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RESEARCH PAPER

Drought tolerance effects on maize hybrids

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Abstract : Drought is one of the most important abiotic stress limiting crop yields including maize. Maize is being grown in drought prone, marginal lands having low fertility in South East Asia resulting in lower grain yields. Drought stress has deleterious effects on the seedling establishment, vegetative growth, photosynthesis, root growth, anthesis, anthesis silking interval, pollination and grain formation in maize crop. Improvement of grain yield in maize under large environments is of utmost importance, inorder to meet the increasing demands of food for the ever increasing population. Grain yield under water deficit stress is culmination of various physiological and metabolic functions in a plant. Assessing the drought tolerance on the basis of yield stability or drought susceptibility index is a major approach to identify drought tolerant genotypes. Drought tolerance studies in maize help to understand the parameters which are associated with drought stress in the crop. This research was conducted to analyze the impact of drought on yield of maize (*Zea mays* L.). The initial study started with 100 genotypes from which the 10 best genotypes (lines) were selected for drought tolerance studies. Screening was carried out using physiological and phenotypic data. Thirty hybrids were developed from the 10 lines and 3 testers (locally adapted varieties) utilizing a LxT analysis. Parents and hybrids were phenotypically assessed in two field conditions: irrigated and moisture stress. Results showed that hybrid IBET IE 1253-8 x UMI 61 was best under normal irrigation and IBET IE 1256-6 x COH (M)5 was best under moisture stress. Taking both fields together, the best hybrid was IBET IE 1253 x UMI 61 which averaged 6.4t/ha. The best parental lines for both conditions were COH (M) 5 and Hy R'06 6143-16. Results support the fact that yields are low when maize is subjected to drought stress. The best hybrid was equal to the local variety under both irrigated and moisture stress condition. Drought susceptibility index developed based on yield as well as morpho-physiological traits across the environments were useful in identifying the best genotypes with high yield and very good drought tolerance. Drought tolerant maize hybrids can help to improve productivity in drought stressed areas.

Key Words : Anthesis silking interval, Dorught tolerance, Hybrids, Susceptibility

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INTRODUCTION

Drought is a serious threat for crop production and food security. Drought takes place when there is more moisture loss from soil surface and fewer water supplies to soil. During the drought conditions water potential and turgor are decreased and this situation disturbs the normal functioning of the plant body Hsiao (1973). Drought is a worldwide problem which is dangerous for arable field crops growth and subsequently for food security as a whole Jaleel *et al.* (2009). Drought stress or water deficit stress is a globally renowned feature of climate, an alarming threat to our agriculture.

Maize is an important cereal and fodder crop cultivated across the world White and Johnson (2003). The crop of future- Maize, as mentioned by Dr. Norman E. Borlaugh is currently one of the third most important crop next to wheat and rice in the world agricultural economy. According to FAO (2003) report, out of 593 million tonnes of maize produced in 142.3 million hectares globally, 17 per cent is used as food for humans and 66 per cent as feed for animals. In India with the growth in demand of poultry feed, the demand for maize is also going up.

The adverse effects of various abiotic stresses including drought, high temperature are likely to be attenuated by the impending climatic change. Drought is a major constraint to maize production in all areas where it is grown. The average annual yield losses in maize due to drought are estimated to 17 per cent in the tropics Edmeades *et al*. (2004). Drought tolerance is not a simple character governed by one or two genes but controlled by a number of morpho-physiological characters being independently controlled by more than two genes (Fukai and Cooper, 1995). Global climate change is now generally considered to be underway Hillel and Rosenzweig (2002) and is expected to result in a long-term trend towards higher temperature, greater evapotranspiration and an increased incidence of drought in specific regions. India is expected to experience severe water stress by 2020 with the per capita availability of water projected to be less than 1,000 cubic meters. The water scenario in the country was a matter of concern, as 85 per cent of water was used for agriculture, 10 per cent for industry and 5 per cent for domestic use. These trends, coupled with an expansion of cropping into marginal production areas, are generating increasingly drought-prone maize production environments. Possible climate change due to global warming could further increase the chances of drought.

