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Identification of maize (*Zea mays* L.) inbreeds for developing drought tolerance

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Abstract

Hundred maize inbreds were evaluated for physiological, phenological and grain yield traits under managed stress conditions during *rabi*/summer season, 2014- 15 at Main Agricultural Research Station, University of Agricultural Sciences Dharwad. Inbreeds differed significantly for anthesis to silking interval (ASI), relative water content (RWC), SPAD value, photosynthetic rate, transpiration rate, cob height, cob weight and grain yield per plant under both non stress and stress conditions. Based on their performance, the ten selected drought tolerance inbred lines were identified based on shorter ASI, seed yield and yield components, Chlorophyll content (SPAD) relative water content (RWC). Shorter ASI under water stress condition could be effectively utilized for developing drought tolerant genotypes in maize breeding programme *viz.*, DMIL 230, DMIL 438, DMIL 447, DMIL 516, DMIL 553, DMIL 607, DMIL 692, DMIL 715, CML 425 and NC 468; these genotypes were recorded highest grain yield under water stress condition. These inbred lines could be used as a donor parents for developing drought tolerant single cross hybrids.

Keywords: Identification, maize, drought tolerance

Introduction

Maize (*Zea mays* L.) is a staple food crop that plays a major role in the diet of millions of human consumption if the demand for rice and wheat is not full filled through increased production. Area under maize is increasing rapidly in the state because of better environment, high yield potential and ease with which crop is cultivated. Maize has attained a commercial crop status due to easiness in cultivation, tolerance to drought, pest and diseases, high yield and better market price. it comes up well under a wide range of soil and climatic conditions. There is a lot of scope to increase the present maize yields. Maize ranks third next to wheat and rice in production. By origin, maize is native to South America and has adapted magnificently to temperate with much higher productivity. In India the maize occupies an area of 9.2 million hectares with a production of 24.7 million tones and average productivity of 2.56-ton ha^{-1} (*Anon.*, 2016) [3]. In Karnataka, the maize occupies an area of 1.34 thousand ha with production of 3.95 thousand tonnes and average productivity of 2921 kg ha^{-1} (*Anon.*, 2016) [3]. It's providing half of the calorific intakes of peoples. It is cultivated in many states like Gujarat, Bihar, Andhra Pradesh, Karnataka, Madhya Pradesh, Rajasthan, Chattishgarh, Maharashtra, Tamil Nadu and Uttar Pradesh. The productivity of maize in India is increasing in recent years during *rabi* season particularly in the states of Bihar, Andhra Pradesh, Karnataka, Jharkhand and Madhya Pradesh. It is also widely believed that, in the very near future maize may become a staple food for human consumption if the demand for rice and wheat is not fulfilled through increased production.

Drought is the most pervasive limitation to the realization of yield potential in maize (Edmeades *et al*., 2001) [10]. 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 (Edmeades *et al*., 2000b) [9]. Today, many places in the guinea savannas that are arguably the current maize belt of Nigeria now experience yearly drought that often coincides with flowering period of maize crops and consequently leads to poor grain yields or total crop failure. It is being speculated that the frequency and intensity of drought would intensify in the years ahead in response to climate change. Therefore, the survival of resource-poor, keeping in view the fact that the global climatic change is under way, intensity and frequency of disturbances like *EL-Nino* effects is predicted to further increase, as realized in the past. *El-nino* is defined as a large scale shift in water currents and wind of the equatorial and tropical Pacific, resulting in extreme climatic changes characterized by excessive rains and strong winds in some areas and drought in others. Such disturbances are certainly going to adversely affect rainfall, particularly distribution pattern that will result in poor and scanty rainfall in one area causing severe water deficit and heavy and concentrated rainfall in other, causing water logging coupled with heavy nutrient leaching in light soils (Zaidi *et al.*, 2007) [26]. The most economically viable and sustainable option for salvaging the situation is breeding and releasing improved drought tolerant and high yielding maize cultivars for the farmers in order to guarantee profitable yields even in years of drought. Introduced maize germplasm can serve as important source of novel alleles for improvement of adapted germplasm for drought tolerance and high productivity. A set of new single-cross hybrids developed from adapted and exotic drought tolerant maize inbred lines at MARS, UAS Dhrawad. Respectively, were evaluated under well-watered and drought stress conditions in order to assess their grain yield potentials and identify superior high yielding and drought tolerant hybrids.

Materials and Methods

The field experiment was conducted during *rabi/*summer season, 2014- 15 with 100 maize inbred lines grown under two water regimes (water stress and nonstress) conditions. The experimental materials composed of one hundred inbred lines maintained at Maize scheme, Main Agricultural Research Station (MARS), University of Agricultural Sciences (UAS) Dharwad.

The experiment was laid out in factorial RBD design with 100 inbred lines (genotypes) in two replications and spacing by 60 cm × 30 cm at two moisture levels. Observations were recorded by following headings. 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. During the dry seasons of 2014 and 2015, Dharwad receives little rainfall from December to April of the year, making the site suitable for conducting drought tolerance experiments because maize crops planted at this period must be supported with irrigation. The experiment was laid out in medium block clay loam soil. Among 100 inbreds, ten inbreds *viz.,* DMIL 230, DMIL 438, DMIL 447, DMIL 516, DMIL 553, DMIL 607, DMIL 692, DMIL 715, CML 425 and NC 468 have been identified. The data of these selected ten inbreds have been presented and discussed.

