. The overall genotypes leaves temperature results indicated that the experiment with water stress registered an average of 35°C, 10.8% higher than the foliar temperature of the cowpea beans under full irrigation (32.4°C).

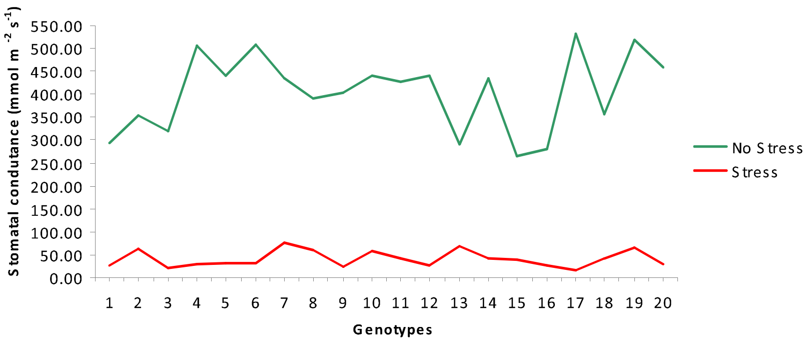


Figure 14. Stomatal conductance values (mmol m^{-2} s^{-1}) of 20 cowpea bean genotypes accesses, with (Stress) and without (No Stress) water stress conditions at Teresina, PI, site.

The results of the leaf water potential in 20 cowpea bean genotypes for two water regimes are presented in Figure 16. These results indicated a variation among the materials regarding the preservation of the water status even under drought. It is possible to verify that in the experiment under water deficit, all genotypes indicated lower values of leaves water potential when compared to the experiment under full irrigation. Thus, there is no doubt that the water stress significantly affected this studied parameter. The genotypes most tolerant to water deficit were the CNCx 689-128G (8), BR17-Gurguéia (9) and Santo Inácio (20), while the least tolerant were the IPA-206 (18), TE-898 (3) and Pingo-de-ouro-2 (14).

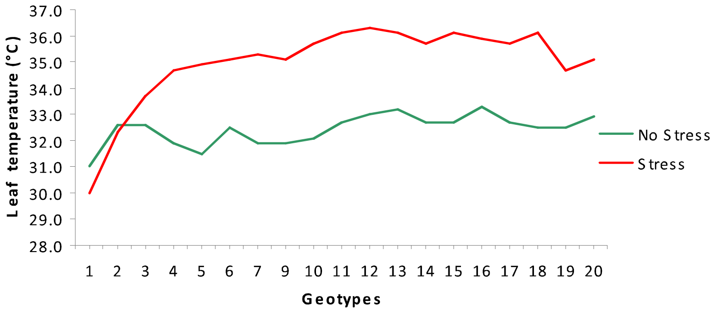


Figure 15. Leaf temperature values of 20 cowpea bean genotypes, with (Stress) and without (No Stress) water stress conditions.

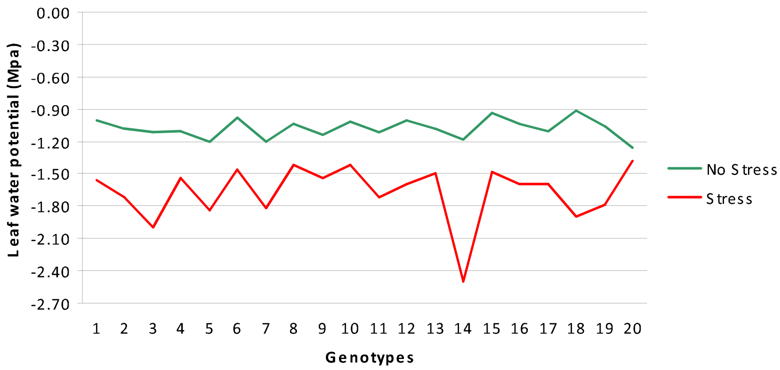


Figure 16. Values of leaf water potential in 20 cowpea bean genotypes of bean-cowpea, with (Stres) and without (No Stress) water stress conditions.

The productivity and production components of cowpea beans genotypes under full irrigation and water deficit condition, induced during post-flowering, at Teresina, PI, are presented on Table 5. It can be verified that the pod length (PL) and number of grains per pod (NGP) were severely affected by water deficit, resulting in average values of 10.6 cm and 5.9, respectively. In the experiment under full irrigation, the average values of these variables were 19.4 and 14.1 cm. The mass of one hundred grains (MHG) in the experiment with water deficit (16.7 g) was 27% lower compared with the experiment without water stress (21.2 g).

