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GENERAL COMBINING ABILITY OF DROUGHT TOLERANT MAIZE HYBRIDS

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ABSTRACT

Combining ability estimates are important genetic attributes to maize breeders in anticipating improvement via hybridization and selection. The current research 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 LINE X TESTER analysis. Parents and hybrids were phenotypically assessed in two field conditions: irrigated and moisture stress. The resultant 30 derived F1s were evaluated along with 13 parents to estimate general and specific combining ability variances and effects for 10 characters. The results showed predominant role of non-additive gene action for all the characters studied. Results showed that hybrid IBET IE 1253-8 X UMI61 was best under normal irrigation and IBET IE 1256-6 X COH (M)5 was best under moisture stress. Taking both conditions together, the best hybrid was IBET IE 1253 X UMI61 which averaged 6.4t/ha. The best parental lines for both conditions were COH (M) 5 and Hy R'06 6143-16.

INTRODUCTION

Maize (*Zea mays*.L.) is the most important crop next to wheat and rice in the world agricultural economy. It is important for food, animal feed and industrial utilization. It is the crop of the future as mentioned by Dr. Norman E. Borlaug (Dahiya 2008). Maize can play a vital role in ensuring food security as well as nutritional security for developing countries and the world as a whole. According to the Food and Agriculture Organisation (2003) report, out of 593 million tons of maize produced on 142.3 million hectares globally, 17 per cent is used as human food and 66 per cent as animal feed. Drought is a major constraint to maize production in all areas where there is no adequate rains or irrigation.

The most important breeding objective is increased grain yield. Heterosis acts as an important tool for enhancing hybrid vigour for growth and yield traits (Soni and Khanorkar, 2013). The average annual yield loss in maize due to drought is estimated to be 17% in the tropics (Wilkinson, 1992). Drought tolerance is not a simple character governed by one or two genes but controlled by a number of morpho-physiological characters independently controlled by more than two genes (Fukai and Cooper. 1995). The major problem in drought tolerance breeding is the poor understanding of genetics and the inheritance of drought tolerant traits, and lack of understanding of the relationship between the physiological traits in drought tolerance and plant productivity under stress (Wilkinson 1992). Improvement of drought resistance in high yielding genotypes can be achieved by the incorporation of morphological and physiological mechanisms of drought resistance in new lines through breeding programs.

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 and drought conditions will be useful to farmers and to industries. This research uses physiological and morphological drought tolerant mechanisms for the development of drought tolerant hybrids. The Line x Tester analysis provides information on the type of gene action and general combining ability and specific combining ability (SCA) of genotypes (Iqbal *et al.,* 2014; Kumar *et al.*, 2014; Rajesh *et al.,* 2014). Selection of parents is most important criteria for developing hybrids. Combining ability which is widely used in the breeding of cross-pollinated crop provides information regarding the selection of lines for hybrid combination (Khan and Dubey, 2015).The objective of the study was to provide useful information for breeders in developing drought tolerant maize hybrids. The paper deals with screening of the germplasm for drought tolerance and Line X Tester analysis.

MATERIALS AND METHODS

The present investigation was carried out from 2007– 2009 at the Department of Millets, Centre for Plant Breeding and Genetics, Tamil Nadu Agricultural University, Coimbatore, India (11ºNorth latitude, 77ºEast longitude). Soils for the experiment were black cotton soils (vertisols) with a loamy texture for the irrigated treatment and a clay loam for the induced moisture stress treatment. During the experiment the mean annual rainfall was 17.7mm received in 4 rainy days. The mean maximum and minimum temperatures were 30.2°C and 21.5ºC, respectively.

Screening of maize genotypes for drought tolerance

A hundred lines obtained from the maize germplasm collection at the Department of Millets, Centre for Plant Breeding and Genetics, Tamil Nadu Agricultural University, Coimbatore were screened for drought and identification of tolerance traits. Initial Screening was done in a greenhouse and the third leaf from top was used for all the observations. Mean values of relative water content (Bars and Weatherly. 1962), chlorophyll content values using SPAD-502, Minolta, Tokyo, Japan. and specific leaf area measurements were used to do cluster analysis by numerical taxonomy techniques, using NTSYS-pc package, version 2.01, (Rohlf. 1997). An Unweighted Pair-Group Method of the Arithmatic (UPGMA) (Sokal and Michener. 1958) average clustering procedure was employed to construct the dendrogram. Based on the groupings in the dendrogram, highly diverse 34 genotypes were selected for further studies.

