

## Assessment of Inbred Lines of Maize for Water Stress Tolerance in Field Conditions

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### ABSTRACT

Drought stress is an important environmental stress confining growth and development of crops which limits plant performances and productivity. Water stress during flowering and grain filling stage causes reduction in crop yield up to 90%. Drought is a complex trait at plant level and no single trait or parameter can be used for selection of drought tolerance. The genotypic variability of selective traits has found to be important in crop improvement. To identify maximum number of traits related drought tolerance and drought recovery, we tried to evaluate the fourteen inbred lines of maize in field conditions. The experiment was carried out in split plot design with 2 main plots (stress and non-stress) and 14 sub plots (inbred lines). The analysis of variance reported significant differences among the inbred lines indicating variability of the selected inbred lines. The interaction effects between stress and inbred lines were also significant for all investigated traits. Our results indicate that there is a great opportunity for selection of drought tolerance genotypes which can be further used in hybridization and crop improvement programs.

#### Keywords

Maize, Drought stress, Tolerance, Split plot design.

#### Article Info

##### Accepted:

19 July 2017

##### Available Online:

10 September 2017

### Introduction

Maize is an important cereal crop grown all over the world. It is known as queen of cereals because it has the highest genetic yield potential among the cereals. It is the only cultivated species with greater economic importance in the tribe Maydeae of the family Poaceae and plays an enormous role in food and nutritional security worldwide. Maize is one of the most versatile emerging crops having wider adaptability under varied agro-climatic conditions (Dowswell *et al.*, 1996). The environmental stresses such as drought, heat, salinity, pollution, heavy metals and pesticides are major limiting factors in crop production (Hernandez *et al.*, 2001; Lawlor and Comic, 2002). Drought stress is a major

environmental stress that has negative impacts on plant growth and development which limits plant performances and productivity causing the loss of about 50% of agricultural yields worldwide (Bray *et al.*, 2000). It inhibits cell growth, cell expansion thereby affecting leaf extension, leaf area, chlorophyll content, growth rate, reproductive development and source-sink relationship (NeSmith and Ritchie, 1992; Hsiao and Xu, 2000; Pandey *et al.*, 2000; Jaleel *et al.*, 2009). Meiosis, anthesis, male and female reproductive stage are all extremely susceptible to drought stress thus leading to a significant yield penalty (Cattivelli *et al.*, 2008; Zinselmeier *et al.*, 1995).

In maize, the drought affects all growth stages from seedling to grain filling stage. The extent of yield reduction depends not only on the severity of drought occurrence but also on the stage of crop. Drought during germination results in reduction of germination percentage, germination rate, seed vigor, radicle length, plumule length and crop stand (Khayatnezhad, 2010; Khodarahmpour, 2011; Batool *et al.*, 2014). Water stress at vegetative stage causes reduction in relative water content, leaf area development and plant height. Short-duration water deficits during the rapid vegetative growth period leads to 28–32% loss of final dry matter weight (Lu and Neumann, 1998; Cakir, 2004; Chen *et al.*, 2012). Maize is highly susceptible to drought at flowering stage. Reproductive development which determines sink strength, especially over the period of time from about one week before to one week after flowering has found to be highly sensitive to water stress (Claasen and Shaw, 1970; Zinselmeier *et al.*, 1999).

Drought during this crucial stage results in stimulation of protandrous pattern of development and increasing the anthesis-silking interval. Maize has short period of flowering and pollen remains viable for only short period of time and each day delay between pollen shed and silk emergence will reduce the rate of sexual fertilization and increase barrenness thereby finally affecting the yield of the plant (Sangoi and Salvador, 1998). Nesmith and Ritchie (1992) also have reported that yield reductions in maize were up to 90% when drought occurs prior to tassel emergence and during grain filling stage.

Agricultural practices to mitigate drought have their own importance but genetic improvement of plants can fill the gap up to 30% between theoretical yield and the actual yield under drought conditions (Edmeades *et al.*, 2004). The use of genetics to improve drought tolerance and provide yield stability

is an important part of the solution to stabilizing global maize production. But drought tolerance is a very complex trait influenced by a broad range of processes spanning both the time scale and at the plant organization level. Genotypic variability of selective traits for drought tolerance can be utilized in this regard which have been claimed to be important in crop improvement (Maiti *et al.*, 1994; Rosa-Ibarra and Maiti, 1995). The selection of genotypes with wide variability and diversity in respect to drought tolerance becomes crucial. The objective of this study was to evaluate and select maize cultivars for tolerance to drought in field conditions so that they can be used in further crop improvement programs.

