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PERFORMANCE OF SUNFLOWER GENOTYPES FOR STRESS TOLERANCE BASED ON PHYSIOLOGICAL PARAMETERS AND DROUGHT TOLERANT INDICES

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ABSTRACT

To study the stress tolerance and to assess their response to moisture stress, 32 contrasting sunflower genotypes were selected based on their performance for root traits, total dry matter (TDM) and $\Delta^{13}C$ values from the previous study and plants were grown in temporary cement root structure and field. One set of plants raised under normal irrigation condition and for another set irrigation was withheld from star bud stage till flowering for 20 days. Moisture stress at flowering reduced the grain yield (48%), test weight (34%), seed volume (4%) and oil content (5%) over the control. Total leaf area was reduced by 30% under stress leading to a significant reduction in TDM. Based on the traits, several genotypes with high TDM coupled with high root traits were selected. They also maintained better yield under stress compared to other genotypes. Some indices to determine the drought tolerance are drought susceptibility index (DSI) and drought tolerance efficiency (DTE) which is based on how much reduction is realized under drought stress. Genotype with highest DTE and low DSI were considered as drought resistant genotypes and the following lines were identified IB-84, P-62-R, R-297, CMS-851A, CMS-343A, RCR-60-P, RES-834-1, IB-47, IB-60 and BGR-135-2. From this study, it can be concluded that DSI and DTE are the important parameters to evaluate genotypes under stress to select drought tolerant or resistant genotypes based on yield realized under non-stress and stress conditions.

Key words: Carbon isotope discrimination, drought tolerant efficiency, drought susceptibility index, rate of water loss, sunflower.

INTRODUCTION

Water deficit is an important productivity limiting factor in all oilseed crops. Genetic improvement through enhanced drought tolerance, believed to be very rewarding, has not received the significant attention of crop breeders. This is mainly due to the physiological complexities involved in the development of adequate screening techniques to precisely document the available variability. Some selection gains have been reported, but these have mostly been due to empirical screening using absolute yield under stress in comparison to that obtained under conditions as a selection criteria. These yield gains possibly resulted from indirect selection for traits conferring some adaptive advantage under water stress conditions. Use of water use efficiency (WUE) and high root traits are important screening techniques helps to find out the significant variation among the genotypes (Condon *et al.,*, 2004 and Wery *et al.,,* 1997). Most of the released hybrids are evolved under normal environments and are not well adapted for drought conditions. Hence, screening or breeding for drought tolerance should be the prime objective. In turn it depends on the presence of diverse germplasm so that potential sources of drought tolerance might be identified and subsequently used to assure high yield when drought occurs. Fukai *et al.,,* (1999) has shown that, multiple interactions contributing to drought tolerance of crops, as drought events occur at different phases during the growing season or the spatial variability. This contributes to a large genotype × environment (GE) interaction. In most cases, no clear cause of the G x E interaction has been identified because of lack of information about the environment (such as weather or soil) or the genotypes themselves (Voltas *et al.,*, 2002). Several indices have been proposed to describe the behavior of a given genotype under stress and non-stress conditions (Yadav and Bhatnagar, 2001). In our study, along with several physiological traits, yield stability parameters like drought susceptible index (DSI) and drought tolerant efficiency (DTE) were calculated to determine the difference of yield potential under irrigated conditions and yield under drought for each genotype (Vannozi *et al.,,* 1999). A higher value of susceptibility index indicates higher susceptibility of a genotype to the stress. All these significant

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parameters help in identifying sunflower genotypes which can survive better under water limited condition with improved seed yield (Nishtman *et al.,*, 2013).

