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Research Article

EVALUATION OF SELECTED SINGLE CROSS MAIZE (*ZEA MAYS* L.) HYBRIDS AND THEIR PARENTS FOR PHYSIOLOGICAL TRAITS UNDER DROUGHT STRESS

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Abstract: The present study was conducted at Main Agricultural Research Station (MARS), Dharwad the experiment was evaluation of selected single cross maize (*Zea mays* L.) hybrids and their parents for physiological traits under drought stress. Plant height, relative water content, gas exchange (net photosynthesis rate, stomatal conductance, transpiration rate and leaf temperature) and grain yield per plant ultimately hybrids which are least susceptibility index for drought with different soil moisture availability. Identified the hybrids shown least drought susceptibility index and highest grain yield under drought stress condition *viz*., DMIL 516 × DMIL 230 (6,338 kg per ha), DMIL 715 × DMIL 607 (3,665 kg per ha), CML 425 × DMIL 516 (3,905 kg per ha), CML 425 × DMIL 607 (3,052 kg per ha), NC 468 × DMIL 692 (3,641 kg per ha) and DMIL 553 × DMIL 447 (3.687 kg per ha) were identified as drought tolerant hybrids for commercial cultivation. Similarly, among the parents shown least drought susceptibility index *viz*., DMIL 230 (0.65 %), DMIL 715 (0.53 %) and DMIL 516 (0.56 %) showed least drought susceptibility index with least change in physiological parameters under two moisture levels. We found that all these physiological traits, grain yield and drought susceptibility index (DSI) were inhibited by drought stress.

Keywords: Hybrid lines, Grain yield, Drought susceptibility index

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Introduction

Maize is one of the important cereal crops occupying 144 m ha with a production of 695 million tonnes in the world. In India, maize occupies an area of 9.20 million hectares with the production of 24.70 million tons and the average productivity is 2,566 kg ha^{-1} [3]. Drought is the most pervasive limitation for realizing of potential yield in maize [11]. Average annual global losses due to drought in maize range from 15 % in temperate zone to 17 % in tropical zone as estimated by empirical methods [10]. A precise measurement of yield losses worldwide is not possible due to range of occurrences of drought from individual fields to regional from slight to catastrophic. Losses are greatest in the parts of world where soils and weather patterns are less favourable than US Corn Belt, which is named for its long-term suitability for growing maize at relatively low level of risk of crop failure. Soil water deficits are often the greatest constraint in plant growth transpiration response to water availability for winter wheat as affected by soil textures. With global climate change, varying rainfall patterns make droughts more severe and frequent climate extremes a 25% decrease in soil moisture between 2000 and 2040 Likely effects of climate change on growth of which will bring great challenges because almost 66% of total cereal crop production is by rain-fed greater sensitivity to drought accompanies maize yield increase in the US midwest. Drought affects plant growth, photosynthetic activity and yield identification of physiological traits underlying cultivar differences in drought tolerance [9,26]. Maize height and cob height noticeably decreased with increasing drought stress. Another major effect is a reduction in photosynthesis, which is caused by decreased leaf expansion and impaired photosynthetic machinery and in addition, drought can affect the photosynthetic pigments reduce the relative water content (RWC) [26]. To more fully understand the response of maize to different soil moisture availability, the objectives of this study were to investigate the changes in various physiological traits (morphology, water relation and gas exchanges) in maize hybrids and their parents under drought conditions and to clearly establish the best evaluation index as well as identified drought tolerant hybrids / genotypes.

Materials and methods

The site of the present study was located at the Main Agricultural Research Station (MARS), Dharwad in plot number 125 of E-Block. Dharwad is located at 15º 26' N latitude, 75º 07' E longitude and at the altitude of 678 m above the mean sea level. The research station comes under Northern Transition Zone (Zone-8) of Karnataka, which lies between the Western Hilly Zone (Zone-9) and Northern Dry Zone (Zone-3) of Karnataka. The experiment was layout in split plot design with ten hybrids and their parents along with two checks (CP-818 and GH-0727) as treatments (sub plot) in three replications and two moisture levels (main plot treatments). The crop was sown at 60 cm x 30 cm and size of the plot was 5 m x 0.6 m during *rabi* / summer in 2016-17. The observations recorded and the methodologies followed are as under.