Line × tester analysis

The selected 34 genotypes were taken to a field crossing block during June 2008. Each genotype was raised on a ridge spaced 60 cm apart, five meter long, and 30 cm between plants; sowing of genotypes was at three dates, 10 days apart, for synchronization of flowering. From 34, 10 were selected for the line x tester analysis based on the anthesis to silking interval of 1-2 days (Bolaòos and Edmeades, 1993). The ten lines selected (Table 1) were crossed with three testers (locally adapted varieties) individually in a line x tester model (Kempthorne, 1957) to obtain 30 hybrids.

All thirteen parent lines (10 lines and 3 testers) (Table1) along with the 30 hybrids were evaluated from December 2008 to February 2009, under irrigated and induced moisture stress conditions in two different fields. Each entry was grown in two rows of five-meter long using a randomized block design(RBD) replicated thrice; spacing was 60 x 30 cm. Recommended agronomic and plant protection practices were followed to maintain healthy growth.

Observations were recorded on five plants selected randomly from each entry and replication. The parents and F1 hybrids were examined for morphological traits and yield components whose genes were found to have an impact on drought stressed output as grains. The yield components which were responsible for yield were cob weight, 100 seed weight, number of kernels per row, number of rows per cob, and single plant yield. The morphological traits which showed an influence on drought tolerance of the crop includes, anthesis silking interval (ASI), root volume, chlorophyll stability index (CSI), and relative water content (Table.2). Combining ability analysis was done following standard procedure of Kempthorne (1957).

Statistical analysis

The data was subjected to statistical analysis using the INDOSTAT statistical package developed by Indostat Services, Hyderabad, India. Analysis of variance for all characters was determined (Panse and Sukhatme. 1961). The mean values were used to estimate heterosis per cent under three categories of mid parent, better parent and standard parent (Fonesca and Paterson, 1968).

RESULTS AND DISCUSSION

Drought tolerance screening of maize genotypes

The selection of suitable plants from a germplasm collection using specific physiological traits is a viable way for crop improvement for water stress tolerance (Kiani *et al*., 2007, Reynolds *et al*., 2005, Tambussi *et al*., 2007) The initial selections of 34 inbred lines from the 16 clusters in the dendrogram (Fig. 1) were based on the physiological traits related to drought. Hence a simple method of screening maize lines using three potential physiological selection criteria, relative water content, chlorophyll content and specific leaf area were tested in the present study. The clusters indicate the diverse nature of the inbred lines used for development of drought tolerant hybrids. (Burke, 2001, Srikanthbabu *et al*. 2002) expressed that genetic variability for water stress response can only be expressed when plants are exposed to water stress. The higher water stress tolerance is due to expression of water stress-responsive genes that can be translated into certain physiological phenomena such as maintenance of relative water content and chlorophyll content (Bruce *et al*. 2002, Waseem *et al*., 2006). Selection of inbreds with the

Table 1: Details of the 10 Lines & 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

Table 2: Description of morphological traits and yield components which had influence on yield and drought

Trait	Abbreviation	Description / Reference
Cob weight	CW	The cob was weighed after harvest at 12% moisture.
100 seed weight	100SW	One hundred normal grains per ear were counted and weighed
Number of kernals per row	K/R	The number of kernals per row of the cob were counted after harvest
Number of kernal rows per cob	KR/C	The numbers of kernal rows in each cob were counted after harvest.
Single plant yield	SPY	The cob of tagged plants were separated, cleaned and weighed
Anthesis silking interval	ASI	Difference in days between 50% tassels have extruded the anther and 50% of cobs have emerged silk
Chlorophyll Stability Index	CSI	(Murty and Majundar. 1962) (Harrigan *et al.* 2007)
Relative Water Content	RWC	(Barrs and Weatherley. 1962)
Root Volume	RV	Plants were uprooted at maturity, roots were cut and washed and the volume was recorded adopting water displacement method

Table 3: Selected Parents for specific traits based on mean values and *gca* (general combining ability)