MATERIALS AND METHODS

To identify superior sunflower lines for root and water use efficiency, 71 sunflower genotypes were evaluated in temporary cement root structures and in field (Vanitha Shree *et al.,*, 2016). Further, in continuation of the experiment, to examine the variations in stress tolerance, contrasting lines differing in drought tolerance traits were identified from the set of 71 genotypes. The selection of genotypes was made by transforming the root biomass and total biomass to standardized normal distribution values (Z) contrasts were identified from the plot of the 'Z' values for total dry matter (TDM) and root biomass.

$$Z = \frac{GM - Xi}{SD}$$

Similarly, from field experiment also, a few more lines were selected by plotting standardized normal distribution plot between TDM and yield. In all, 32 lines were chosen for further experiment (Table 1). All the 32 lines were grown in root structures and in field. One set of plants were grown normally by irrigating regularly from sowing till harvest and for another set of plants the irrigation was withheld from star bud stage to flowering (30 DAS to 50 DAS) both for plants grown in root and field. Control plot had 24% of soil moisture content and stress plot had 16% soil moisture content.

Table 1: List of 32 sunflower genotypes selected for studying their response under stress and control condition both in temporary cement root study structure and in field

Sl No.	Genotypes	Sl No.	Genotypes
1.	CMS-302A	17.	IB-79
2.	NDR-4	18.	CMS-343A
3.	IB-97	19.	CMS-275A
4.	CMS-336A	20.	RHA6D-1
5.	RHA-16	21.	RCR-60P
6.	RHA-272-I	22.	RHA-23
7.	EC-512690	23.	RES-834-1
8.	CMS-335A	24.	IB-47
9.	IB-84	25.	CMS-597A
10.	RHA95-C-2	26.	CMS-135A
11.	RHA-275	27.	IB-20
12.	P-62R	28.	BGR-135-2
13.	CMS-17A	29.	IB-60
14.	DRSF-108	30.	RHA95-C-1
15.	RHA-297	31.	KBSH-44
16.	CMS-851A	32.	KBSH-41

To study the relevance of the roots in sunflower under water limited conditions, the selected 30 contrasting lines with two checks (KBSH-41 and KBSH-44) were sown in temporary cement root study structures and moisture stress was imposed for 20 days from star bud stage to flowering. Cement root structures were built according to the procedure given by Vanitha Shree *et al.,,* (2016) and the seeds of selected lines were treated with apron and sown as per the package of practice. The two water regimes (Control and stress) were imposed in two different root structures. Plant population was maintained by thinning and regular watering was done in done in control and irrigation was completely stopped from 30 DAS to 50 DAS.

In addition to the observations recorded on days to 50% flowering, plant height, number of leaves, total leaf area (TLA), specific leaf area (SLA), SPAD chlorophyll meter reading (SCMR), $\Delta^{13}C$, total dry matter, root length, root volume and root to shoot ratio, following observations were also taken. At vegetative stage, relative water content (RWC) of all the genotypes was estimated for both control and stress treatments at the end of the stress period. Ten leaf discs were obtained from fully expanded leaves and their fresh weight was determined. The leaf discs were immersed in deionised water for 5h and their turgid weight was determined. Leaf discs were dried in hot air oven at 80°C and dry weight was recorded. The RWC was calculated using the following formula and expressed in percent.

$$\text{RWC (\%)} = \frac{\text{(Fresh weight- dry weight)}}{\text{(Turgid weight- dry weight)}} \text{ X } 100$$

The rate of water loss (RWL) with time was also determined. Relative water loss of all the genotypes was estimated for both control and stress treatment at the end of the stress period in three replications. Fully expanded leaf was selected and initial fresh weight was recorded. Leaf area of that leaf sample was measured. The leaf was kept under laboratory conditions and the fresh weight was recorded at hourly interval to determine genotype variation in the rate of water loss. Rate of water loss was calculated using this formula.

$$\text{RWL (\%)} = \frac{\text{Initial leaf fresh weight (g)} - \text{leaf weight at a given time (g)}}{\text{Initial leaf fresh weight (g)}} \text{ X100}$$

At harvest the diameter of the stem between the 6th and 7th true leaves was measured using vernier calipers. Soil moisture was determined when the stress was imposed by gravimetric method.

All the parameters *viz.,* days to 50% flowering, plant height, number of leaves, TLA, SLA, SCMR, Δ^{13}C, total dry matter were recorded in field except root traits. In addition, the following parameters were recorded. Completely dried hundred seeds randomly sampled from all the harvested plants from each genotype were counted and weighed to get test weight (g).