Soil moisture content

Soil moisture content was determined at every thirty days from after 45 days sowing and till harvest by the method suggested by [14] and was expressed in percent. Composite soil samples were collected from two spots per plot in each replication at 0-15, 15-30 and 30-45 cm depth and weighed immediately. Soil samples were oven dried at 80°C for 24 hours or till the weight was constant. Soil moisture content was calculated and expressed in percent by the following formula,

$$\text{Soil moisture content (\%)} = \frac{(B - A) - (C - A)}{(B - A)} \times 100$$

Where,
A = Weight of the container (g)
B = Weight of the container + fresh weight of the soil (g)
C = Weight of the container + oven dry weight of the soil (g)

Plant height
The plant height was recorded on tagged plants by measuring the height from ground level to the base of youngest fully opened leaf before panicle emergence. After panicle emergence height was recorded from the base of the plant to the tip of the panicle at physiological maturity and expressed in centimetres (cm).

Biophysical parameters
Measurement of rate of photosynthetic (μ mole CO_2 $m^{-2}s^{-1}$), stomatal conductance (μ mole $m^{-2}s^{-1}$), rate of transpiration (m mole of H_2O $m^{-2}s^{-1}$) and leaf temperature (°C) were made on the top fully expanded leaf at different growth stages by using portable photosynthesis system (LI-6400 LICOR, Nebraska, Lincoln USA). These measurements were made between 10.00 am to 12.00 noon on all the sampling dates.

Relative water content
Relative water content was estimated following the procedure of Barrs and Weatherly (1962) at 50 and 70 DAS. Twenty leaf discs of third fully expanded leaf from the top were collected and fresh weight was recorded using precision electronic balance. These leaf discs were floated in distilled water for four hours in petridish. Then the discs were removed and to record turgid weight. After that, the leaf discs were oven dried at 80°C for 48 hours and dry weight was recorded. The RWC was calculated by using the following formula and expressed in percentage.

$$\text{Relative water content (\%)} = \frac{\text{Fresh weight (g)} - \text{dry weight (g)}}{\text{Turgid weight (g)} - \text{dry weight (g)}} \times 100$$

Statistical analysis
The data recorded are processed with statistical parameters *viz*, mean, the data was subjected to split plot design analysis. The statistical methods adopted are as follows.

Analysis of variance (ANOVA): A two factorial completely randomized block design with two factors keeping water availability in the one factor and genotypes in second factor was followed with three replications.

Sources of Variation	df	SS	MSS	F
Factor A	a-1	SSA	MSA	MSA/ MS (MPE)
Factor B	b-1	SSB	MSB	MSB/ MS (SPE)
A×B	(a-1) (b-1)	SS (A×B)	MS (A×B)	MS (A×B)/MS (SPE)
Error	(r-1)+(a-1) (b-1)	SS (SPE)	MS (SPE)	
Total	rab-1	TSS		

Where, a = treatments imposed, b = number of genotypes, r = number of replication

Results and discussion
The effect of climate change is looming large on agricultural production in India, as nearly 65 % of the total cultivable area depends on rain. Maize is an important cereal crop of the world as well as India. Drought is the most pervasive limitation of yield potential in maize [11]. About 58 percent of the maize area in Karnataka is dependent on rains and drought appears frequently in recent years. Moisture stress in maize affects both yield and yield stability. During drought, maize under rainfed situation is likely to suffer profoundly. Therefore, identification of the best drought tolerant maize hybrid yield and drought related traits for commercial recommendation are important to close the gap between rainfed and well-watered yields. The experiment was conducted during 2016-17 at MARS Dharwad. Selected best and least single cross hybrids were tested for drought tolerance.

Soil moisture content
In addition, a decline in soil water availability also resulted in a decrease in the diffusion rate of nutrients from the soil to the root surface [5]. A reduction in the energy supply to the roots caused by a reduction in photosynthesis would also affect the absorption of nutrients [4]. Soil moisture content was measured both in non-stress and stress plots at different periods of crop growth. The observations were taken 0 - 15 cm, 15 - 30 cm and 30 - 45 cm depth of soil at different plant growth stages. The data on soil moisture content is presented in [Table-1]. 30 DAS initial (0-15 cm) soil moisture content was high 38.43 percent under non-stress as compared to 28.20 percent moisture stress condition and gradually decreased at 120 DAS 21.26 percent under non-stress and 18.76 percent under moisture stress condition during 2016-17.