Traits	Selected parents	
	Irrigated	Moisture stress
*Plant height	L10, T2	L10,T2
*100 Kernel weight	L10,T1	L10,L1,T2
*Number of kernel rows per cob	L3	L8
*Number of kernels per row	L3,T2	L10,T3
Harvest index	L10	L4,L10,T2
*Grain yield/ Plant	L10,L7,T2	L10,L5,T1,T2
Anthesis Silking Interval	L1	L7,L10,L3,T2
*Root volume	L5,L3,L10,L4,T1	L10,L5,L1,T1
*Chlorophyll Stability Index	L5,L10,L2,L4	L5,L2,L4,L7,L10
*Relative Water Content	L5	L1

Table 4: Selected Hybrids for specific traits based on mean values, *sca* (specific combining ability) and standard heterosis.

Traits	Selected hybrids	
	Irrigated	Moisture stress
*Plant height	L10XT2	L7XT3,L6XT2
*100 Kernel weight	L5XT3,L10XT2	L5XT3,L6XT2
*Number of kernel rows per cob	L6XT2,L3XT1	L1XT3
*Number of kernels per row	L10XT2,L5XT3	L6XT2,L4XT3
Harvest index	L5XT3,L8XT1	L5XT3
*Grain yield/ Plant	L6XT2,L5XT3	L6XT2,L5XT3
Anthesis Silking Interval	L6XT2	L4XT2
*Root volume	L4XT2	L7XT2,L5XT3
*Chlorophyll Stability Index	L2XT1,L5XT3	L5XT3,L1XT1
*Relative Water Content	L8XT2,L5XT3	L5XT3

physiological parameters in the initial stage of seedlings itself has an impact on the final development of hybrids since physiological traits are found to have its impact in drought tolerance. The 34 genotypes were selected as drought tolerant genotypes for further study which are diverse from each other. These genotypes were planted in field. The 10 genotypes (lines) which had an ASI of 1-2 days were further selected for Line X Tester analysis, since ASI is the major criteria for selection of lines with drought tolerance in maize (Bolaòos and Edmeades. 1993).

Analysis of line × tester for combining ability

The ten inbred lines identified as female parents and three testers as male parents, according to the Line X Tester analysis, the genetic potential and the nature of the gene action of the genes involved was assessed. The best parents L10 (Hy R'06 6143-16) and T2 (COH (M) 5) identified had a better general combining ability, but those were not able to produce the better hybrids (Table 3). The reason could be the good combiners will not result in specific combiners leading to better hybrids. The F1 hybrids which were evaluated for grain yield under irrigated as well as in stress conditions (Ganunga. 2007). In the present study, the magnitude of heterosis, and general and specific combining abilities were studied for drought specific characters (Dadheech and Joshi. 2007 ; Fonesca and Paterson, 1968) (Table 5). Since yield is a complex trait, knowledge of the association of different components with yield like cob weight, number of kernel rows per cob, number of kernels per cob and interrelation among themselves is useful.

Per cent heterosis over mid parent and better parents were estimated to know the possible gene action and to exploit heterosis for drought associated traits and yield. Parents with high mean values like L10 and T2 are preferred for using in hybridization program as they are expected to produce

Table 5: Magnitude of heterosis over mid parent and better parent for morphological traits for drought in normal irrigated (NI) & induced moisture stress (IMS) condition