Rate of photosynthesis and rate of transpiration

Measurement of rate of photosynthesis (μ mole CO_2 $m^{-2}s^{-1}$) and rate of transpiration (m mole of H_2O $m^{-2}s^{-1}$) 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.

SPAD chlorophyll meter reading (SCMR)

SPAD (Soil Plant Analytical Development) Chlorophyll meter readings (SPAD device 502; Minolta company ltd) measures the greenness or relative chlorophyll content of the leaves. SCMR were taken at about 50, and 70 DAS. The third leaf from top in five random plants was used for measuring SCMR, which was taken on one side of leaf blade, midway between the leaf base and tip. The reading was taken between 10.00 and 12.00 hours of the day A mean of 30 reading per plot was taken from five tagged plants.

Relative water content

Relative water content was estimated following the procedure of Barrs and Weatherly (1962b) [4] at 50 and 70 DAS. Twenty leaf discs of third fully expanded leaf from the top were collected and fresh weight was recorded using precission 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.

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

Anthesis to silking interval (ASI, Days): It was obtained by the difference between days to 50 per cent anthesis (AD) and days to 50 per cent silking (SD).

$$ASI = SD - AD$$

Cob height: The cob height (cm) was recorded in centimeters from the base to the upper most cob bearing node.

Cob weight: The weight of five randomly selected cobs recorded separately and expressed in gram per plant (g)

Grain yield per plant: The cobs from randomly selected five plants were dried, shelled, cleaned and weight of grains was recorded and expressed as gram per plant.

Results and Discussion

Maize is the third most important cereal in the world. Maize is often subjected to drought, which is a major abiotic factor among harsh environmental stresses that adversely affect plant growth, metabolism and yield. The effect of moisture stress manifest in varying degrees on growth and yield amongst the inbred lines within the species. Maize is more susceptible to moisture stress at flowering (two weeks before and after). Some inbred lines of maize yield better than the others under moisture stress by reducing their anthesis to silking interval. Moisture stress affects almost all morpho-physiological traits. Identification of maize germplasm with superior drought tolerance ability is prerequisite for developing drought tolerance hybrids (Chen *et al.,* 2012). With this view in mind, screening of available inbred lines at Maize scheme, Main Agricultural Research Station (MARS), Dharwad was initiated during *rabi/summer* of 2014-15, under non-stress and moisture stress situations. The ten drought tolerance inbred lines were identified based on shorter ASI, seed yield and yield components, Chlorophyll content (SPAD) relative water content (RWC). The performance of one hundred inbred lines under non-stress and stress is presented in Appendix I to Appendix II.

Anthesis to silking interval

Significant difference was observed in the anthesis to silking interval under non-stress and stress condition. The mean ranged from 1.00 (DMIL 230, DMIL 438, DMIL 447, DMIL 485, DMIL 531, DMIL 607, DMIL 692, DMIL 715, CML 425 and NC 468) to 8.00 days (DMIL 446) and 1.00 days (DMIL 230, DMIL 438, DMIL 447, DMIL 485, DMIL 531, DMIL 607, DMIL 692, DMIL 715, CML 425 and NC 468) to 6.50 days (DMIL 683) under non-stress and stress situations (Table 2 and Appendix II). Respectively, the respective mean was 3.48 and 3.01 days. The anthesis to silking interval in the non -stress was delayed when compared to stress. The effect of moisture stress on morphological traits was drastic and it significantly reduced the expression of many traits but significantly increased days to silking and ASI. Among the inbred lines DMIL 230, DMIL 438, DMIL 447, DMIL 516, DMIL 553, DMIL 607, DMIL 692, DMIL 715, CML 425 and NC 468 showed very shorter ASI under water stress condition and could be effectively utilized for developing drought tolerance genotypes in maize breeding programme. Floral development and flowering stages are very sensitive to moisture stress and cause delay in anthesis, silking and anthesis to silking interval in maize (Bolanos and Edmeades, 1996, Ribaut *et al.,* 1996) [5, 21]. Meena Kumari *et al.* (2004) [17] reported that under severe stress, the anthesis-silking interval ranged from 1.00-2.00 days in drought tolerant inbred lines and 9-11 days in drought sensitive inbred lines.

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. The photosynthetic rate ranged from 19.57 (KI 50) to 30.67 (DMIL 438) in the non-stress and 12.57 (DMIL 720) to 19.40 DMIL 516 in the stress condition. The respective mean was 23.94 and 16.32 for the non-stress and stress treatments (Table 1 and Appendix I). The mean photosynthetic rate was found to be reduced in the stress as compared to the non-stress. The mean reduction in photosynthetic rate due to stress was 7.62 per cent. 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) [24] and stated that higher chlorophyll content is one of the important factors responsible for higher photosynthetic rate. In the current study, rate of photosynthesis was highest in irrigated condition in DMIL 438 as compared to stress. Similarly rate of photosynthesis was higher in high yielding genotype DMIL 516.