Seed volume weight (g/100cc) was obtained by randomly chosen seeds filled in100 ml beaker and weighed.

Drought susceptibility index (DSI) was computed using formula developed by Fischer and Maurer (1978) was used.

DSI = (1 - Yd/Yp)/D

Yd = Grain yield of the genotype under moisture stress

Yp = Grain yield of the genotype under non-stress

D = 1- (Mean yield of all genotypes under stress / Mean yield of all genotypes under non-stress).

Drought tolerance efficiency (DTE) was estimated by the equation of Fischer and Wood (1981). According to this equation:

$$\text{DTE (\%)} = \frac{\text{Yield under stress}}{\text{Yield under control}} \text{ x } 100$$

RESULTS AND DISCUSSION

Tables 2 and 3 represents the range and mean values for all the parameters studied under stress and control condition for hybrids, CMS lines, R-lines and inbreds. There was a wide genetic variability observed for all the parameters under both the conditions. The mean values for days to 50% flowering reduced by 3 days under stress compared to control. Kumar *et al.,,* (2006) reveals that delay in flowering due to drought stress was negatively associated with grain yield and seemed to be governed by a lower plant water status. The mean SCMR values also reduced from 2-4% under stress, indicating the effect of moisture stress on chlorophyll content. Similarly, stress affected many parameters in all the selected entries. Plant height exhibited a wide variation and it was decreased during stress. Plant height is considered as genetically controlled. However, environmental conditions have modified their genetic potential. Under stress, TLA was reduced from 27.6% in R-lines to 32.6% in inbreds. In the present study, reduced leaf area under stress suggests that whenever the plants experience stress, they reduce their photosynthetic area as one of the strategies. The decreased leaf area under moisture stress can be attributed to the reduced leaf expansion rate and inhibition of emergence of leaf primordial. The stress increased SLA in all the entries and maximum SLA was observed in R lines (406.3). More leaf thickness and low SLA is found to be a good trait as genotypes possessing low SLA types are expected to be productive with high WUE. Total dry matter was reduced drastically under stress. The percent reduction varied from 42.1% (hybrids) to 55.3% (CMS-lines). Stem girth of each plant was measured at the time of harvest. Maximum stem girth was observed in KBSH-41 (2.2), KBSH-44 (2.20), IB-46 (2.2) and BGR-135-2 (2.1), IB-20 (2.3), CMS-343A (2.0)

Table 2: Range and mean values for the different parameters in hybrids, CMS-lines, R-lines and inbreds in plants grown under stress and non stress condition in temporary cement root study structure

Entries	Treatment	Hybrids		CMS-lines		R-lines		Inbreds	Mean
		Range	Mean	Range	Mean	Range	Mean	Range	
Days to 50% flowering	Control	70.00-73.67	71.33	66.33-76.00	71.96	67.67-75.00	70.81	70.33-73.67	71.63
	Stress	73.33-75.67	74.33	71.67-76.67	74.67	69.67-76.67	73.14	72.67-76.00	73.96
SCMR	Control	36.17-42.07	39.91	31.50-43.10	36.77	34.87-41.13	36.93	35.70-42.73	38.79
	Stress	35.70-37.73	36.50	28.30-38.87	33.53	30.40-36.83	33.38	31.27-39.13	34.92
Plant height (cm/pl)	Control	126.67-140.00	134.22	56.67-111.67	86.52	47.33-128.33	86.32	82.33-136.67	105.46
	Stress	101.67-106.67	103.89	49.33-95.67	70.87	45.33-80.50	63.83	61.33-125.33	94.00
TLA (cm^2/plant)	Control	4979.33-13983.88	9661.78	4149.58-10913.00	7298.92	4842.13-12650.00	7427.84	4226.08-10756.20	7265.65
	Stress	3855.03-9605.14	6950.80	2766.61-8512.01	4943.51	2717.89-9743.66	5379.42	2984.46-9162.60	4898.65
SLA (cm^2/plant)	Control	108.13-270.80	216.06	106.77-453.38	258.17	170.16-579.71	318.17	108.06-298.94	209.84
	Stress	157.93-257.99	222.40	154.13-494.21	325.63	211.67-544.03	406.33	161.85-500.13	336.63
Stem girth (mm)	Control	2.00-2.20	2.13	1.20-2.00	1.47	0.90-1.90	1.49	1.40-2.30	1.79
	Stress	1.60-1.90	1.77	0.80-1.60	1.06	0.70-1.40	1.04	1.10-1.40	1.28
RWC (%)	Control	79.51-97.06	80.93	78.68-95.51	85.04	73.15-84.41	82.29	69.98-93.04	81.52
	Stress	59.07-71.39	65.47	63.80-78.05	72.00	52.38-75.52	67.63	60.97-74.31	70.15
RWL (%)	Control	28.62-39.31	34.51	36.64-51.42	42.96	31.84-55.10	44.37	31.79-58.27	44.45
	Stress	20.98-30.59	24.64	23.6-43.57	30.10	21.51-45.69	30.37	25.80-40.35	31.66