Character	Anthesis silking interval (NI)		Anthesis silking interval (IMS)		Root volume (NI)		Root volume (IMS)		Chlorophyll stability index (NI)		Chlorophyll stability index(IMS)		Relative water content (NI)		Relative water content (IMS)	
HYBRIDS	di	Dii	Di	dii	di	dii	di	dii	di	dii	di	dii	di	dii	di	dii
$L_1 \times T_1$	-14.46 *	-29.00 **	-24.11 **	-32.28 **	14.23 **	4.20	-6.01	-17.16 **	9.26 **	0.54	23.64 **	12.87 **	14.78 **	1.56	-13.49 **	-14.20 **
$L_1 \times T_2$	-10.29	-12.86	22.12 **	-12.66 **	-1.38	-6.90	31.11 **	22.57 **	-9.93 **	-19.22 **	-46.00 **	-61.66 **	3.75	-9.51 **	72.07 **	19.10 **
$L_1 \times T_3$	26.25 **	7.45	-36.76 **	-49.37 **	-10.10	-10.91	3.45	1.76	5.24 *	14.30 **	117.66 **	88.21 **	12.78 **	0.43	41.46 **	0.16
$L_2 \times T_1$	-47.22 **	-50.86 **	93.18 **	37.10 **	-34.74 **	-40.43 **	2.38	-17.16 **	3.18*	3.08*	3.78	-3.21	41.62 **	1.56	5.68	-11.95 **
$L_2 \times T_2$	46.24 **	17.24 **	58.33 **	39.71 **	-27.68 **	-31.68 **	17.43 **	13.43	-19.27 **	-20.66 **	-23.43 **	-27.73 **	24.50 **	-11.61 **	32.45 **	3.79
$L_2 \times T_3$	29.52 **	17.24 **	15.65	-10.53	15.72 **	14.77 *	-18.78 **	-27.56 **	5.03 *	5.79 *	58.35 **	6.50 *	44.61 **	4.16	113.70 **	72.47 **
$L_3 \times T_1$	13.39 **	2.42	-0.47	-15.32 **	4.05	-1.79	-2.14	-17.22 **	-7.92 **	-17.19 **	-41.81 **	-56.96 **	37.48 **	4.66	7.76	-8.20 *
$L_3 \times T_2$	-10.31	-29.84 **	30.32 **	16.09	7.70	5.34	-28.92 **	-30.37 **	-21.53 **	-30.45 **	-12.23 **	-34.55 **	41.53 **	6.51 **	-25.30 **	-42.58 **
$L_3 \times T_3$	-58.72 **	-63.71 **	50.55 **	44.21 **	3.11	0.31	-22.33 **	-27.10 **	3.10	13.40 **	31.75 **	6.93	50.56 **	15.18 **	86.79 **	47.71 **
$L_4 \times T_1$	-19.46 **	-26.45 **	-6.08	-19.19 **	-12.66 *	-19.97 **	-35.77 **	-39.80 **	-30.58 **	-31.58 **	-43.39 **	-45.07 **	18.03 **	4.29	-36.16 **	-44.47 **
$L_4 \times T_2$	-5.76	-25.62 **	-59.17 **	-11.05 **	31.01 **	24.26 **	-15.30 **	-25.53 **	-2.93	-3.12	4.32	2.48	23.75 **	7.77 **	79.61 **	35.71 **
$L_4 \times T_3$	-15.35 **	-24.79 **	49.06 **	15.70 **	7.91	7.47	27.69 **	31.25 **	-1.42	-2.15	58.32 **	4.30 **	12.61 **	0.13	76.16 **	36.82 **
$L_5 \times T_1$	-38.92 **	-39.81 **	-40.66 **	-56.45 **	11.78 **	6.99	-10.97 *	-18.18 **	3.64	4.32	-2.35	-5.70 *	15.53 **	7.16 **	-2.64	-16.95 **
$L_5 \times T_2$	34.10 **	12.62 *	-42.86 **	-47.06 **	-8.17	-15.11 **	10.67	-0.86	-8.37 **	-9.22 **	-10.52 **	-12.51 **	-2.30	-10.76 **	2.26	-21.50 **