Transpiration rate

Plant regulation of water utilization and loss is important in determining the drought tolerance in crop plants. The control of stomatal aperture is one of the major methods by which plants regulate water loss. Adjei and Kirkham (1980) [2], Yordanov *et al.* (2003) [25] and Meena Kumari *et al.* (2004) [17] found that the drought resistant cultivars are having higher stomatal resistance than drought sensitive cultivars. The transpiration rate ranged from 3.76 (CML 225) to 4.30 (CML 422) in the non-stress and 3.54 (DMIL 553) to 4.08 (DMIL 485) in the stress condition. The respective mean was 4.03 and 3.80 under non-stress and stress treatments (Table 1 and Appendix I). The mean transpiration rate was found to be reduced in the stress when compared with the non-stress. In the present study higher CML 422 and lower transpiration rate CML 225 was recorded under non stress. Respectively, DMIL 553 showed lower transpiration rate under stress condition.

Chlorophyll content (SPAD value)

The chlorophyll content in the non-stress and stress ranged from 42.75 (KI 50) to 54.60 (CML 730) and from 44.08 (DMIL 538) to 56.56 (CML 425), respectively. The mean was 51.19 and 49.58, respectively in the non-stress and stress conditions (Table 1 and Appendix I). The chlorophyll content was less under stress condition when compared with non-stress and the per cent reduction was 1.61. Under drought conditions, the decrease in chlorophyll content was reported by Chaves *et al.* (2003) [6]. Meena Kumari *et al.* (2004) [17] reported that chlorophyll content and stability index decreased under drought stress. The similar results were also observed in the present study but inbred lines CML 425, DMIL 715 and DMIL 607 recorded the maximum chlorophyll content under water stress condition and these could be utilized for development of maize genotypes with enhanced chlorophyll content during drought condition.

Relative water content

The relative water content (RWC) gives an idea of water retention capacity of a tissue. Many scientists have observed differences in RWC among genotypes of crop species (Barrs and Weatherly, 1962 and Parameshwar, 1978) [4, 19]. Results of the present study indicated that the RWC decreased with a progress in crop growth among all genotypes and the decrease was more in stress situation. The relative water content in the non-stress and stress ranged from 68.10 per cent in CML 161 to 87.59 per cent (KI 50) and from 51.11 per cent in DMIL 648 to 75.24 per cent (NC 468) respectively. The mean was 78.73 per cent and 63.92 per cent, respectively in the non-stress and stress treatments (Table 1 and Appendix I). The relative water content was less when compared with non-stress and the per cent reduction was 14.81 per cent. The genotype GPM-10 and K-2011 recorded higher mean relative water content of 86.87 per cent and 85.88 per cent compared to other genotypes. Similar results were reported by Oregan *et al.* (1993) [18]; patil *et al.* (1984) [20]; Li-Ping *et al.* (2006) [16] and Guang-hua Yin *et al.* (2012) [11]

Cob height

The cob height ranged from 51.50 cm (CML 163) to 110.90 cm (CML 472) in the non-stress and 22.53 cm (CML 168) to 77.63 cm (DMIL 715) in the stress condition. The respective mean was 80.45 and 59.83 cm for the non-stress and stress treatments. The mean cob height was found to be reduced in the stress when compared with the non-stress (Table 2 and Appendix II). The mean reduction in cob height due to stress was 20.62 per cent. Severe drought stress in early growing stage affects the length of internodes (Jurgens *et al.,* 1978) [15] and causes reduction of plant height Desai (1997). Reduction in ear height was also reported in maize when subjected to drought (Hemalatha Devi, 1989; Abellandsa and Cauny, 1991) [13, 1]. The present study revealed a reduction in plant height and cob height in all the inbred lines. However, CML 229, CML 59 and DMIL 720 recorded highest plant heights, whereas, DMIL 230 and DMIL 715 exhibited maximum cob height under stress condition.

Cob weight

The cob weight ranged from 39.39 g per plant (DMIL 595) to 174.99 g per plant (NC 468) and from 13.52 g per plant (DMIL 735) to 107.18 g per plant (CML 425), respectively, in the non-stress and stress treatments (Table 2 and Appendix II). The non-stress and stress mean was 78.96 g per plant and 56.80 g per plant, respectively. The cob weight was reduced in the stress compared with non-stress and the mean reduction being 22.16 per cent. Drought stress during grain filling period primarily affects kernel weight due to decrease in leaf carbon exchange rates (Jurgens *et al.,* 1978) [15]. The reduced yield under water stress could be due to reduced grain number, kernel weight and cob length (Hall *et al.*, 1981; Coasta., *et al* 1988; Subba Rao, 1992 and Vinod kumar, 1996) [12, 8, 22, 23]. The present study, inbred lines DMIL 438, and CML 425 recorded the highest cob weight under drought.

Seed yield

Differences in seed yield were observed in the non-stress and stress treatments (Table 2 and Appendix II). The seed yield per plant ranged from 28.88 g per plant (DMIL 615) to 120.06 g per plant (CML 472) with a mean of 60.62 g per plant in the non-stress. It ranged from 4.26 g per plant (DMIL 735) to 78.24 g per plant (DMIL 553), the mean being 42.17 g per plant in the stress. The mean seed yield was reduced due to stress. The mean seed yield reduction was 18.45 per cent. Hossien *et al.* (2013) [14] reported, reduction in grain yield per plant under water limitation at grain filling stage. Among the morpho-physiological traits in the present study grain yield showed maximum reduction per cent due to water stress. The inbred lines exhibited DMIL 230, DMIL 438, DMIL 516, DMIL 553, DMIL 607, DMIL 715, CML 425 and NC 468 recorded highest grain yield under water stress condition. These inbred lines could be used as a donor parents for developing drought tolerant single cross hybrids.