Table 3: Range and mean values for TDM, root traits and $\Delta^{13}C$ hybrids, CMS-lines, R-lines and inbreds in plants grown under stress and non stress condition in temporary cement root study structure

Entries	Treatment	Hybrids		CMS-lines		R-lines		Inbreds	
		Range	Mean	Range	Mean	Range	Mean	Range	Mean
Total dry matter (g/pl)	Control	139.28-194.13	167.95	80.66-143.60	111.59	46.85-151.55	91.19	81.44-152.38	112.79
	Stress	80.20-114.84	97.25	33.05-67.85	49.88	26.54-66.91	42.42	53.07-81.93	62.45
Root length (cm/pl)	Control	35.33-47.33	42.77	19.66-39.66	34.81	22.00-53.33	32.69	30.33-52.66	40.37
	Stress	38.33-43.00	40.22	15.33-40.00	24.44	19.00-36.00	26.22	25.00-40.66	31.95
Root Volume (cc/pl)	Control	50.00-100.00	80.56	25.00-83.33	60.93	20.00-75.00	47.50	50.00-91.67	68.54
	Stress	46.67-73.33	63.33	18.33-58.33	34.93	11.67-50.00	26.89	22.67-58.33	42.42
Root dry weight (g/pl)	Control	17.15-35.71	28.05	10.91-37.76	25.42	3.99-35.85	17.66	6.54-25.10	14.78
	Stress	10.00-11.83	11.12	2.52-16.93	6.18	1.27-11.36	5.14	3.06-17.42	10.37
Root to shoot ratio	Control	0.14-0.13	0.20	0.14-0.54	0.30	0.06-0.49	0.23	0.07-0.24	0.15
	Stress	0.11-0.14	0.13	0.05-0.33	0.14	0.05-0.23	0.13	0.06-0.34	0.20
$\Delta^{13}C$ (‰)	Control	19.80-20.80	20.40	19.87-22.79	21.09	19.68-22.74	21.08	19.97-21.88	20.72
	Stress	19.94-20.78	20.72	20.11-22.29	21.03	19.34-21.84	20.60	19.67-21.21	20.32