Plant height
Plant height plays an important role in determining the morphological frame work relating to plant type and canopy development in maize. It is one of the important characters of growth and yield of maize and is influenced by both genetic and environmental factors. When the drought cycles increase highest percent of reduction was observed in the plant height. The plant height ranges from 146.00 cm (CML 425) to 178.44 cm (DMIL 516 × DMIL 230) and 129.71 cm (NC 468) to 154.00 cm (DMIL 607) under non-stress and stress condition. Respectively, mean value 157.61 cm and 143.02 cm the irrespective mean and percent change over the control 150.32 cm and 9.26 percent [Table-2]. Hence, the highest plant height was recorded under non-stress compare to stress. Thus, it could be concluded that the plant height is good indicator of drought tolerance mechanism. Several studies [2, 19] reported in drought condition reduced plant height compared to the normal condition. Significantly plant height was higher in the hybrids *viz*., DMIL 516 × DMIL 230 (178.44 cm) and (150.03 cm) followed by DMIL 715 × DMIL 607 (166.83 cm) and (150.83 cm) as compare to checks the plant height is highest under both non-stress and stress condition. Hence, the hybrids and parents were recorded non-significant plant height under both the conditions. Irrespective of the mean value and percent change over the control of the following highest hybrids DMIL 516 × DMIL 230 (164.23 cm) and (15.92 %), DMIL 715 × DMIL 607 (158.83 cm) and (9.59 %), The lower the differences of plant height recorded DMIL 607 (-0.60 %), DMIL 516 (1.01 %), CML 425 (3.63 %) and (NC 468 × DMIL 692) (4.35 %) of two conditions these lines are proved to be good fit for drought conditions. thus, this may be the important genotype less affected with environmental factor and better plant growth observed in the drought condition.

Relative water content
Higher relative water content in drought condition is the good indicator of drought tolerance. Relative water content was range from 63.90 percent (NC 468) to 79.11 percent DMIL 715 and 54.17 percent DMIL 692 to 63.76 percent (cp-818) under non-stress and stress condition. Respectively, mean value 73.41 percent and 59.30 percent the irrespective mean and percent change over the control 66.35 percent and 19.22 percent. Hence the leaf relative water content was reduced under stress as compared to non-stress. Significantly higher relative water content was in the hybrid DMIL 692 × DMIL 230 (76.69 percent) irrespective of mean values (68.96 percent) and percent change over the control (21.15 %) followed by CML 425 × DMIL 607 (75.64 percent) irrespective of mean values (67.09 percent) and (22.61 %) under non-stress and the lowest relative water content in the hybrid DMIL 553 × DMIL 447 (66.69 percent) (67.90 percent) and (11.38 %) followed by (DMIL 715 × DMIL 607) (63.90 percent) irrespective of mean values (61.18 percent) and percent change over the control (8.52 %) under non-stress. Significant lowest relative water content was in the hybrid (DMIL 715 × DMIL 607) (58.46 percent) irrespective of mean values (61.18 percent) and percent change over the control (8.52 %) followed by DMIL 516 × DMIL 447 (55.40 percent) (62.91 percent) and (21.33 %) under stress and in the hybrid recorded highest relative water content DMIL 516 × DMIL 230 (62.11 percent) irrespective of mean values (68.08 percent) and percent change over the control (16.12 %) followed by NC 468 × DMIL 692 (61.01 percent) irrespective of mean values (67.29 percent) and (17.08 %) under stress the checks were greater relative water content than the parent and hybrids under stress [Table-2].

Table-1 *Periodical soil moisture content at different plant growth stages of maize under two moisture levels*

Particulars	Soil moisture content (%)							
	30 DAS		60 DAS		90 DAS		120 DAS	
Depth (cm)	Stress	Non-stress	Stress	Non-stress	Stress	Non-stress	Stress	Non-stress
0-15	28.2	38.43	30.59	34.29	28.43	29.1	18.76	21.26
15-30	26.16	31.24	32.65	36.56	30	31.28	24.65	24.39
30-45	22.86	26.33	34	37.41	31.21	34.12	26.18	27.88
Mean	25.74	32	32.41	36.09	29.88	31.5	23.2	24.51

Table-2 *Plant height and relative water content at in selected maize hybrids and their parents under two moisture levels*