Table 1: Mean performance of parents selected for production of single cross hybrids for Photosynthetic rate, Transpiration rate, SPAD value and Relative water content under non-stress and stress condition in maize.

Inbreds	Photosynthetic rate (μmole CO_2 m^{-2} s^{-1})		Transpiration rate (m mole H_2O m^{-2} s^{-1})		SPAD value		Relative water content (RWC %)	
	Non stress	Stress	Non stress	Stress	Non stress	stress	Non stress	stress
DMIL 230	28.42	15.53	4.16	3.85	86.46	84.86	53.53	52.34
DMIL 438	30.67	17.07	3.99	3.74	85.08	80.69	50.57	52.08
DMIL 447	22.01	17.24	4.01	3.97	85.36	80.47	54.16	51.04
DMIL 516	22.05	19.40	3.93	3.71	84.57	83.47	52.24	52.30
DMIL 553	22.59	18.19	4.14	3.78	86.42	81.67	54.48	52.90
DMIL 607	21.86	16.39	4.14	3.92	84.35	80.64	54.47	53.08
DMIL 692	25.37	18.92	3.97	3.96	86.71	82.23	54.67	53.58
DMIL 715	22.53	16.50	4.06	3.88	86.27	84.86	53.19	53.52
CML 425	23.15	16.01	3.77	3.84	89.11	81.78	54.32	56.56
NC 468	23.95	18.57	3.83	3.62	81.73	80.78	53.77	53.15
Mean	23.94	16.32	4.03	3.80	78.73	63.92	51.19	49.58
Range	19.57 to 30.67	12.57 to 19.40	3.76 To 4.30	3.54 to 4.08	68.10 To 87.59	51.11 To 71.37	42.75 To 54.60	44.08 to 56.48
C. V	10.43	11.16	3.35	5.14	6.08	6.93	3.20	5.25
S. Em. +	1.77	1.29	0.10	0.14	3.39	3.13	1.16	1.84
C. D at 5%	4.95	-	-	-	9.50	8.79	3.25	5.17

Table 2: Mean performance of parents selected for production of single cross hybrids for Anthesis to silking interval, cob height, cob weight and seed yield per plant under non-stress and stress condition in maize.

Inbreds	Anthesis to silking interval (days)		Cob height (cm)		Cob weight (g/ plant)		Seed yield (g /plant)	
	Non stress	Stress	Non stress	Stress	Non stress	stress	Non stress	Stress
DMIL 230	1.00	1.00	67.30	52.00	53.56	73.97	41.85	62.41
DMIL 438	1.00	1.00	66.75	57.20	91.44	86.76	77.97	70.62
DMIL 447	1.00	1.00	60.55	52.13	82.03	74.59	68.35	65.09
DMIL 516	1.00	1.00	56.13	58.45	96.98	93.09	76.65	78.21
DMIL 553	1.00	1.00	81.70	64.13	105.05	94.79	82.24	78.24
DMIL 607	1.00	1.00	56.33	51.20	87.47	84.21	75.09	70.00
DMIL 692	1.00	1.00	67.40	58.40	90.28	86.05	73.15	66.65
DMIL 715	1.00	1.00	63.45	52.83	97.91	100.14	82.24	74.15
CML 425	1.00	1.00	63.68	55.20	75.58	76.99	54.41	62.65
NC 468	1.00	1.00	52.25	56.45	87.26	82.76	59.12	67.65
Mean	3.48	3.01	80.45	59.83	78.96	56.80	60.62	42.17
Range	1.00 to 8.00	1.00 to 6.50	51.50 to 110.90	22.53 to 77.70	39.39 to 174.99	13.52 to 107.18	28.88 to 120.06	4.26 to 78.24
C. V	42.00	48.71	5.69	18.25	21.41	24.47	17.39	21.80
S. Em. +	1.03	1.04	3.24	7.72	11.95	9.83	7.45	6.50
C. D at 5%	2.90	-	9.09	21.66	33.55	27.57	20.92	18.24

Appendix I: Diversity means of photosynthetic rate, transpiration rate, SPAD value, and relative water content in maize inbreds under two moisture levels.

Sl No	Inbred lines	Photosynthetic rate (μmole CO_2 m^{-2} s^{-1})		Transpiration rate (m mole H_2O m^{-2} s^{-1})		SPAD value		Relative water content (RWC %)	
		Non -stress	Stress	Non -stress	Stress	Non -stress	Stress	Non -stress	Stress
1	DMIL 105	28.22	15.48	4.11	3.93	50.98	52.73	74.73	61.19
2	DMIL 106	28.00	16.82	4.23	3.57	53.78	51.83	78.02	61.49
3	DMIL 107	27.30	15.43	4.12	3.76	52.74	48.38	72.19	60.83
4	DMIL 141	28.81	17.02	4.12	3.71	51.63	49.43	75.61	62.75
5	DMIL 223	26.39	16.69	4.22	3.90	54.32	51.79	72.37	64.68
6	DMIL 225	26.87	14.36	4.16	3.89	51.14	49.53	83.63	58.00
7	DMIL 230	28.42	15.53	4.16	3.85	53.53	52.34	76.33	69.97
8	DMIL 314	28.26	16.89	4.23	3.85	51.03	48.59	76.37	60.39