$L_5 \times T_3$	19.80 **	14.56 *	84.31 **	48.42 **	9.87 *	-2.90	17.69 **	14.22 *	1.89	1.89	59.36 **	5.23 **	24.39 **	16.15 **	21.38 **	-4.13
$L_6 \times T_1$	-27.83 **	-36.15 **	83.87 **	83.87 **	18.21 **	-4.34	-45.48 **	-50.99 **	2.99	-11.39 **	5.48	-22.91 **	1.54	1.09	33.09 **	1.81
$L_6 \times T_2$	34.00 **	3.08	95.83 **	51.61 **	11.93	-6.75	0.62	-7.85	1.84	-13.57 **	16.22 **	-14.37 **	-10.00 **	-11.10 **	156.54 **	119.77 **
$L_6 \times T_3$	-14.29 **	-26.15 **	18.72 **	4.84	34.06 **	16.41 *	-16.36 **	-16.83 **	-24.86 **	-35.74 **	37.44 **	13.16 *	1.90	0.73	117.78 **	92.97 **
$L_7 \times T_1$	34.78 **	24.00 **	0.00	-15.32 **	19.62 **	3.72	20.74 **	-8.19	-7.86 **	-10.99 **	-12.71 **	-19.21 **	-6.29 **	-6.54 *	69.53 **	17.55 **
$L_7 \times T_2$	14.29 *	4.76	-45.45 **	-51.16 **	42.67 **	27.74 **	62.68 **	45.19 **	-12.73 **	-17.01 **	-19.31 **	-24.44 **	-1.71	-3.08	189.56 **	186.29 **
$L_7 \times T_3$	2.25	-3.19	-50.28 **	-52.63 **	23.41 **	15.67 *	-32.60 **	-44.05 **	-6.95 **	-10.72 **	51.20 **	2.13	13.33 **	12.22 **	67.28 **	62.70 **
$L_8 \times T_1$	4.76	-1.00	100.00 **	65.32 **	9.87	-7.23	-21.37 **	-34.44 **	-21.93 **	-22.64 **	-33.09 **	-34.01 **	21.94 **	6.77 **	17.53 **	9.99 *
$L_8 \times T_2$	50.94 **	34.83 **	8.72	0.00	-7.41	-19.36 **	16.87 **	16.50 *	-17.35 **	-17.96 **	-57.50 **	-57.55 **	27.52 **	10.07 **	-15.90 **	-39.71 **
$L_8 \times T_3$	32.24 **	28.72 **	106.82 **	91.58 **	-7.89	-16.16 *	-26.33 **	-31.98 **	8.65 **	8.83 **	38.11 **	9.74 **	15.59 **	1.83	-40.24 **	-56.09 **
$L_9 \times T_1$	-28.50 **	-30.84 **	90.35 **	75.00 **	-0.92	-18.60 **	-47.70 **	-55.09 **	7.54 **	26.40 **	-15.48 **	-38.35 **	2.21	1.96	-29.68 **	-30.81 **
$L_9 \times T_2$	18.64 **	-1.87	-34.88 **	-46.15 **	-17.27 **	-29.97 **	10.46	6.29	12.31 **	-11.68 **	17.15 **	13.87 **	-6.75 **	-8.07 **	20.00 **	-18.04 **
$L_9 \times T_3$	10.45	3.74	21.61 **	16.35 *	-6.18	-17.15 **	-26.30 **	-29.62 **	14.33 **	-9.47 **	125.92 **	86.50 **	4.34 *	3.35	-28.12 **	-49.83 **
$L_{10} \times T_1$	-2.88	-6.48	-21.78 **	-36.29 **	-4.64	-12.26 *	-8.57	-15.83 **	-13.89 **	-16.75 **	-57.03 **	-59.42 **	-4.32	-6.14 *	-60.81 **	-60.87 **
$L_{10} \times T_2$	-44.94 **	-54.63 **	-20.55 *	-25.64 **	9.19	4.01	3.24	-7.66	3.72	-1.30	9.68 **	4.84	6.40 **	2.68	67.11 **	15.04 **
$L_{10} \times T_3$	-50.50 **	-53.70 **	4.05	-5.26	20.21 **	20.16 **	12.23 *	8.73	0.87	4.82 *	56.12 **	4.29	3.65	2.39	39.07 **	-2.10