SN	Plant height (cm)					Relative water content %			
	Treatments	Non-stress	Stress	Mean	% Changes	Non-stress	Stress	Mean	% Changes
1	DMIL 516 × DMIL 230	178.44	150.03	164.23	15.92	74.05	62.11	68.08	16.12
2	DMIL 553 × DMIL 447	166.83	150.83	158.83	9.59	73.76	59.58	66.67	19.23
3	CML 425 × DMIL 516	156.5	139.91	148.21	10.6	76.95	60.67	68.96	21.25
4	DMIL 607 × DMIL 516	160.54	142.5	151.52	11.24	74.35	58.87	66.61	20.81
5	CML 425 × DMIL 607	164.68	148.35	156.52	9.92	73.58	61.01	67.29	17.08
6	DMIL 715 × DMIL 607	162.24	145.54	153.89	10.29	66.69	59.1	67.9	11.38
7	NC 468 × DMIL 692	154.76	148.02	151.39	4.35	74.73	58.7	66.72	21.16
8	DMIL 692 × DMIL 230	165.81	142.14	153.97	14.28	70.42	55.4	62.91	21.13
9	CML 425 × DMIL 553	163.2	142.19	152.7	12.87	75.64	58.53	67.09	22.61
10	DMIL 516 × DMIL 447	159.45	147.3	153.38	7.61	63.9	58.46	61.18	8.52
11	DMIL 230	151.58	129.88	140.73	14.32	72.23	59.21	65.72	18.02
12	DMIL 438	151.12	149.47	150.3	1.09	69.03	55.45	62.24	19.67
13	DMIL 447	153.58	141.23	147.4	8.04	74.35	57.25	65.8	23
14	DMIL 516	147.92	146.42	147.17	1.01	68.8	54.17	61.48	21.26
15	DMIL 553	147.43	139.35	143.39	5.48	76.03	60.14	68.08	20.9
16	DMIL 607	153.08	154	153.54	-0.6	78.77	59.79	69.28	24.1
17	DMIL 692	170.81	147.03	158.92	13.92	70.94	60.85	65.9	14.23
18	DMIL 715	155.19	142.25	148.72	8.34	78.23	58.37	68.3	25.39
19	CML 425	146	140.71	143.35	3.63	70.43	61.41	65.92	12.8
20	NC 468	147.05	129.71	138.38	11.79	74.92	63.76	69.34	14.91
21	cp-818	151.11	132.81	141.96	12.11	74.04	63.73	68.88	13.92
22	gh-0727	160	136.68	148.34	14.58	79.11	59.97	69.54	24.2
	Mean	157.61	143.02	150.31	9.26	73.41	59.3	66.35	19.22
		Genotypes	Condition	Interaction		Genotypes	Condition	Interaction	
	S. Em ±	2.31	0.85	4		2	0.74	3.46	
	C. D. @ 5 %	6.49	2.4	11.25		5.62	2.08	9.73	

Table-3 *Photosynthetic rate and Stomatal conductivity at 70 DAS in selected maize hybrids and their parents under two moisture levels*

SN	Photosynthetic rate (μ mole CO_2 $m^{-2}s^{-1}$)					Stomatal conductivity (m mole $m^{-2}s^{-1}$)			
	Treatments	Non-stress	Stress	Mean	% Changes	Non-stress	Stress	Mean	% Changes
1	DMIL 516 × DMIL 230	39.64	25.27	32.46	36.25	0.57	0.46	0.51	19.83
2	DMIL 553 × DMIL 447	39.01	25.11	32.06	35.64	0.51	0.46	0.48	9.13
3	CML 425 × DMIL 516	39.87	26.35	33.11	33.9	0.52	0.46	0.49	13.15
4	DMIL 607 × DMIL 516	38.16	22.38	30.27	41.35	0.53	0.45	0.49	14.09
5	CML 425 × DMIL 607	35.06	22.61	28.84	35.51	0.51	0.45	0.48	12.52
6	DMIL 715 × DMIL 607	35.42	19.45	27.44	45.09	0.48	0.44	0.46	8.96
7	NC 468 × DMIL 692	31.46	18.71	25.08	40.53	0.53	0.43	0.48	18.17
8	DMIL 692 × DMIL 230	34.57	19.88	27.23	42.5	0.49	0.43	0.46	10.75
9	CML 425 × DMIL 553	32.46	19.47	25.96	40.01	0.5	0.43	0.46	12.79
10	DMIL 516 × DMIL 447	32.14	19.16	25.65	40.38	0.49	0.44	0.46	10.77
11	DMIL 230	31.71	19.48	25.59	38.56	0.49	0.43	0.46	12.62
12	DMIL 438	32.72	19.4	26.06	40.72	0.48	0.44	0.46	7.7
13	DMIL 447	30.43	17.7	24.07	41.82	0.51	0.43	0.47	14.97
14	DMIL 516	33.14	19.47	26.3	41.24	0.48	0.43	0.46	10.83
15	DMIL 553	30.11	18.36	24.24	39.02	0.51	0.43	0.47	15.55
16	DMIL 607	31.44	19.11	25.27	39.22	0.51	0.43	0.47	16.48
17	DMIL 692	31.63	19.86	25.75	37.21	0.51	0.44	0.48	14.33
18	DMIL 715	31.52	19.46	25.49	38.26	0.49	0.42	0.46	13.53
19	CML 425	33.28	19.82	26.55	40.43	0.51	0.42	0.47	16.29
20	NC 468	30.83	19.66	25.24	36.24	0.49	0.42	0.46	14.31
21	cp-818	34.95	19.6	27.27	43.91	0.51	0.45	0.48	11.12
22	gh-0727	33.04	21.92	27.48	33.64	0.5	0.43	0.47	14.2
	Mean	33.75	20.56	27.15	39.1	0.51	0.44	0.47	13.36
		Genotypes	Condition	Interaction		Genotypes	Condition	Interaction	
	S. Em ±	0.44	0.16	0.75		0.01	0.01	0.01	
	C. D. @ 5 %	1.22	0.45	2.12		0.02	0.01	0.03	