and DRSF-108A (2.0). Moisture stress also reduced stem girth in all the entries. Relative water content (%), indicate moisture content of leaf was low in stress plants. Genotypic variation in leaf RWC was observed. Some of the entries like KBSH-41, CMS-597A, CMS-17A, CMS-135A, RES-834-1, R-23, RCR-60P, IB-20 and EC-512690 showed more RWC and less rate of water loss. This is one of the drought adoptive mechanisms for water stress. Decrease in leaf water potential was associated with reduced water supply from the soil to the roots and ultimately to the leaves (Wood and Goldsbrough, 1997). Rate of water loss was less in stress plants compared to control. Significant variability was also observed for all the root traits under stress and control. Though the mean values for root length was more in hybrids, maximum root length was observed in R-lines and inbreds. Longer root length may help to explore water and nutrients deeper in soil profile. This phenomenon is especially important when water supply is limited (Rauf and Sadaqat 2008b). RHA 6D-1 (44.6cm), NDR-4 (53.3cm) and IB-20 (52.6cm) exhibited more root length compared to checks KBSH-41 (45.6cm) and KBSH-44 (47.3cm), though their per cent reduction in root length under stress was more. Interestingly, in CMS-335 the root length (40cm) was not affected by stress. The per cent reduction in root length compared to stress was high in CMS-lines (29.8%). Similar observations were seen for root volume also. Varietal differences were also found significant. Root volume has positive correlation between stress and control. This indicates that those which maintain good root volume under control has maintained relatively high root volume under stress also. Stress affected the root dry weight severely in all the 32 selected genotypes. Percent reduction was more in CMS lines (Table 3). The mean root to shoot ratio was more in CMS-lines (0.3) and R-lines (0.23) compared to inbred (0.15). Inbreds maintained higher root to shoot ratio (0.2) under stress compared to control (0.15) and some of the inbred *viz.*, IB-60 (0.2), IB-97 (0.23), IB-20 (0.3) and EC-512690 (0.34) exhibited more root to shoot ratio under stress, indicating more root growth even under stress compared to above ground biomass. There is a genetic variability for $\Delta^{13}C$ values in all the selected 32 genotypes both under stress and control condition.

Field grown plants flowered 1 or 2 days earlier under stress compared to control (Table 4). There was a reduction in chlorophyll content under stress when it was measured by SPAD chlorophyll meter. Stress also reduced plant height, number of leaves and TLA. Though the leaf area of hybrids is more, there was only 13% reduction in TLA (cm^2/pl) under stress when compared to plants grown in cement root structure (28%). Entries like CMS-335A (11,158.3), CMS-336A (11,150.3) maintained good TLA. More SLA (cm^2/pl) was observed in CMS-335A (586.9), CMS-336A (574.0), RCR-60P (553.6), EC-512690 (587.6). Some of the entries *viz.,* CMS-135A (81.2), DRSF-108 (98.2), IB-84 (73.6) exhibited lesser SLA. Total dry matter (g/pl) was less in field grown plants compared to plants grown in cement root structure, where the root dry weight was included. Inbreds showed more TDM (g) under control. BGR-135-2 (121), IB-97 (117), IB-47 (108.6) showed more TDM but their percent decrease in TDM under stress was more. As in the plants grown under temporary cement root study structure, field grown plants were also affected by stress for the parameters like stem girth and senescence of leaves. The mean grain yield was more in inbred. Stress affected grain yield up to 50% in all the entries. The mean 100 seed weight was more in inbred (6.35g) similar to the total grain yield. Stress affected the mean grain yield in inbreds up to 42% and it was less in R-lines (29%). The mean value for seed volume in all the entries was similar, though the % reduction in grain yield by stress was more the seed volume was affected by stress was minimum (4%). The variability for oil content was less between the genotypes. There was only 2.7% (hybrids) to 4.7% (inbreds) reduction in oil content under stress. Harvest index was decreased under stress. Genotypic variations in $\Delta^{13}C$ values were significant.

Some of the indices determine drought tolerance *viz.,* drought tolerant efficiency (DTE) and drought susceptibility index (DSI). These are yield stability parameters which are based on how much reduction in grain yield are realized under drought stress. Drought resistant genotypes will have lower DSI and higher DTE. We selected the genotypes to consider them as drought resistance with lowest DSI values and high DTE and more grain yield under stress. The range for DTE was from 24.7% to 63.9%. The

Table 4: Range and mean values for the different parameters in Hybrids, CMS-lines, R-lines and inbreds in plants grown under stress and non stress condition in field