Table 5: Cont……

Character	Cob Weight (NI)		Cob Weight (IMS)		100 Seed Weight (NI)		100 Seed Weight (IMS)		No of Kernal rows per Cob (NI)		No of Kernal rows per Cob (IMS)		Single Plant Yield (NI)		Single Plant Yield (IMS)	
HYBRIDS	di	Dii	di	dii	di	dii	di	dii	di	dii	di	dii	di	dii	di	dii
$L_1 \times T_1$	-15.39 *	-21.56 **	44.90 **	41.15 **	10.38**	2.65 **	5.50 **	29.27 **	-7.32	-13.96 **	21.99 **	26.85 **	-17.33 *	-18.89 *	56.17 **	48.16 **
$L_1 \times T_2$	-16.55 *	-17.42 *	10.50	-9.57	9.50	8.42	33.56 **	6.86	-20.41 **	-27.17 **	-18.76 **	-24.23 **	-19.90 *	-23.13 **	8.73	-14.19 *
$L_1 \times T_3$	5.72	-8.70	26.05 **	20.27 *	27.81 **	18.66 *	104.86 **	98.65 **	-15.32 **	-20.75 **	15.07 **	18.70 **	-4.88	-16.29 **	52.65 **	48.80 **
$L_2 \times T_1$	6.96	6.59	10.88	9.77	-8.24	-10.73 **	21.61 *	7.43	0.68 *	-2.64**	-5.88	-19.07 **	-16.20 *	-17.07	11.23	10.15
$L_2 \times T_2$	17.31 *	7.36	7.51	-9.41	10.35	-0.83	9.29	-7.40	11.11 *	9.09	-10.11 *	-23.08 **	4.63 **	3.37**	19.35 *	2.60 *
$L_2 \times T_3$	-13.88	-20.01 *	-10.99	-12.00	2.48	-0.12	-7.38	-16.09	-1.58	-5.63	-10.90 *	-21.95 **	-33.59 **	-40.01 **	-20.35	-21.80
$L_3 \times T_1$	38.91 **	29.08 **	28.24 **	19.50 *	-10.71	-10.82	8.11	-2.97	18.00 **	14.10 *	-8.58	-17.12 **	12.57	-1.61	36.69 **	28.89 *
$L_3 \times T_2$	-9.01	-21.84 **	-7.89	-18.14 **	21.58 **	12.16**	11.11	-4.44	1.39	-0.45	-17.70 **	-25.77 **	-10.68	-20.39 *	-5.82	-18.65 *
$L_3 \times T_3$	8.33	7.88	24.00 **	17.90 *	16.96 **	16.61 **	11.53	-0.56	-6.55**	-10.39 **	-5.05	-12.20 *	9.42	6.51 *	39.06 **	27.74 *
$L_4 \times T_1$	-6.08	-14.27	25.62 **	25.05 *	-0.13	-7.03	14.63	4.75	-7.11	-7.93	-2.47	-15.56 **	0.19*	-12.76 **	34.47 **	34.32 *
$L_4 \times T_2$	5.25	-11.03	-24.55 **	-37.17 **	-9.45	-21.83 *	-27.85 **	-36.88 **	8.80	8.07	1.34	12.69 *	-5.12	-15.75*	-26.30 **	-39.45 **
$L_4 \times T_3$	51.62 **	49.33 **	32.05 **	28.69 **	36.30 **	27.10 **	46.52 **	28.37 **	4.41 **	2.60 **	13.82 **	23.98 **	21.34 *	17.62	57.26 **	53.10 **
$L_5 \times T_1$	-20.59 **	-23.36 **	-14.40	-25.06 **	-9.34	-21.10 **	-8.55	-17.46 *	-14.94 **	-18.50 **	-16.82 **	-28.79 **	-27.26 **	-28.52 **	-20.36 *	-32.75 **
$L_5 \times T_2$	9.09	3.58	-19.94 **	-24.18 **	-25.62 **	-30.14 **	-37.81 **	-41.27 **	15.42 **	12.27 *	-9.71	-23.08 **	-1.83	-2.31	-26.71 **	-29.07 **
$L_5 \times T_3$	6.87	-4.24	14.33 *	1.98	12.77	-2.01	47.09 **	10.41	-8.88	-13.42 *	-5.83	-17.89 **	15.74*	13.85*	25.73 **	3.79 *
$L_6 \times T_1$	-5.47	-12.17	-9.88	-14.20	-9.54	-14.06	-25.60 **	-33.73 **	-0.46 **	-4.85**	-13.54 **	-22.96 **	-10.76 *	-20.32 *	-21.63 *	-25.38 *
$L_6 \times T_2$	9.75	-5.74	0.21	13.05**	-15.25	-25.47 **	4.02	21.17**	6.32**	3.18**	-19.74 **	-28.85 **	5.45*	-3.92**	1.00	15.21**
$L_6 \times T_3$	-7.92	-8.28	-4.78	-7.45	-9.10	-13.49	-3.28	-13.12	3.65	-1.73	14.99 **	22.76 **	-3.36 **	-3.61*	0.06	7.33
$L_7 \times T_1$	42.40 **	27.32 **	18.09 *	12.85*	-7.96	-18.40 *	18.64 *	18.11 *	21.78 **	14.54 *	5.41	-8.95	18.09**	0.98**	23.52 *	4.69 *
$L_7 \times T_2$	20.79 *	0.21	-22.61 **	-26.29 **	2.64	-1.62	7.03	2.42	13.33 *	8.18	10.51 *	5.00 *	15.12**	0.34*	-26.92 **	-29.58 **
$L_7 \times T_3$	3.21	-0.62	-4.83	-15.55 *	-23.10 **	-31.94 **	-8.74	-26.22 **	0.70	-6.06	-2.08	-13.82 **	10.55	4.97	8.42	24.13 **
$L_8 \times T_1$	13.05	0.68	20.44 *	18.34	14.94	14.80	43.25 **	23.03 **	14.74 **	11.45	0.91	-13.62 **	3.04	-15.23	23.32 *	23.04 *
$L_8 \times T_2$	-11.95	-27.22 **	-20.24 **	-32.38 **	-21.85 **	-28.07 *	-31.97 **	-43.88 **	13.36 *	11.82**	-10.16 *	-23.46 **	-20.08 *	-33.05 **	-30.05 **	-42.38 **
$L_8 \times T_3$	21.58 *	16.57	18.16 *	17.71	31.48 **	31.40 **	40.35 **	31.06 *	-7.42	-10.82	-5.83	-17.89 **	14.30 *	3.84*	22.43	18.80
$L_9 \times T_1$	13.87	10.48	-0.69	-10.11	-17.72 *	-25.33 **	-32.20 **	-41.05 **	2.20 **	-7.93**	4.99	-14.01 **	-11.41	-14.81	-6.75	-16.10
$L_9 \times T_2$	-10.70	-15.65 *	-20.54 **	-27.34 **	-27.75 **	-28.94 **	-17.17 **	-24.81 **	3.98 *	-5.00 *	-7.08	-24.23 **	-23.98 **	-25.27 **	-29.96 **	-36.75 **
$L_9 \times T_3$	24.85 **	12.41	-3.95	-11.35	-16.58 *	-24.42 **	13.38	-17.23 **	-5.08	-15.15 *	-3.90	-19.92 **	5.00*	11.86 **	-14.65	-25.08 *
$L_{10} \times T_1$	4.88	-1.25	-3.64	-21.24 **	-0.76	-11.72	11.21	0.48	-3.56	-8.00	-12.97 **	-22.96 **	-21.87 **	-21.89 *	14.61	30.90 **
$L_{10} \times T_2$	9.81	6.90	-3.96	-6.58	19.92 **	15.37	14.27 *	8.03	-8.94	-14.40 **	9.61 *	20.38 **	4.65 *	2.32*	-0.82	-2.84
$L_{10} \times T_3$	27.83 **	11.97	10.21	-8.37	19.85 *	6.44	59.62 **	19.90 **	-8.94	-12.40 *	11.26 *	19.92 **	1.58	-9.10 *	17.47	-6.94