Table-4 *Transpiration rate and Leaf temperature at 70 DAS in selected maize hybrids and their parents under two moisture levels*

SN	Transpiration rate (m mole of H_2O $m^{-2}s^{-1}$)					Leaf temperature (^0C)			
	Treatments	Non-stress	Stress	Mean	% Changes	Non-stress	Stress	Mean	% Changes
1	DMIL 516 × DMIL 230	4.3	4.07	4.18	5.39	26.85	29.37	28.11	-9.37
2	DMIL 553 × DMIL 447	4.27	4.05	4.16	5.08	27.98	29.48	28.73	-5.36
3	CML 425 × DMIL 516	4.26	4.05	4.15	5.04	27.8	29.38	28.59	-5.7
4	DMIL 607 × DMIL 516	4.23	3.95	4.09	6.54	28	29.5	28.75	-5.36
5	CML 425 × DMIL 607	4.18	4	4.09	4.35	28.07	29.7	28.88	-5.81
6	DMIL 715 × DMIL 607	4.11	3.79	3.95	7.94	28.38	30.98	29.68	-9.16
7	NC 468 × DMIL 692	4.16	3.75	3.95	9.74	28.6	31.47	30.03	-10.02
8	DMIL 692 × DMIL 230	4.09	3.83	3.96	6.47	28.62	30.22	29.42	-5.59
9	CML 425 × DMIL 553	3.99	3.87	3.93	2.97	28.75	31.03	29.89	-7.94
10	DMIL 516 × DMIL 447	4.08	3.62	3.85	11.39	28.55	30.2	29.38	-5.78
11	DMIL 230	4.07	3.76	3.91	7.66	28.83	30.15	29.49	-4.57
12	DMIL 438	4.14	3.8	3.97	8.22	28.95	30.42	29.68	-5.07
13	DMIL 447	4.04	3.78	3.91	6.52	28.77	30.8	29.78	-7.07
14	DMIL 516	4	3.85	3.92	3.67	28.6	30.72	29.66	-7.4
15	DMIL 553	4.1	3.77	3.94	7.93	28.42	30.6	29.51	-7.68
16	DMIL 607	4.09	3.77	3.93	7.91	28.68	30.15	29.42	-5.11
17	DMIL 692	4.04	3.78	3.91	6.6	28.7	30.38	29.54	-5.87
18	DMIL 715	4.07	3.74	3.91	8.18	28.82	30.4	29.61	-5.49
19	CML 425	4.1	3.73	3.91	9.04	28.19	30.42	29.3	-7.89
20	NC 468	4.11	3.83	3.97	6.93	28.72	30.65	29.68	-6.73
21	cp-818	4.15	3.92	4.03	5.62	28.23	29.7	28.97	-5.19
22	gh-0727	4.1	3.9	4	4.68	28.27	29.95	29.11	-5.96
	Mean	4.12	3.84	3.98	6.72	28.4	30.26	29.33	-6.54
		Genotypes	Condition	Interaction		Genotypes	Condition	Interaction	
	S. Em ±	0.03	0.01	0.05		0.15	0.06	0.26	
	C. D. @ 5 %	0.08	0.03	0.13		0.43	0.16	0.74	

Table-5 *Grain yield per plant and grain yield kg per ha in selected maize hybrids and their parents under two moisture levels and drought susceptibility index*