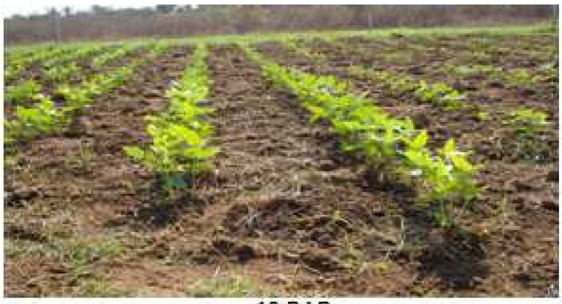
It was possible to verify a deleterious effect of the water stress upon the grain productivity (GY), resulting in average value of 60,7 kg ha^{-1}, 21.5 times smaller than the average from the experiment without water deficit (1.303 kg ha^{-1}). Under water deficit 6 genotypes stood out, presenting a grain productivity above the experiments' average. The Tvu-36 genotype reached the highest grain productivity (242 kg ha^{-1}) under water deficit conditions.

Table 5. Productivity (GY= grain yield) and production components (PL=pod length, NGP= number of grains per pod, MHG= mass of one hundred grains, GPR= grains to pods ratio) results of cowpea beans

genotypes under full irrigation (NWS= No Water Stress) and under water deficit (WS= Water Stress) at Teresina, PI, site, 2007.

Genotypes	**PL (cm)**		**NGP (g)**		**MHG (g)**		**GPR (%)**		**GY (Kg ha^{-1})**	
	WS	**NWS**	**WS**	**NWS**	**WS**	**NWS**	**WS**	**NWS**	**WS**	**NWS**
Tvu 36	15.4	15.3	11.9	15.9	9,5	11.3	68.7	66.4	242	1.293
TE96-290-12G	7.5	18.5	3.8	13.4	16.3	17.9	74.2	73.6	110	1.323
EPACE-10	11.6	22.3	7.8	16.1	17,8	20.9	75.3	66.6	105	1.380
BR17- Gurgueia	9.5	17.1	6.2	15.4	11,1	13.1	73.0	69.0	88	1.177
Pingo-de-ouro-2	9.1	20.2	4.5	15.3	19.2	25.8	73.2	63.4	71	1.324
Canapuzinho-2	6.3	20.0	4.0	14.8	15.1	26.1	75.4	70.6	62	1.122
Pingo-de-ouro-1-2	10.3	18.5	4.6	13.5	21.4	26.8	71.1	73.4	59	1.434
Tracuateua-192	5.4	15.7	3.2	10.6	12.3	24.5	40.8	55.8	33	906
Santo Inácio	7.9	21.9	4.6	15.1	18.1	21.5	59.1	59.5	44	1.100
Patativa(sempre-verde-PB)	9.6	18.4	5.6	12.7	18.0	22.9	74.1	63.1	54	1.225
Pingo-de-ouro-1	13.7	13.3	0.0	0.0	16.5	22.1	73.6	69.9	52	1.515
Capela	15.0	22.2	9.4	15.2	19.0	22.1	61.9	43.7	42	940
CNCx 689-128G	5.5	18.1	3.9	15.7	13.5	16.3	61.0	71.5	46	1.573
BRS- Paraguaçu	11.4	20.7	6.2	15.8	14.4	18.5	74.6	81.8	41	1.603
Pitiuba	14.3	19.9	9.9	15.5	12.3	15.1	76.4	64.7	40	1.354
Canapuzinho-PE	11.9	19.2	6.6	15.4	16.9	24.2	67.1	74.6	34	1.524
IPA-206	9.8	25.0	4.2	16.4	19.6	21.6	62.1	58.9	31	1.273
TE-898	14.8	21.2	9.8	15.7	15.9	24.2	38.2	65.7	15	918
Canapuzinho	10.9	20.2	5.7	15.5	18.5	24.5	66.2	81.4	21	1.573
Canapu- BA	11.9	21.3	6.4	14.8	16.7	23.9	76.9	70.9	24	1.510
Average	**10.6**	**19.4**	**5.9**	**14.1**	**16.7**	**21.2**	**67.1**	**67.2**	**60.7**	**1.303**

13 DAP (Divine access tube)



13 DAP

NWS 27 DAP

4 days before WS

NWS 48 DAP

WS 48 DAP

NWS 48 DAP (IPA 206)

WS 48 DAP

Figures 17. Pictures of some cowpea beans genotypes accesses phenotyped for drought tolerance under two water regimes (full irrigated or no water stress = NWS, and with water stress =WS) for different phenological stages (DAP= days after planting) at Teresina, PI, site, 2007.

Figures 17 illustrates of some cowpea beans genotypes accesses phenotyped for drought tolerance under two water regimes (full irrigated or with stress and without water stress) for different phenological stages (DAP= days after planting) at Teresina, PI, specific site, for the year 2007.

CONSIDERATIONS

The utilized methodology, parameters and tools in this study allowed to identify and phenotype genotypes accesses of cowpea beans, maize and sorghum which exhibited tolerance to drought when submitted to water stress regime condition. The results obtained with the used crop species genotypes can be used in a breeding genetic improvement programs for plants with the aim of generating varieties tolerant to water stress.

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