## **Materials and Methods**

The experiment was conducted for during *rabi*2015 in experimental field of UAS, GKVK campus, Bangalore, India under irrigated and stress conditions. The experimental material comprises of fourteen maize inbred lines viz. BTM1, BTM2, BTM4, BTM5, BTM6, BTM7, BTM10, BTM13, BTM14, BTM15, BTM 18, BTM 19, DT3 and MAI105. The experiment was laid out in a split plot design with two main plot (Stress and Non-stress) treatments and fourteen genotypes as sub-plot treatments in two replications. The inbred lines were sown with a spacing of 30 cm between plants and 60 cm between the rows and as one row per genotype. The recommended Phosphorus and Potash (each at the rate of 125 kg ha<sup>-1</sup>) was applied at the time of sowing while Nitrogen (at the rate of 250 kg ha<sup>-1</sup>) was applied in a two split dose. All the necessary agronomic practices were timely followed to ensure good plant stand. All the plots were irrigated immediately after sowing and irrigation was given to all plots at an interval of 5 days. After 45 days from sowing and before flowering initiation, the irrigation was

withheld for the stressed plot treatments up to 20 days whereas the non-stressed (control) plot was irrigated at regularly till physiological maturity. The weather data for the crop period has been recorded and presented in table 1.

### **Morphological observations**

In each treatment and replication the observations of randomly selected five plants were considered. The growth parameters like plant height (cm), days to tassel initiation, days to 50% anthesis and days to silking were measured. The cobs were harvested at physiological maturity and the yield parameters recorded were cob length (cm), cob diameter (cm), number of rows per cob, number of seeds per cob, test weight (g) and grain yield per plant (g). The mean of all the five observations were used for analysis.

### **Statistical analysis**

Split plot statistical analysis was carried out to analyze the variance of the traits for which the observations were recorded to ensure the existence of significant differences between treatments, within treatments and their interaction (Jayaraman, 1999).

### **Results and Discussion**

In the present study, drought was induced through the most critical stage of life cycle for water requirement so as to identify effect of moisture stress on inbred lines in natural field conditions. The effect of drought stress on the growth and yield parameters were not found to be significant. However, there were significant differences for all traits viz. days to tassel initiation, days to silking, days to anthesis, cob length, cob diameter, number of rows per cob, number of seeds per cob, test weight and grain yield per plant among inbred lines. The analysis of variance also showed that the interaction effects between stress and

inbred lines were significant for all investigated traits (Table 2).

The inbred lines showed the significant variation for plant height and number of seeds whereas the variation was not significant for the other traits. This is due to the frequent rainfall encountered during the stress period, which disrupted the stress treatment. Significant variation in plant height may be due to the stress treatment encountered by plants before the occurrence of rainfall. Olawuyi *et al.*, (2015) has reported the positive correlation between plant height and drought stress supporting our observations. The rainfall which occurred during the reproductive stage may have caused the plants to adapt to drought stress and resulted in recovery of yield and other yield parameters (Chen *et al.*, 2016).

The comparisons of treatment means revealed that maximum plant height was recorded in BTM7 (132 cm) and minimum in BTM14 (82.50 cm) (Table 3). The mean days to silking and anthesis ranged from 57 days to 71 days indicating variability in time required for reproductive development. Inbred line BTM13 required lowest days for reproductive phase development signifying drought escaping strategy in plants (Basu *et al.*, 2016). The highest test weight and yield per plant was recorded in BTM6 (28.31g) and BTM10 (115.1g) while both traits recorded lowest in BTM14 (12.88g and 35.90g) respectively. Correspondingly, all the other parameters recorded showed variability among the inbred lines. The results indicated the vast diversity and variability among the inbred lines which can be further utilized in hybridization programs. Similarly, Maiti *et al.*, (1996) had reported large variations in resistance to drought and saline stress in maize cultivars. Grzesiak (2001) also observed considerable genotypic variability among various maize genotypes for different traits which could be used in selection for drought tolerance.

**Table.1** Weather Data for cropping period sown during *rabi* 2015 at University of Agricultural Sciences, GKVK, Bangalore

Month	Total rainfall (mm)	Mean relative humidity (per cent)	Mean maximum air temperature (°C)	Mean minimum air temperature (°C)	Mean daily Sunshine (hours)
September-15	254.6	91	28.7	19.2	5.5
October-15	80.8	89	29.3	19.1	6.6
November-15	180.4	94	25.3	17.9	3.3
December-15	4.2	91	27.6	19.9	6.5