Traits	Treatment	Hybrid		CMS-lines		R-lines		Inbreds	
		Range	Mean	Range	Mean	Range	Mean	Range	Mean
Days to 50% flowering	Control	69.00-74.00	71.83	62.67-76.00	70.59	64.66-74.00	69.69	68.00-72.67	70.29
	Stress	71.00-76.33	72.67	63.33-75.33	69.44	61.66-71.67	67.86	67.33-70.67	68.41
SCMR	Control	37.71-43.51	41.05	36.34-40.91	39.40	36.04-41.21	39.00	37.44-44.70	40.12
	Stress	32.02-38.72	36.27	33.45-38.46	34.77	31.05-37.26	34.70	33.66-39.53	36.08
Plant height (cm/pl)	Control	147.66-165.00	156.42	88.66-152.33	122.45	65.00-130.66	106.67	119.00-143.20	134.50
	Stress	107.33-155.66	125.33	61.66-126.33	97.81	55.00-104.33	83.61	93.00-124.00	108.17
TLA (cm^2/pl)	Control	4676.16-12797.00	9270.52	2459.38-11158.33	5925.64	1473.00-8539.55	4349.99	2177.06-12029.62	6447.57
	Stress	2002.57-10338.39	6436.90	1230.73-10050.73	4030.35	1000.33-7617.00	3388.46	1103.38-9654.23	4265.31
SLA (cm^2/pl)	Control	76.37-335.04	236.06	79.96-499.79	239.14	82.71-486.31	214.16	93.00-477.09	221.09
	Stress	98.21-525.86	367.80	81.18-586.95	305.92	132.32-553.56	300.93	73.66-587.59	261.03
TDM (g/plant)	Control	138.65-190.06	170.71	61.99-95.73	80.58	39.02-120.88	64.57	63.81-116.99	93.40
	Stress	72.97-88.25	79.39	26.51-50.74	39.66	18.91-65.98	34.09	40.42-67.14	50.41
Stem girth (mm)	Control	2.00-2.20	2.13	1.20-2.00	1.56	0.90-1.90	1.48	1.40-2.30	1.79
	Stress	1.60-1.90	1.75	0.80-1.60	1.08	0.70-1.40	1.06	1.10-1.40	1.28
RWC (%)	Control	63.27-72.79	67.66	68.13-81.34	73.94	57.60-86.05	71.37	65.35-79.70	73.87
	Stress	51.99-64.24	56.42	40.83-67.18	56.50	48.15-65.76	59.50	47.84-66.83	57.55
RWL (%)	Control	28.32-36.37	32.30	21.48-49.71	34.37	30.17-56.00	39.40	28.00-52.53	37.23
	Stress	13.87-29.65	20.87	15.45-39.12	25.58	21.26-41.69	29.13	17.32-27.24	22.49
Grain yield (g/pl)	Control	68.44-95.75	84.84	20.18-45.21	31.71	8.50-58.95	25.19	21.24-50.78	40.08
	Stress	38.01-46.52	42.96	7.32-25.77	14.73	2.87-30.35	12.70	12.01-25.72	18.58
Test weight (g)	Control	5.45-7.81	6.65	3.49-7.88	5.66	3.26-5.74	4.63	4.16-8.39	6.35
	Stress	3.92-5.76	4.81	2.34-4.60	3.49	1.99-4.23	3.38	2.88-5.07	3.67
Seed volume(g/cc)	Control	46.40-55.76	50.12	42.44-48.59	46.18	36.16-47.37	43.37	40.96-48.58	44.21
	Stress	42.77-49.12	46.02	37.15-43.25	40.90	32.34-42.79	39.19	36.07-42.91	40.08
Oil content (%)	Control	37.22-39.22	38.48	37.22-39.22	38.48	34.91-40.00	37.68	35.66-39.29	37.50
	Stress	36.46-38.96	37.42	36.46-38.96	37.42	33.75-38.29	35.99	33.98-37.15	35.73
Oil yield (kg/ha)	Control	1837.80-1939.58	1888.69	357.48-1358.85	693.41	167.66-1202.32	459.39	378.65-1112.25	770.64
	Stress	864.07-984.66	920.23	131.23-651.79	329.30	54.59-685.25	256.17	203.99-550.32	368.96
Harvest index	Control	0.49-0.50	0.50	0.33-0.48	0.39	0.13-0.49	0.39	0.33-0.49	0.43
	Stress	0.47-0.48	0.48	0.28-0.41	0.37	0.08-0.52	0.37	0.25-0.47	0.36
$\Delta^{13}C$ (‰)	Control	20.69-22.52	21.79	20.35-22.87	21.31	20.85-22.58	21.63	20.87-21.87	21.31
	Stress	20.74-22.01	21.18	20.08-22.42	20.85	19.96-22.12	20.97	20.36-21.59	20.73