The major setback in drought tolerance breeding is the poor understanding of genetics and inheritance of drought tolerant traits and complete ignorance of the relationship between the physiological traits in drought tolerance and plant productivity under stress Blum (1982). Improvement of drought resistance in high yielding genotypes could be brought about only through the incorporation of such morphological and physiological mechanisms of drought resistance. The use of genetics to improve drought tolerance and to provide yield stability is an important part of the solution to stabilizing global maize production. Breeding genotypes suitable for both irrigated as well as drought condition will be much useful to farmers and industries. Studies on the genetic basis of the drought tolerance in maize will help in evolving maize hybrids suitable for rainfed cultivation.

An understanding of the genetic architecture of parents and their mode of inheritance will greatly assist the breeder to formulate appropriate breeding methodologies to incorporate the desirable traits into an adapted variety. Developing maize genotypes with tolerance to drought is complex. This is due to factors, including the largely polygenic nature of the tolerance, the typically low frequency of tolerance alleles in most maize germplasm and the difficulties commonly encountered in field evaluations.

MATERIAL AND METHODS

For any plant breeding programme to be successful, the choice of parents is an important criterion to enhance genetic variability and in synthesizing new genotypes. More so, if the aim is for the improvement of quantitative traits like yield and its components, the genetic architecture of the parents has to be diverse so as to produce heterotic combinations.

Hundred inbreds were grouped into sixteen major clusters at the similarity co-efficient of 7.72 and thirty four inbreds were selected based on mean performance in SPAD chlorophyll meter reading, relative water content and leaf area. These inbreds were planted in field. The inbreds which showed tolerance to drought and based on the ASI, about 10 inbreds were selected for line x tester analysis (Table A)TEN inbred lines *viz.*, IBET IE1207-6 (L1), IBET IE 1554-5 (L2), IBET IE 1224-9w (L3), IBET IE 1051-5 (L4), IBET IE 1256-6 (L5), IBET IE 1253-8 (L6), IBET IE 1076-5 (L7), IBET IE 1182-5(L8), Hyd . 2199-1(L9), Hy R‘06 6143-16(L10) and testers *viz.*, UMI 285(T1), COHM5 (T2) and UMI 61(T3) were crossed in a Line x Tester design. The crossed seeds of thirty hybrids and their parents were evaluated along with a standard check Co (H) M 5 for 19 characters under induced drought stress (moisture stress) and irrigated conditions.

RESULTS AND DISCUSSION

The results obtained from the present investigation as well as relevant discussion have been summarized under following heads :

Response of drought to drough indices :

In any plant, the definition of drought resistance must be linked to survivability. Indexing yield to some quantifiable measure of stress severity, therefore, is the only means of quantitatively evaluating relative drought resistance in a larger collection of cultivars. A procedure for assessing drought resistance should identify genotypes whose performance under stress is better than that predicted from the combined effect of their yield potential and phenology (Bidinger *et al.*, 1987).

Drought susceptibility index (S) :

Drought susceptibility index (S) is a measure of yield stability. DSI is used for identifying genotypes with yield stability in moisture-limited environments (Edhaie *et al.*, 1988; Bansal and Sinha, 1991 and Clarke *et al.*, 1984) used DSI for identifying genotypes with yield stability in moisture limited environments and reported that DSI provide a measure of yield stability based on minimization of yield loss under stressed and non stressed conditions rather than an yield level under dry conditions. Bruckner and Frohberg (1987) considered genotypes with low drought susceptibility index values to be drought resistant as they exhibited smaller yield reductions under water stress compared with well-watered conditions than the mean of all genotypes. Blum *et al.* (1989) estimated stability in grain yield for each genotype by the drought susceptibility index, derived from the yield difference between stress and non-stress environments. In this study, the drought susceptibility index range for parents and hybrids were 0.21 to 0.75 and 0.11 to 0.63, respectively. Among the hybrids, L1 x T1 registered the minimum drought susceptibility index of 0.11 and L6 x T1 registered the maximum drought susceptibility index of 0.63. Among the parents L10 showed the minimum susceptibility index (0.21) and L1 had the maximum of 0.75.