**Table.2** ANOVA for growth and yield traits of different maize inbred lines in irrigated and stressed condition

Source	Replication	Main plot (C)	Sub plot (G)	G×C
Plant height (cm)	433.71**	3932.98*	990**	315.89**
Tassel Initiation	21.86	11.15	69.86**	22.35**
Days to Silking	19.44	50.16	54.32**	16.85**
Days to Anthesis	20.63	16.05	65.26**	17.22**
Cob length (cm)	0.24	2.41	10.12**	2.02**
Cob diameter (cm)	0.054	0.05	0.47**	0.06**
No. of rows per cob	2.55	5.76	23.28**	14.16**
No. of seeds per cob	419.10*	12447.10*	13781.13**	1208.67**
Test weight (g)	3.22	31.04	66.72**	4.3**
Grain yield per plant (g)	31.29	38.23	3.95**	7.56**

\*\*Significant at 1 % probability level \*Significant at 5 % probability level

**Table.3** Mean values of growth and yield parameters of different maize inbred lines

	PH	DT	DS	DA	COL	COD	NOR	NOS	TW	YP
BTM 1	84.81	60.00	69.25	64.00	9.56	3.72	24.56	456.77	12.53	57.05
BTM 2	122.98	63.25	66.75	67.75	10.56	3.78	19.90	268.13	18.44	53.01
BTM 4	113.13	68.50	72.00	71.25	11.55	3.91	23.27	293.56	21.44	63.48
BTM 5	114.23	67.25	71.50	71.00	13.66	3.99	27.02	415.67	20.17	85.62
BTM 6	103.54	66.25	67.75	68.50	13.94	3.63	21.75	281.94	28.31	89.87
BTM 7	132.00	63.25	64.50	65.75	13.75	3.74	28.81	433.21	19.88	86.36
BTM 10	120.56	62.00	69.00	67.75	12.38	3.84	24.17	352.58	24.33	115.1
BTM 13	92.38	53.50	57.75	57.50	9.94	3.00	21.19	287.90	19.31	73.86
BTM14	82.50	63.75	69.50	68.00	11.75	3.41	22.25	277.63	12.88	35.90
BTM 15	86.90	68.50	68.50	71.25	12.11	3.47	23.58	313.81	18.88	58.80
BTM 18	101.88	59.50	64.50	63.50	11.91	3.59	23.13	347.75	20.36	70.66
BTM 19	97.13	66.25	71.00	71.75	13.28	3.66	24.38	295.44	20.92	61.88
DT 3	101.73	65.75	67.75	70.25	8.97	3.35	18.17	272.50	17.35	54.91
MAI 105	124.00	60.00	65.50	63.75	12.97	4.53	25.33	407.92	21.26	86.39
Mean	107.67	63.41	67.51	67.28	11.62	3.68	23.36	339.62	19.78	65.02
CD @ 5%	10.76	3.11	2.64	3.47	1.57	0.41	4.20	71.41	2.75	23.45

PH: Plant height; DT: Days to tassel initiation; DS: Days to Silking; DA: Days to Anthesis; COL: Cob length; COD: Cob diameter; NOR: Number of rows per cob; NOS: Number of seeds per cob; TW: Test weight; YP: Grain yield per plant