values for DSI ranged from 0.71 to 1.48. CMS-302A (56.51%), RHA-272-I (54.44%), P-62-R (56.73%), DRSF-108 (55.54%), RCR-60-P (57.77%), RES-834-1 (63.91%) CMS-597A (54.85) IB-60 (62.8%) and IB-46 (59%) showed more DTE and their DSI values were low (0.85, 0.89, 0.85, 0.87, 0.83, 0.71, 0.89, 0.73 and 0.80, respectively). CMS-17A, CMS-275A, RHA 6D-1, IB-20 showed very less DTE with high DSI and their grain yield was also less under stress. These genotypes can be considered as drought susceptible ones. The checks, KBSH-41 and KBSH-44 showed more DSI with moderate DTE (Table 5).Though they showed more grain yield compared to all other entries. The percent reduction in grain yield under stress was around 50% compared to control. Hence these two checks are considered as moderately tolerant to drought stress.

Table 5: Drought susceptibility index and drought tolerance efficiency of 32 genotypes grown under stress

Sl. No	Entries	Drought susceptibility index (DSI)	Drought tolerant efficiency (DTE) (%)
1	CMS-302A	0.85	56.51
2	NDR-4	1.14	42.09
3	IB-97	1.07	45.41
4	CMS-336A	1.08	44.74
5	RHA-16	1.24	36.96
6	RHA-272-I	0.89	54.44
7	EC-512690	1.16	40.93
8	CMS-335A	1.23	37.08
9	IB-84	0.92	53.09
10	RHA95-C-2	0.98	50.04
11	RHA-275	1.17	40.20
12	P-62R	0.85	56.73
13	CMS-17A	1.33	32.02
14	DRSF-108	0.87	55.54
15	RHA-297	1.03	47.38
16	CMS-851A	0.97	50.50
17	IB-79	1.14	41.68
18	CMS-343A	0.77	60.75
19	CMS-275A	1.40	28.77
20	RHA6D-1	1.30	33.78
21	RCR-60P	0.83	57.77
22	RHA-23	1.17	40.45
23	RES-834-1	0.71	63.91
24	IB-47	0.91	53.37
25	CMS-597A	0.89	54.85
26	CMS-135A	1.03	47.58
27	IB-20	1.48	24.71

Based on the traits, genotypes with high TDM coupled with high root traits *viz.,* CMS-343A, BGR-135-2, IB-97, EC-512690, KBSH-41 and KBSH-44 were selected. They also maintained yield under stress compared to other genotypes. In the present study, good root systems (high root types) were found to perform better over low root types under moisture stress condition. Some indices to determine the drought tolerance are drought susceptibility index (DSI) and drought tolerance efficiency (DTE). This is based on how much reduction is realized under drought stress. From this study, it can be concluded that DSI and DTE are the important parameters to evaluate genotypes under stress to select drought tolerant or resistant genotypes based on yield realized under non-stress and stress conditions. In present study high variation were observed for both drought resistant parameters and DTE ranged from 24 to 63% and DSI ranged from 0.71 to 1.48. IB-84, P-62-R, R-297, CMS-851A, CMS-343A, RCR-60-P, RES-834-1, IB-47, IB-60 and BGR-135-2 were identified as genotypes with high DTE and low DSI with minimum yield reduction.

Traits are consistent and heritable between the cement root structure and field, for both growth parameters like TDM and TLA and between the seasons for TLA, TDM, root length, grain yield, harvest index and oil content. As the traits are consistent, the identified lines could serve as important traits for the trait based crop improvement programme.

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