SN	Grain yield (g /plant)					Grain yield (kg /ha)				Drought susceptibility index (DSI)
	Treatments	Non-stress	Stress	Mean	% Changes	Non-stress	Stress	Mean	% Changes	Mean
1	DMIL 516 × DMIL 230	145.91	111.85	128.88	23.34	8,268	6,338	7,303	23.34	0.61
2	DMIL 553 × DMIL 447	121.6	64.69	93.14	46.8	6,890	3,687	5,289	46.48	0.85
3	CML 425 × DMIL 516	122.52	68.92	95.72	43.75	6,942	3,905	5,424	43.75	1.17
4	DMIL 607 × DMIL 516	110.16	64.25	87.21	41.67	6,242	3,416	4,829	45.27	1.24
5	CML 425 × DMIL 607	104.14	60.29	82.22	42.1	5,901	3,052	4,971	41.61	1.31
6	DMIL 715 × DMIL 607	108.28	53.87	81.08	50.25	6,277	3,665	4,476	48.27	1.12
7	NC 468 × DMIL 692	101.46	59.58	77.02	48.18	5,749	3,641	4,695	36.67	1.28
8	DMIL 692 × DMIL 230	94.73	47.02	70.87	50.36	5,367	2,664	4,016	50.36	1.37
9	CML 425 × DMIL 553	96.6	52.58	78.09	38.32	5,473	3,376	4,425	38.32	0.99
10	DMIL 516 × DMIL 447	94.94	65.08	80.01	31.45	5,380	2,979	4,179	44.62	1.23
11	DMIL 230	64.69	48.38	56.53	25.2	3,665	2,741	3,203	25.2	0.65
12	DMIL 438	103.43	55.77	79.6	46.08	5,861	3,160	4,510	46.08	1.24
13	DMIL 447	83.08	53.24	68.16	35.92	4,707	3,016	3,862	35.92	0.87
14	DMIL 516	62.86	49.86	56.36	20.68	3,562	2,825	3,193	20.68	0.56
15	DMIL 553	77.59	51.05	64.32	34.21	4,396	3,178	3,787	27.7	0.74
16	DMIL 607	105.99	77.55	91.77	26.83	6,006	4,394	5,200	26.83	0.67
17	DMIL 692	110.13	71.55	90.84	35.03	6,240	4,054	5,147	35.03	0.94
18	DMIL 715	73.61	59.41	66.51	19.29	4,171	3,366	3,768	19.29	0.53
19	CML 425	75.13	46.63	60.88	37.94	4,257	2,642	3,449	37.94	1.03
20	NC 468	57.18	44.91	51.04	21.45	3,240	2,545	2,892	21.45	0.58
21	cp-818	98.78	55.4	77.09	43.92	5,597	3,139	4,368	43.92	1.15
22	gh-0727	110.94	65.58	88.26	40.89	6,286	3,716	5,001	40.89	1.09
	Mean	96.53	60.34	78.44	37.49	5,476	3,432	4,454	37.33	0.96
		Genotypes	Condition	Interaction		Genotypes	Condition	Interaction		
	S. Em ±	4.46	1.65	7.73		262.05	96.77	453.88		0.17
	C. D. @ 5 %	12.55	4.63	21.73		736.47	271.96	1275.61		0.5

When the drought cycles increase the relative water content decreases in the plants, leads to disrupt the normal physiological process like photosynthesis, respiration and transpiration by producing some toxic compounds like H_2O_2 and ROS. Several studies [18, 20, 8] indicated that the relative water content in leaves decreased significantly in drought susceptible variety than resistant variety.

Photosynthetic rate

Photosynthesis is a process which converts solar energy into chemical energy in the presence of water and CO_2 which occur in green chlorophyll of the cells. The net carbohydrate production from the plant is a balance between photosynthesis and respiration. Maize being a C_4 tropical crop had relatively higher net photosynthesis. This C_4 pathway has advantage in maize under high temperature and drought stress conditions. Photosynthetic rate ranged from 30.11 DMIL 553 to 39.87 DMIL 692 × DMIL 230 and 17.70 DMIL 447 to 25.27 (DMIL 516 × DMIL 230) under non-stress and stress condition. Respectively, mean value 33.75 and 20.42 the irrespective mean 27.09 and percent change over the control 39.51 percent. Hence, the photosynthetic rate was reduced under stress as compared to non-stress [Table-3]. Highest photosynthetic rate was recorded in DMIL 692 × DMIL 230 (39.87) and (26.35) followed by DMIL 516 × DMIL 230 (39.64) and (25.27) under non-stress and stress condition.

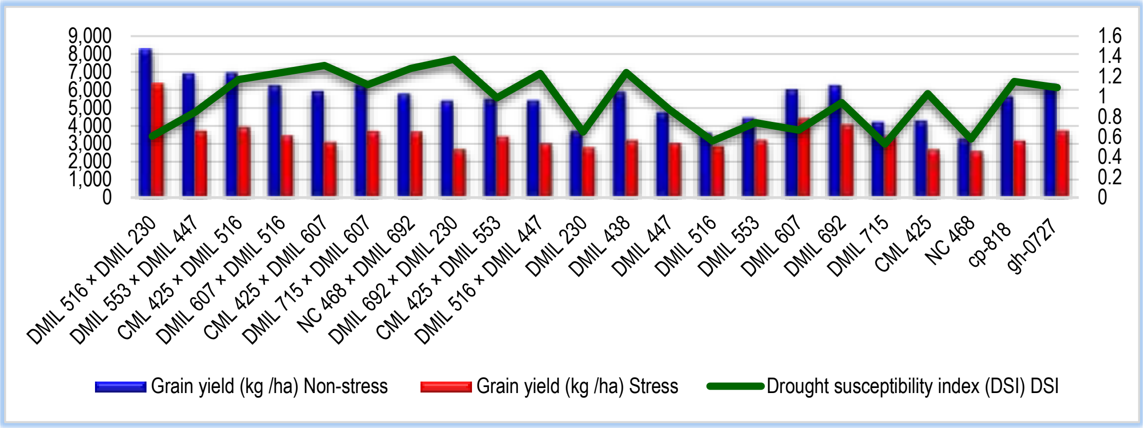

Fig-1 Seed yield and drought susceptible index in selected maize hybrids and their parents under two moisture levels