\*Significant at 5 % probability level

**Table.4** Mean values and percent reduction of growth and yield parameters in irrigated (N) and stressed condition(S)

	PH		DT		DS		DA		COL		COD		NOR		NOS		TW		YP	
	N	S	N	S	N	S	N	S	N	S	N	S	N	S	N	S	N	S	N	S
<b>BTM 1</b>	84.33	85.29	60.50	59.50	69.50	69.00	65.00	63.00	9.63	9.50	3.69	3.75	24.83	24.29	455.58	457.96	13.44	11.63	0.61	0.53
<b>BTM 2</b>	128.63	117.33	63.50	63.00	67.00	66.50	68.00	67.50	10.88	10.25	3.69	3.88	21.46	18.33	277.50	258.75	18.88	18.00	0.52	0.54
<b>BTM 4</b>	106.88	119.38	73.00	64.00	76.00	68.00	75.50	67.00	10.94	12.17	3.81	4.00	22.58	23.96	260.33	326.79	18.75	24.13	0.49	0.79
<b>BTM 5</b>	106.33	122.13	73.00	61.50	77.50	65.50	75.50	66.50	13.00	14.31	3.92	4.06	25.67	28.38	384.75	446.58	17.09	23.25	0.67	1.04
<b>BTM 6</b>	133.71	73.38	63.00	69.50	66.00	69.50	66.00	71.00	14.75	13.13	3.63	3.63	23.50	20.00	306.00	257.88	29.38	27.25	1.11	0.70
<b>BTM 7</b>	147.38	116.63	62.50	64.00	65.00	64.00	65.50	66.00	14.50	13.00	3.67	3.81	30.50	27.13	449.17	417.25	19.50	20.25	0.88	0.85
<b>BTM 10</b>	149.13	92.00	61.00	63.00	68.50	69.50	66.50	69.00	12.25	12.50	3.75	3.94	24.67	23.67	372.54	332.63	26.50	22.17	1.27	1.03
<b>BTM 13</b>	98.50	86.25	54.00	53.00	59.50	56.00	59.50	55.50	9.13	10.75	2.69	3.31	20.50	21.88	236.67	339.13	20.50	18.13	0.49	0.97
<b>BTM14</b>	84.33	80.67	65.00	62.50	71.50	67.50	69.50	66.50	10.69	12.81	3.44	3.38	24.25	20.25	310.13	245.13	13.75	12.00	0.43	0.30
<b>BTM 15</b>	88.13	85.67	68.50	68.50	68.00	69.00	71.50	71.00	11.56	12.67	3.63	3.31	23.08	24.08	329.63	298.00	18.38	19.38	0.60	0.57
<b>BTM 18</b>	106.63	97.13	59.50	59.50	65.50	63.50	63.00	64.00	12.69	11.13	3.63	3.56	25.25	21.00	386.13	309.38	19.50	21.21	0.76	0.66
<b>BTM 19</b>	104.88	89.38	64.00	68.50	70.00	72.00	70.00	73.50	12.81	13.75	3.88	3.44	18.29	30.46	252.25	338.63	20.96	20.88	0.54	0.71
<b>DT 3</b>	111.38	92.08	65.00	66.50	67.50	68.00	69.00	71.50	9.35	8.58	3.46	3.25	21.58	14.75	322.83	222.17	17.17	17.54	0.61	0.46
<b>MAI 105</b>	138.00	110.00	61.50	58.50	67.00	64.00	65.00	62.50	13.56	12.38	4.63	4.44	25.50	25.17	403.50	412.33	22.03	20.50	0.88	0.84
<b>Mean</b>	116.05	99.29	63.85	62.96	68.46	66.57	67.82	66.75	11.83	11.42	3.71	3.65	23.69	23.04	354.53	324.71	20.52	19.03	66.34	63.71

PH: Plant height; DT: Days to tassel initiation; DS: Days to Silking; DA: Days to Anthesis; COL: Cob length; COD: Cob diameter; NOR: Number of rows per cob; NOS: Number of seeds per cob; TW: Test weight; YP: Grain yield per plant



All the growth and yield parameters viz. plant height, cob length, cob diameter, number of rows per cob, number of seeds per cob, test weight and grain yield per plant recorded lower values in stressed condition compared to non-stressed condition (Table 4). Non-stressed condition had a mean of 116.05 plant height, 11.86 cm cob length, 3.71 cm cob diameter, 23.69 number of rows per cob, 354.53 number of seeds per cob, 20.52 g test weight, 66.34 g grain yield per plant while the stressed condition exhibited a mean of 99.29 plant height, 11.42 cm cob length, 3.65 cm cob diameter, 23.04 number of rows per cob, 324.71 number of seeds per cob, 19.03 g test weight, 63.71 g grain yield per plant (Table 4). In accordance with our results, Ziyomo *et al.*, (2013) also had demonstrated that under drought conditions, the mean grain yields for the drought tolerant maize hybrids (9.66 mg ha<sup>-1</sup>) was significantly more than drought-susceptible maize hybrids (5.46 mg ha<sup>-1</sup>) involving 10 maize hybrids.

In earlier studies, it has been reported that grain yield reduced by 25% to 73.5% when drought was induced during post anthesis stage (Pandey *et al.*, 2000; Olaoye *et al.*, 2009). Our results recorded only 3.96% reduction in total grain yield indicating drought adaptation after rainfall. The results of this study indicate that maize inbred lines have large potential to display variations to drought tolerance. Under the drought condition, the discovery of variability among maize inbred lines in growth and yield parameters provide an ample opportunity for the selection of genotypes for tolerance to drought. As it has been reported that genetic variation is essential prerequisite for any crop improvement programs, sampling more variables at more time points along with final grain yields will provide us with a better understanding of drought-adaptive mechanisms. The genetic variation in the present study for drought tolerance reflected genotypic differences which require further work to rigorously test the genetic basis of these genotypic differences. The divergent responses

to drought stress help the breeders to explore in greater detail that influence drought tolerance.

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**How to cite this article:**

Ashwini S., Ashutosh Singh and Pavankumar Jingade. 2017. Assessment of Inbred Lines of Maize for Water Stress Tolerance in Field Conditions. *Int.J.Curr.Microbiol.App.Sci.* 6(9): 1451-1457.  
doi: <https://doi.org/10.20546/ijcmas.2017.609.176>