9	DMIL 326	29.68	14.71	4.10	3.79	50.05	48.60	79.05	64.90
10	DMIL 336	25.78	15.98	4.12	3.96	49.17	47.29	73.39	61.73
11	DMIL 348	22.99	13.78	4.13	3.81	49.80	46.90	73.45	64.85
12	DMIL 356	23.37	15.86	4.10	3.94	53.39	49.63	77.82	61.11
13	DMIL 416	27.16	17.98	4.14	3.77	49.65	47.90	76.32	63.30
14	DMIL 426	23.43	15.12	3.99	3.87	52.62	50.11	74.86	63.96
15	DMIL 437	25.04	15.14	4.00	3.68	50.33	51.03	78.57	64.19
16	DMIL 438	30.67	17.07	3.99	3.74	50.57	52.08	81.93	70.43
17	DMIL 456	28.27	18.98	4.15	3.67	49.42	51.75	82.59	63.64
18	DMIL 473	30.21	16.04	4.14	3.72	49.64	47.12	75.74	63.88
19	DMIL 478	25.43	16.30	4.04	3.93	51.32	51.07	74.90	65.31
20	DMIL 490	24.56	17.33	4.07	3.56	48.50	51.14	81.68	67.93
21	DMIL 538	23.46	18.75	4.13	3.77	51.47	44.08	79.94	66.40
22	DMIL 539	24.01	17.90	4.10	3.92	50.54	47.20	81.07	66.18
23	DMIL 540	24.35	18.33	4.06	3.69	51.23	50.49	80.24	63.64
24	DMIL 552	22.75	16.88	3.95	3.63	51.44	47.52	82.48	61.77
25	DMIL 553	22.59	18.19	4.14	3.54	49.87	50.23	82.23	64.42
26	DMIL 446	23.30	15.86	4.14	3.81	49.09	49.82	81.98	64.40
27	DMIL 447	22.01	17.24	4.01	3.97	54.16	51.04	77.94	69.84
28	DMIL 456	23.96	17.24	3.88	3.61	50.73	51.13	70.16	64.23
29	DMIL 481	20.73	17.89	3.99	3.81	53.06	50.07	85.57	63.54
30	DMIL 485	22.88	19.40	4.12	4.08	50.47	50.82	83.42	63.29
31	DMIL 516	22.05	16.79	3.93	3.71	52.24	52.30	77.51	70.84
32	DMIL 520	24.87	16.50	3.83	3.87	50.59	49.76	79.20	65.04
33	DMIL 531	22.82	17.40	4.11	3.72	50.99	51.03	77.62	54.40
34	DMIL 538	22.71	15.80	4.08	3.81	51.22	50.30	74.93	51.67
35	DMIL 539	25.22	15.38	4.08	3.81	51.25	47.74	80.54	57.18
36	DMIL 540	22.34	15.86	3.97	3.92	50.63	49.39	80.10	63.28
37	DMIL 553	22.14	16.20	3.94	3.89	54.48	52.90	80.57	69.85
38	DMIL 556	21.45	18.59	3.88	3.83	50.35	47.99	68.18	59.90
39	DMIL 572	22.54	17.12	4.05	3.95	49.38	46.15	78.41	60.37
40	DMIL 590	20.98	17.73	4.00	4.03	49.78	47.50	76.93	63.36
41	DMIL 595	23.85	16.48	3.94	3.87	52.32	49.06	83.49	63.70
42	DMIL 606	20.81	15.66	4.04	4.00	48.30	51.08	85.59	66.39
43	DMIL 607	21.86	16.39	3.95	4.05	54.47	53.08	85.16	69.96
44	DMIL 610	21.76	17.03	4.14	3.92	53.80	52.66	76.88	53.68
45	DMIL 613	24.66	15.49	4.03	3.96	52.64	51.31	84.04	64.27
46	DMIL 615	23.79	18.53	3.91	4.04	51.02	47.93	81.75	61.29
47	DMIL 645	21.62	16.54	4.04	3.87	51.14	49.61	72.23	65.57
48	DMIL 648	22.86	17.39	4.02	3.87	49.91	48.83	81.17	51.11
49	DMIL 653	24.22	18.63	4.06	3.82	52.55	49.92	78.26	65.72
50	DMIL 656	21.58	17.18	4.15	3.92	50.53	47.35	81.28	66.03
51	DMIL 680	23.02	18.36	3.97	3.88	50.23	45.21	75.64	68.71
52	DMIL 682	22.89	16.08	4.01	3.86	51.13	46.97	77.31	63.31
53	DMIL 683	23.50	17.96	3.98	3.68	50.17	45.62	75.82	65.52
54	DMIL 692	25.37	18.92	4.00	3.83	54.67	53.58	74.74	70.43
55	DMIL 693	22.16	16.41	3.97	3.96	50.35	49.81	75.04	65.00
56	DMIL 695	22.42	14.86	4.18	3.94	49.61	46.55	75.19	61.67
57	DMIL 700	22.84	15.50	4.01	3.82	51.52	50.00	75.91	63.17
58	DMIL 706	23.97	15.98	4.05	3.81	51.44	44.91	79.91	66.62
59	DMIL 710	21.86	15.63	3.94	3.96	51.50	47.61	75.53	61.12
60	DMIL 711	25.39	14.47	4.09	3.97	52.52	50.56	78.68	62.54
61	DMIL 713	26.31	15.68	4.08	3.94	50.83	51.07	79.02	62.68
62	DMIL 715	22.53	16.50	3.89	3.70	53.19	53.52	80.51	69.80
63	DMIL 720	24.00	12.57	4.06	3.88	53.19	49.25	78.86	60.19
64	DMIL 721	22.75	14.24	4.04	3.77	50.42	50.06	84.73	60.21
65	DMIL 723	23.56	14.16	4.08	3.86	54.51	53.28	73.70	59.86
66	DMIL 726	24.25	14.57	4.06	3.79	52.73	51.23	77.70	62.02
67	DMIL 728	24.84	14.92	4.01	3.66	51.74	49.50	81.64	65.30
68	DMIL 730	26.53	16.75	4.01	3.90	51.32	50.74	79.19	62.66
69	DMIL 735	21.71	14.99	3.88	3.62	52.63	46.49	79.10	59.80
70	DMIL 738	21.97	14.85	3.95	3.75	54.10	51.48	68.71	56.12
71	CML 217	22.46	16.93	3.95	3.67	48.99	50.52	83.77	56.52
72	CML 223	23.94	14.93	4.21	3.61	50.07	50.49	78.37	64.39
73	CML 224	21.55	15.11	4.11	3.97	51.31	48.30	86.78	67.81
74	CML 225	22.86	14.04	3.76	3.85	50.19	49.70	85.55	63.06
75	CML 226	23.53	17.82	3.90	3.63	51.12	49.03	82.10	56.14
76	CML 227	24.35	14.15	4.08	3.55	50.03	48.92	82.98	58.92
77	CML 228	25.76	18.65	3.87	3.90	49.22	49.82	81.83	69.15