Significant lowest the photosynthetic rate was recorded by (DMIL 715 × DMIL 607) (32.14) and (19.16) followed by NC 468 × DMIL 692 (31.46) and (18.71) under both the condition. Higher photosynthetic rate under limited water supply conditions is one of the factors for realizing higher grain yield because, it is expected to provide the raw material and the energy required for growth and development. A close relationship between leaf chlorophyll content and photosynthetic rate was observed by Watanabe and Yoshida (1970) and stated that higher chlorophyll content is one of the important factors responsible for higher photosynthetic rate. Irrespective value of normal and stress condition mean DMIL 692 × DMIL 230 (33.11) difference between two conditions (33.90 %) followed by the hybrid DMIL 516 × DMIL 230 (32.46) and (36.25 %) and similarly, the lower hybrid irrespective mean (DMIL 715 × DMIL 607) (25.65) difference between (40.38 %) followed by NC 468 × DMIL 692 (25.08) difference of two condition (40.53 %).

Stomatal conductivity

Plant regulation of water utilization and loss is important in determining the drought tolerance in crop plants. [1,17,25]. Stomatal conductivity ranged from 0.48 DMIL 438 DMIL 516 and (DMIL 553 × DMIL 447) to 0.57 (DMIL 516 × DMIL 230) and 0.42 DMIL 715 CML 425 and (NC 468) to 0.46 (DMIL 516 × DMIL 230) (DMIL 715 × DMIL 607) and DMIL 692 × DMIL 230 under non-stress and stress condition. Respectively, mean value 0.51 and 0.44 the irrespective mean 0.47 and percent change over the control 13.36 percent [Table-3]. Hence the stomatal conductivity was reduced under stress as compared to non-stress [15, 16, 21-24].

Transpiration rate

Transpiration rate recorded in [Table-4] ranged from 3.99 (CML 425 × DMIL 607) to 4.30 (DMIL 516 × DMIL 230) and 3.62 (DMIL 715 × DMIL 607) to 4.07 (DMIL 516 × DMIL 230) under non-stress and stress condition. Respectively, mean value 4.12 and 3.84 the irrespective mean 3.98 and percent change over the control 6.72 percent. Hence the transpiration rate was reduced under stress as compared to non-stress.

Leaf temperature

Leaf temperature ranged from 26.85 (DMIL 516 × DMIL 230) to 28.95 DMIL 438 and 29.37 (DMIL 516 × DMIL 230) to 31.47 (CML 425 × DMIL 715) under non-stress and stress condition. Respectively, mean value 28.40 and 30.26 the irrespective mean 29.33 and percent change over the control -6.54 percent. Hence the leaf temperature was reduced under non-stress as compared to stress. So, the per change values are negative [Table-4].

Grain yield per plant

Grain yield per plant was observed to be correlated with plant height, ear height, ear length, and ear diameter and 100-grain weight under drought. Leaf temperature was observed to be correlated with days to 50 percent anthesis, stomatal diffusion, rate of transpiration and recovery from water stress [13]. The degree of yield reduction due to water deficit depends on the timing and severity of stress. In the present study, the soil moisture content depleted continuously with an advancement of crop growth. Grain yield per plant range from 57.18 g per plant (NC 468) to 145.91 g per plant (DMIL 516 × DMIL 230) and 44.91 g per plant (NC 468) to 111.85 g per plant (DMIL 516 × DMIL 230) under non-stress and stress condition [Table-5] and [Fig-1]. Respectively, mean value 96.53 g per plant and 60.34 g per plant the irrespective mean and percent change over the control 78.44 g per plant and 37.49 percent, hence the lowest grain yield per plant was reduced under stress compare to non-stress. This indicates that the yield variability could be due to differential soil moisture extracting capacity of these genotypes. Significantly higher grain yield per plant was recorded in the hybrids *viz*., DMIL 516 × DMIL 230 (145.91 g per plant and 111.85 g per plant) followed by DMIL 692 × DMIL 230 (122.52 g per plant and 68.92 g per plant), DMIL 715 × DMIL 607 (121.60 g per plant and 64.69 g per plant) under both the normal and stress condition, respectively. However, the mean grain yield was also highest in DMIL 516 × DMIL 230 (128.88 g per plant) and (23.34 %) followed by DMIL 692 × DMIL 230 (95.72 g per plant) (43.75 %) followed by DMIL 715 × DMIL 607 (93.14 g per plant) and (46.80 %) as compared to checks and parents. These hybrids recorded significantly highest grain yield per plant under both the condition. Significant lowest grain yield per plant was recorded in hybrids *viz*., CML 425 × DMIL 607 (96.60 g per plant) and (52.58 g per plant) followed by DMIL 516 × DMIL 447 (47.02 g per plant) under both the non-stress and stress conditions, irrespective of mean value CML 425 × DMIL 607 (78.09 g per plant) the percent change over the control (38.32 %) followed by DMIL 516 × DMIL 447 (70.87 g per plant) percent change over the control (50.36 %) the checks are highest grain yield than the hybrids.