Relative yield :

Relative yield (yield of an individual genotype under drought relative to that of the highest yielding genotype in the population) could be used to assess the yield potential of a genotype under water stress conditions. Higher relative yield shows that the genotype performed relatively well under drought. Pinter *et al.* (1990) proposed the combination of high yield stability and high relative yield under drought, as the useful selection criterion for characterizing genotypic performance under varying degree of water stress. Ahmed *et al.* (1999) found combination of drought susceptibility index (measure of yield stability) vs. relative yield useful in identifying genotypes with yield potential and relatively stable yield performance under different moisture environments. Ahmed *et al.* (2003) conducted a field study to evaluate genotypes for combined high yield potential and stability under water stress conditions and reported that the varieties Parwaz-94, Pasban-90 and Punjab-96 showed high yield potential and stability (*i.e.* DSI < 1 and RY > Mean RY) and hence, these varieties could be further tested for their drought confirming characteristics.

The relative yield for the genotypes in this study ranged from 0.51 to 1.00. Among the hybrids, L6 x T1 recorded the minimum relative yield of 0.51. The parent L10 recorded the maximum relative yield of 1.00. This is a comparative measure, which expresses the yield of specific genotype under stress to highest yielding

Table A : Details of the 10 lines and 3 testers used

		Genotype	Source /origin
Testers	T1	UMI 285	Selection from (96123 (Sarhaelx Suwan1)x (Suwan)
	T2	COH(M) 5	UMI 285 * UMI 61
	T3	UMI 61	Selection from (Taiwan DMR13)
Lines	L1	IBET IE1207-6	Department of Millets, Coimbatore
	L2	IBET IE 1554-5	Department of Millets, Coimbatore
	L3	IBET IE 1224-9w	Department of Millets, Coimbatore
	L4	IBET IE 1051-5	Department of Millets, Coimbatore
	L5	IBET IE 1256-6	Department of Millets, Coimbatore
	L6	IBET IE 1253-8	Department of Millets, Coimbatore
	L7	IBET IE 1076-5	Department of Millets, Coimbatore
	L8	IBET IE 1182-5	Department of Millets, Coimbatore
	L9	Hyd .R`06. 2199-1	Department of Millets, Coimbatore
	L10	Hy R`06 6143-16	Department of Millets, Coimbatore

genotype under stress.

Stress tolerance index (STI) :

The stress tolerance index was calculated based on the formula given by Fernandez (1992). This index is used mainly for the measurement of drought tolerance. It was used by Farshadfar *et al*. (2002) to measure the drought tolerance nature of maize in rainfed situation.

Stress tolerance index among the 30 hybrids ranged from 0.32 (L2 xT3) to 1.16 (L10 x T2) and for parents the ranges were from 0.47 (L8) to 1.17 (L10).

Yield stability ratio (YS) :

The yield stability ratio was calculated as suggested by Lewis (1954). This was used by Islam *et al.* (1998) to screen the genotypes for drought tolerance in wheat. They reported that tolerant genotypes are having more than 50 per cent of yield stability ratio. If the yield stability ratio is more under drought condition its likely to screen for drought tolerance breeding programme.

Yield stability ratio among the genotypes ranged from 45.27 to 94.17. The yield stability ratio was the maximum for the hybrid L1 x T1 (92.17) and the minimum for L6 x T1 (54.31).Yield stability index takes into consideration, grain yield under stress as well as in controlled condition.