78	CML 229	22.21	16.97	3.87	3.80	53.62	53.09	78.17	60.71
79	CML 430	22.75	15.63	3.91	3.90	50.44	50.33	77.81	60.03
80	CML 431	23.78	13.55	3.86	3.65	53.02	52.49	80.16	68.04
81	CML 432	22.33	14.56	4.05	3.70	50.37	47.38	75.35	68.18
82	CML 433	23.13	16.29	3.98	3.71	48.14	48.93	74.93	67.29
83	CML 472	23.01	17.71	4.17	3.67	54.56	52.06	76.27	68.89
84	CML 471	22.87	16.61	4.23	3.83	50.75	49.55	79.68	66.59
85	CML 425	23.15	16.01	3.77	3.84	54.32	56.56	82.35	71.37
86	CML 67	24.75	16.02	4.18	3.62	51.30	49.94	78.12	69.01
87	CML 59	24.20	16.77	4.16	3.63	49.64	45.41	68.95	68.58
88	CML 60	23.37	16.31	3.83	3.61	50.21	47.77	76.50	67.09
89	CML 73	24.56	15.63	3.96	3.74	54.60	48.73	75.83	66.80
90	CML 422	22.66	14.80	4.30	3.79	53.06	50.66	84.09	65.97
91	CML 161	22.78	13.35	4.02	3.90	48.94	45.75	68.10	60.64
92	CML 163	21.19	17.86	3.98	3.90	48.32	46.80	75.70	63.23
93	CML 168	24.04	15.58	4.28	3.78	48.72	47.45	79.67	68.44
94	CML 169	22.43	15.51	3.97	3.58	49.18	48.20	87.42	65.56
95	CML 415	24.77	16.68	4.00	3.87	49.50	47.01	85.28	62.65
96	NC 468	23.95	18.57	3.83	3.62	53.77	53.15	80.33	75.24
97	NEI 411008	24.15	16.90	4.02	3.76	50.31	51.26	81.15	59.81
98	NEI 411014	23.23	16.88	3.95	3.71	50.36	45.79	77.96	66.44
99	NEI 411023	25.65	16.21	4.07	3.93	51.04	53.20	84.93	66.87
100	KI 50	19.57	16.18	4.03	3.62	42.75	47.17	87.59	66.89
	Mean	23.94	16.32	4.03	3.80	51.19	49.58	78.73	63.92
	Range	19.57 to 30.67	12.57 to 19.40	3.76 to 4.30	3.54 to 4.08	42.75 to 54.60	44.08 to 56.48	68.10 to 87.59	51.11 to 71.37
	C.V	10.43	11.16	3.35	5.14	3.20	5.25	6.08	6.93
	S. Em. ±	1.77	1.29	0.10	0.14	1.16	1.84	3.39	3.13
	C. D at 5%	4.95	-	-	-	3.25	5.17	9.50	8.79

Appendix II: Diversity means of Anthesis to silking interval, cob height, cob weight, and Grain yield in maize inbreds under two moisture levels.