Grain yield kg per hectare

Grain yield kg per ha recorded the range from 3,240 kg per ha (NC 468) to 8,268 kg per ha (DMIL 516 × DMIL 230) and 2,545 kg per ha (NC 468) to 6,338 kg per ha (DMIL 516 × DMIL 230) under non-stress and stress condition, respectively. The yield of mean 5,476 and 3432 kg per ha under non-stress and stress respectively with 37.33 percent reduction. Significant recorded highest grain yield kg per ha in the hybrids *viz*., DMIL 516 × DMIL 230 (8,268 kg per ha and 6,338 kg per ha) followed by (CML 425 × DMIL 516) (6,942 kg per ha and 3,905 kg per ha), under both the normal and stress condition. Respectively, irrespective of the mean value and percent change over the control of the highest hybrids. DMIL 516 × DMIL 230 (7,303 kg per ha) and (23.34%) followed by (CML 425 × DMIL 516) (5,424 kg per ha) (43.75 %) as compared to checks and parents the hybrids recorded significant highest grain yield kg per ha under both the condition. Significant lowest grain yield per plant was recorded in hybrids *viz*., DMIL 516 × DMIL 447 (5380 kg per ha and 2979 kg per ha) followed by DMIL 692 × DMIL 230 (5367 kg per ha and 2664 kg per ha) under both the non-stress and stress conditions, irrespective of mean value DMIL 516 × DMIL 447 (4179 kg per ha) the percent change over the control (44.62 %) followed by DMIL 692 × DMIL 230 (4016 kg per ha) percent change over the control (50.36 %) the checks are highest grain yield than the drought susceptible hybrids. Under severe moisture stress, yield was significantly correlated with interval between male and female flowering and canopy temperature [12].

Drought susceptible index

The drought susceptibility index which plant breeders debate on the question of optimum environment (the environment that improves efficiency and effectiveness of the breeding programme) for selection for yield. Three strategies have been considered [7]. Significant recorded the drought susceptible index range from 0.53 percent DMIL 715 to 1.37 percent (DMIL 516 × DMIL 447) overall mean 0.96 percent and the hybrid highest drought susceptibility index was recorded by DMIL 516 × DMIL 447 (1.37 %) followed by NC 468 × DMIL 692 (1.31 %) and lowest susceptible index was recorded by CML 425 × DMIL 607 (0.85 %) followed by DMIL 516 × DMIL 230 (0.61 %) hence these two hybrids are proved to be drought resistant as compare to checks. Given that optimum environment for selection isone, which maximizes the genetic variation and hence, the response to selection in the target environment. The first strategy is based on the assumption that when the growing conditions are optimum, high yielding cultivars selected under optimal growing conditions will perform well under all conditions. The second strategy assumes that the optimum environment for selection should be as representative as possible of the target environments. In the third strategy involves the use of both optimum and stressed conditions for selecting the genotypes that yield well in both the situations.

Conclusion

Effective methods for judging whether maize is suffering drought stress have become very important. However, numerous studies show that all these physiological indicators decreased synergistically with each other, which was also confirmed by our results. RWC, photosynthetic rate, transpiration and leaf temperature are important characteristics under drought stress. The hybrids shown least drought susceptibility index *viz*., DMIL 516 × DMIL 230, DMIL 715 × DMIL 607, CML 425 × DMIL 516, CML 425 × DMIL 607, NC 468 × DMIL 692 and DMIL 553 × DMIL 447 were identified as drought tolerant hybrids for commercial cultivation [Fig-1]. Similarly, among the parents DMIL 230, DMIL 715 and DMIL 516 showed least drought susceptibility index with least change in physiological parameters under two moisture levels and hence identified as drought tolerant inbreds. These could be used in future breeding programme.

Abbreviations: DMIL: Dharwad Maize Inbred Lines
NC: National check and CML: CIMMYT Maize lines

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