RESULTS AND DISCUSSION

The results obtained from the present investigation as well as relevant discussion have been summarized under following heads :

Physiological and biochemical characters :

In genetic sense, the mechanism of drought resistance is grouped into three categories, *viz.*, drought escape, drought avoidance and drought tolerance Mitra (2001). Drought escape is defined as the ability of the plant to complete its life cycle before water deficit develops. This mechanism involves rapid physiological development (early flowering and early maturity), developmental plasticity (variation in duration) of growth period depending on the extent of water deficit and remobilization of pre-anthesis assimilates to grain Turner (1982).

Drought avoidance is the ability of plants to maintain relatively high tissue water potential despite shortage of soil moisture. Drought avoidance is performed by maintenance of turgor through increased rooting depth, efficient root system and increased hydraulic conductance and by reduction of water loss through reduced epidermal conductance, reduced absorption of radiation by leaf rolling or folding O'Toole and Moya (1978) and Begg (1980) and reduced evaporation surface Passioura (1976). Plants under drought conditions survive by doing a balancing act between maintenance of turgor and reduction of water loss Sashidhar *et al.* (2000). Mechanisms for improving water uptake, storing in plant cell and reducing water loss confer drought avoidance. Drought tolerance is the ability to withstand water-deficit with low tissue water potential. The responses of plants to tissue water deficit determine their level of drought tolerance.

Putative drought tolerance traits have either positive or negative influence on yield, depending on the existing drought situation (timing, severity and duration) and depending on whether a survival or production mechanism is necessary. This calls for attention to the need for a good characterization of drought tolerance in the target area in order to design suitable breeding programmes Fukai and Cooper (1995). The Drought tolerance measurement indices were worked out and given in Table 1.

Conclusion :

Selection for drought tolerance typically involves evaluating genotypes for either high yield potential or stable performance under varying degrees of water stress. Drought susceptibility index (DSI) and relative yield (RY) values were used to describe the yield stability and yield potential. Ahmed *et al.* (1999) and Pinter *et al.* (1990) proposed the combination of drought susceptibility index (DSI) vs. relative yield (RY) as useful selection criteria in identifying the genotypes with yield potential and relatively stable yield performance under different moisture environments.

From this study, two hybrids were identified based on the drought indices *viz.*, susceptibility index (S) and yield stability ratio (YS). The selected drought tolerant hybrids were L6xT2 and L5xT3. The mean performance and the standard heterosis of these hybrids are relatively high. These hybrids had the low drought susceptibility index (S) and high yield stability ratio (YS) (Fig. 1 and 2). Also, these hybrids recorded good stress tolerance index (STI) and high relative yield (RY).

Among parents, L5 showed the desirable minimum drought susceptibility index (S) and maximum yield

Table 1 : Estimates of drought tolerance measurement indices for parents (Lines and Testers) and hybrids

		DSI	STI	YSR	RY
Lines	L1	0.75	0.67	45.27	0.55
	L2	0.65	0.69	52.52	0.61
	L3	0.29	0.61	79.12	0.70
	L4	0.40	0.53	70.55	0.62
	L5	0.29	1.01	78.86	0.90
	L6	0.36	0.63	73.80	0.68
	L7	0.08	0.74	94.17	0.84
	L8	0.25	0.47	81.61	0.62
	L9	0.40	0.83	71.04	0.77
	L10	0.21	1.17	84.77	1.00
Testers	T1	0.65	0.72	52.44	0.62
	T2	0.20	1.07	85.13	0.96
	T3	0.51	0.54	82.72	0.98
Hybrids	L1 x T1	0.11	0.90	92.17	0.92
	L1 x T2	0.17	0.77	87.38	0.82
	L1 x T3	0.21	0.88	84.75	0.87
	L2 x T1	0.42	0.66	69.65	0.68
	L2 x T2	0.30	1.10	78.29	0.93
	L2 x T3	0.43	0.32	68.46	0.47
	L3 x T1	0.31	1.03	77.54	0.90
	L3 x T2	0.18	0.69	86.98	0.78
	L3 x T3	0.14	0.87	89.85	0.89
	L4 x T1	0.26	0.84	80.73	0.83
	L4 x T2	0.53	0.54	61.18	0.58
	L4 x T3	0.19	1.02	86.21	0.94
	L5 x T1	0.39	0.50	71.62	0.60
	L5 x T2	0.53	0.75	61.20	0.68
	L5 x T3	0.20	1.01	85.13	0.93
	L6 x T1	0.63	0.47	54.31	0.51
	L6 x T2	0.34	0.87	75.12	0.81
	L6 x T3	0.40	0.56	70.58	0.63
	L7 x T1	0.30	1.10	78.20	0.93
	L7 x T2	0.55	0.75	59.74	0.68
	L7 x T3	0.42	0.65	69.01	0.67
	L8 x T1	0.32	0.75	76.45	0.76
	L8 x T2	0.37	0.41	73.26	0.55
	L8 x T3	0.32	0.71	76.29	0.74
	L9 x T1	0.48	0.64	64.60	0.65
	L9 x T2	0.38	0.50	72.06	0.61
	L9 x T3	0.54	0.55	60.38	0.58
	L10 x T1	0.34	0.63	74.99	0.69
	L10 x T2	0.27	1.16	80.50	0.97
	L10 x T3	0.18	0.99	86.78	0.93