Sl No	Inbred lines	Anthesis to silking interval (days)		Cob height (cm)		cob wt (g / plant)		Grain yield (g / plant)	
		Non -stress	Stress	Non -stress	Stress	Non -stress	Stress	Non -stress	Stress
1	DMIL 105	3.00	2.50	80.58	60.75	59.68	38.44	47.65	30.50
2	DMIL 106	3.00	3.00	82.75	61.25	113.65	63.00	93.86	52.18
3	DMIL 107	2.50	3.50	66.38	67.33	77.27	37.77	65.62	30.39
4	DMIL 141	3.00	2.00	63.03	42.50	72.59	63.30	61.53	30.15
5	DMIL 223	3.50	3.00	82.90	60.75	83.18	70.15	73.89	58.77
6	DMIL 225	3.50	3.00	86.05	64.65	97.56	50.12	68.74	41.85
7	DMIL 230	1.00	1.00	67.30	52.00	123.27	79.24	98.39	71.71
8	DMIL 314	4.50	5.00	67.85	49.75	56.09	25.82	44.27	19.83
9	DMIL 326	4.00	6.00	86.18	66.13	66.32	73.86	52.21	36.92
10	DMIL 336	4.50	2.50	88.18	65.00	94.59	33.53	53.42	20.24
11	DMIL 348	5.00	5.00	94.20	71.68	136.50	74.97	73.53	42.53
12	DMIL 356	4.50	3.50	80.05	75.65	95.27	70.39	65.94	64.38
13	DMIL 416	3.00	2.00	86.65	63.40	65.68	39.74	61.41	33.50
14	DMIL 426	3.00	3.50	53.65	67.70	53.56	76.97	41.86	62.42
15	DMIL 437	3.50	3.50	61.85	62.88	71.71	54.24	42.65	36.44
16	DMIL 438	1.00	1.00	66.75	57.20	105.36	90.27	77.97	71.62
17	DMIL 456	4.50	3.50	96.03	66.80	50.65	30.39	40.59	22.18
18	DMIL 473	4.50	4.50	96.25	92.18	85.41	42.80	68.89	31.27
19	DMIL 478	4.00	3.00	60.55	33.88	69.71	43.12	39.42	22.00
20	DMIL 490	4.00	3.50	82.40	71.75	87.89	43.50	63.86	28.47
21	DMIL 538	5.00	3.00	83.75	52.20	86.84	42.97	69.53	34.74
22	DMIL 539	5.00	3.00	74.58	52.20	47.75	34.15	33.09	24.15
23	DMIL 540	3.50	2.50	73.75	32.28	60.77	16.12	47.85	11.97
24	DMIL 552	3.50	3.50	90.35	65.40	70.06	58.71	60.24	51.94
25	DMIL 553	5.50	2.00	81.70	64.13	48.47	40.03	34.68	28.62
26	DMIL 446	8.00	5.00	95.05	92.38	78.00	52.56	64.21	40.24
27	DMIL 447	1.00	1.00	60.55	52.13	82.03	74.59	68.35	65.09
28	DMIL 456	2.50	2.50	94.95	62.48	74.72	75.62	72.06	63.59
29	DMIL 481	4.50	2.50	89.23	59.70	65.18	68.12	62.30	48.88
30	DMIL 485	4.50	4.50	85.85	72.23	95.97	40.24	70.59	34.97
31	DMIL 516	1.00	1.00	56.13	58.45	94.39	90.56	76.65	78.21
32	DMIL 520	3.50	3.00	52.60	71.20	44.94	33.21	37.83	25.59
33	DMIL 531	3.50	5.50	93.63	62.20	78.33	49.80	52.83	45.18
34	DMIL 538	4.00	5.00	71.13	65.90	87.59	57.73	72.06	47.32
35	DMIL 539	5.00	4.00	90.58	67.90	56.06	31.59	44.62	23.74

36	DMIL 540	6.50	5.00	88.85	60.78	76.56	37.59	65.77	29.47
37	DMIL 553	1.00	1.00	67.88	57.75	119.30	87.44	82.24	78.24
38	DMIL 556	5.50	3.00	98.30	49.60	73.56	47.33	58.09	35.62
39	DMIL 572	3.50	4.50	79.00	45.55	87.85	74.59	44.32	36.15
40	DMIL 590	4.50	4.50	107.25	70.20	81.62	40.59	65.89	32.74
41	DMIL 595	2.00	3.00	81.00	48.58	39.39	34.33	28.88	25.85
42	DMIL 606	5.00	3.00	95.58	73.83	60.09	49.68	49.68	40.44
43	DMIL 607	1.00	1.00	56.33	51.20	87.47	99.10	75.09	70.00
44	DMIL 610	3.00	3.50	83.03	66.48	89.25	85.01	76.47	60.86
45	DMIL 613	2.00	3.00	90.48	62.13	79.19	70.38	70.89	56.59
46	DMIL 615	3.00	2.00	57.23	42.65	50.32	32.00	35.83	22.36
47	DMIL 645	2.50	2.00	75.18	34.15	53.69	34.33	44.71	25.94
48	DMIL 648	2.00	3.00	79.90	61.33	83.97	85.85	63.65	52.18
49	DMIL 653	4.00	2.50	78.18	64.88	79.41	76.79	67.03	55.00
50	DMIL 656	4.50	3.50	64.30	69.03	68.86	42.00	55.44	32.00
51	DMIL 680	5.00	2.50	71.40	45.23	44.44	33.09	35.88	26.36
52	DMIL 682	5.50	2.50	88.43	48.35	49.27	57.56	41.83	35.18
53	DMIL 683	6.00	6.50	88.18	66.40	75.96	58.42	57.91	49.18
54	DMIL 692	1.00	1.00	67.40	58.40	123.62	96.79	73.15	66.65
55	DMIL 693	4.50	3.50	70.33	70.48	51.23	29.94	42.65	23.50
56	DMIL 695	4.00	3.00	93.43	55.20	59.68	33.85	33.83	24.24
57	DMIL 700	3.50	3.00	92.90	60.85	81.98	54.42	66.35	47.18
58	DMIL 706	3.00	3.00	80.20	59.30	79.36	54.41	64.59	45.27
59	DMIL 710	3.50	2.50	96.48	60.70	84.58	71.27	75.06	57.74
60	DMIL 711	4.00	2.50	71.93	69.85	104.86	75.65	81.91	52.62
61	DMIL 713	2.00	2.50	73.35	77.63	69.86	48.95	58.18	41.80
62	DMIL 715	1.00	1.00	63.45	52.83	97.91	100.15	82.24	74.15
63	DMIL 720	4.50	2.00	81.73	67.63	98.18	73.35	69.77	52.62
64	DMIL 721	2.50	2.50	91.18	48.05	49.21	33.50	38.00	27.03
65	DMIL 723	2.00	3.50	77.63	62.40	108.59	85.45	70.00	53.24
66	DMIL 726	3.00	3.00	71.00	66.50	75.58	76.99	79.59	51.47
67	DMIL 728	4.00	3.50	62.38	65.25	73.47	45.09	65.80	36.68
68	DMIL 730	4.00	3.00	90.25	51.13	45.35	48.68	41.91	31.09
69	DMIL 735	4.00	4.00	70.73	55.08	64.30	13.52	35.85	4.26
70	DMIL 738	3.00	4.50	60.38	68.05	104.12	78.00	87.12	59.77
71	CML 217	2.50	3.50	82.78	69.60	107.56	41.27	87.74	34.94
72	CML 223	3.00	3.00	86.90	52.38	48.15	29.65	37.74	22.92
73	CML 224	3.00	2.50	72.23	57.55	83.15	36.27	69.30	29.44
74	CML 225	3.50	2.00	84.98	60.70	49.15	27.30	36.95	21.59
75	CML 226	4.50	2.50	63.13	56.10	60.18	47.21	50.09	39.97
76	CML 227	3.50	6.00	84.00	73.35	57.68	54.30	46.15	37.06
77	CML 228	5.50	3.50	79.85	53.25	92.62	74.86	81.77	48.65
78	CML 229	4.00	4.00	80.78	55.40	77.09	69.27	69.41	53.97
79	CML 430	2.00	2.00	101.88	53.40	69.21	41.77	65.88	33.53
80	CML 431	3.00	3.50	110.10	60.65	86.98	78.95	73.74	57.88
81	CML 432	3.50	2.50	81.83	53.55	53.71	38.35	46.33	31.21
82	CML 433	2.50	2.50	59.60	66.03	65.60	53.41	53.00	38.35
83	CML 472	2.00	2.50	110.90	63.53	143.71	85.18	120.06	68.24
84	CML 471	3.00	2.50	79.10	51.05	65.06	74.33	60.91	60.91
85	CML 425	1.00	1.00	63.68	55.20	97.48	107.18	54.42	62.65
86	CML 67	3.00	2.00	87.25	48.18	51.81	33.12	39.12	26.94
87	CML 59	3.00	2.00	84.75	56.60	85.18	64.79	65.86	47.94
88	CML 60	5.50	4.00	91.20	55.88	93.47	49.30	69.21	40.80
89	CML 73	6.00	4.50	102.50	69.10	101.86	71.27	60.77	51.18
90	CML 422	5.50	4.50	59.48	62.78	102.47	82.67	95.85	54.41
91	CML 161	3.00	2.50	88.95	75.20	61.62	44.06	53.09	32.00
92	CML 163	5.00	2.50	51.50	63.10	66.02	47.41	61.06	40.35
93	CML 168	5.00	2.00	85.40	22.53	65.71	34.83	34.71	24.00
94	CML 169	5.00	3.50	81.33	65.85	61.97	66.27	56.74	47.74
95	CML 415	3.00	2.00	101.18	68.35	81.77	62.50	69.97	40.56
96	NC 468	1.00	1.00	52.25	56.45	174.99	92.71	59.12	67.65
97	NEI 411008	2.50	2.00	71.83	54.45	74.08	39.38	68.50	30.38
98	NEI 411014	3.00	2.00	93.08	50.50	87.03	63.68	73.62	50.21
99	NEI 411023	2.50	2.50	89.58	63.48	138.95	67.14	62.50	49.15
100	KI 50	4.00	4.00	92.82	52.58	82.56	64.93	49.97	28.74
	Mean	3.48	3.01	80.45	59.83	78.96	56.80	60.62	42.17
	Range	1.00 to 8.00	1.00 to 6.50	51.50 to 110.90	22.53 to 77.70	39.39 to 174.99	13.52 to 107.18	28.88 to 120.06	4.26 to 78.24
	C.V	42.00	48.71	5.69	18.25	21.41	24.47	17.39	21.80

	S. Em. +	1.03	1.04	3.24	7.72	11.95	9.83	7.45	6.50
	C. D at 5%	2.90	-	9.09	21.66	33.55	27.57	20.92	18.24

Conclusion

Inbreds differed significantly for anthesis to silking interval (ASI), relative water content (RWC), SPAD value, photosynthetic rate, transpiration rate, cob height, cob weight and grain yield per plant under both non stress and stress conditions. Based on their performance, the shorter ASI, seed yield and yield components, Chlorophyll content (SPAD) relative water content (RWC). Selected ten drought tolerance inbred lines which were possessed shorter ASI along with desired physiological traits under water stress condition and served to drought tolerant. Hence, these genotypes could be effectively utilized for developing drought tolerant maize hybrids.

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