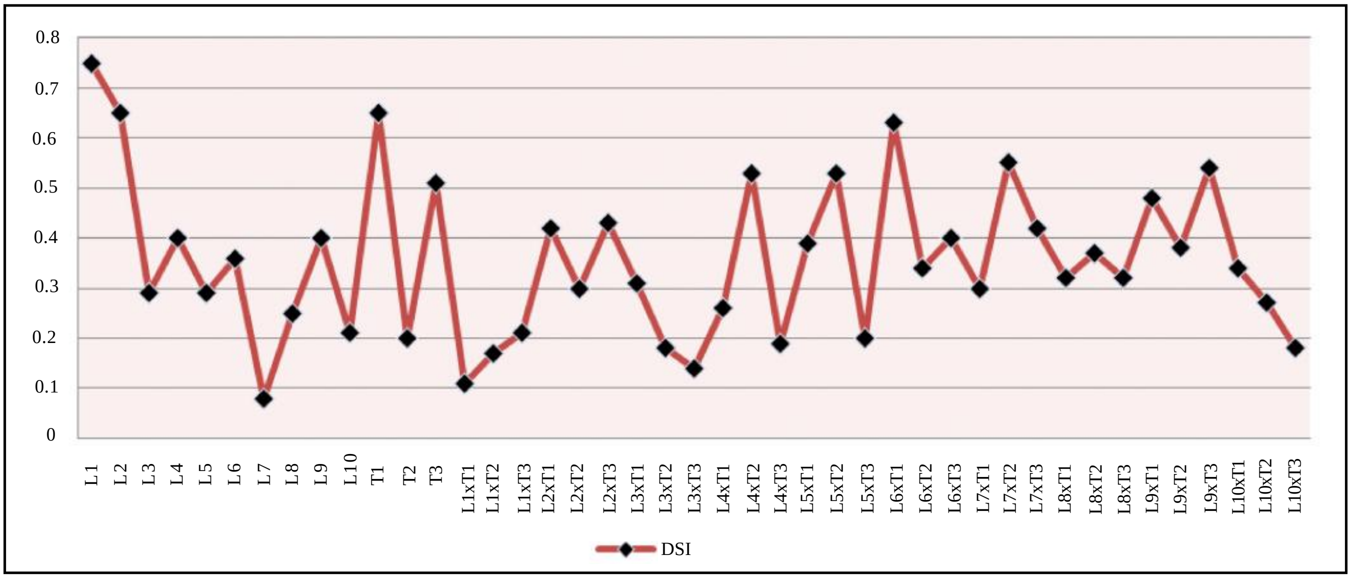

Fig. 1 : Drought susceptability index of parents and hybrids

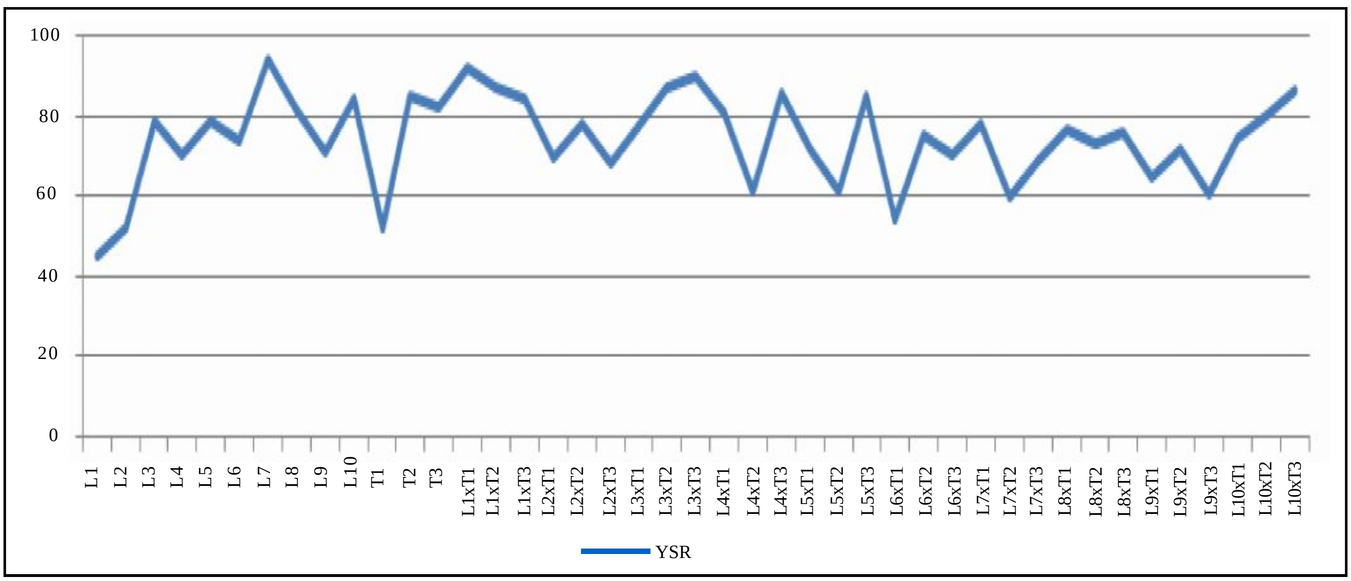

Fig. 2 : Yield stability ratio of parents and hybrids

stability ratio (YS) (Fig. 1 and 2). Also the parent T3 recorded the maximum relative yield (RV) and stress tolerance index (STI). These two parents can be selected for future evaluation and hybridization purpose to produce drought tolerant hybrids.

Based on the drought indices study, two superior hybrids were identified based on susceptibility index (S) and yield stability ratio (YS) L6 x T2 (IBET IE 1253-8 x COHM5) and L5 x T3 (IBET IE 1256-6 x UMI 61).Among these two hybrids, the hybrid L5 x T3 (IBET IE 1256-6 x UMI 61) recorded positively significant values for grain yield per plant and considered as the best hybrid for both conditions of induced moisture stress and normal irrigation. The hybrid in L5 x T3 (IBET IE 1256-6 x UMI 61) was not wide difference in grain yield per plant (104.00, 88.53) for irrigated and induced stress conditions. In the hybrid L5 x T3 (IBET IE 1256-6 X UMI 61) both the parents have recorded positively significant GCA effects for most of the traits. The genotypes with high grain yield under both water stressed and well watered conditions, could be a good genetic resource for genetic improvement of maize for water stressed environments (Maheswari *et* *al.*, 2016). Similar findings on the development of high yielding inbred as well as hybrids for drought prone environments in West and Central Africa has been reported (Badu-Apraku and Oyekunle, 2012 and Oyekunle *et al.*, 2015).

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