di - relative heterosis(over mid parent) dii- heterobeltiosis (over better parent) ** significant at 1% level * significant at 5 % level; NI- Normal Irrigation IMS – Induced Moisture Stress

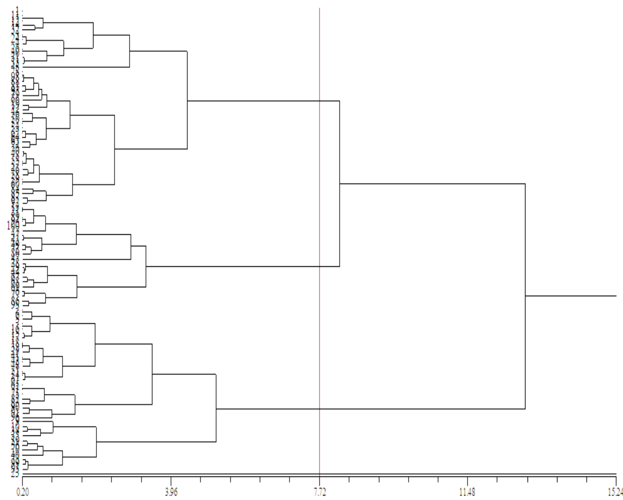

Figure 1: Dendrogram obtained by cluster analysis showing the 16 clusters which constitute the 100 genotypes Indicates the starting of each cluster where cluster numbering starts serially from the top.

desirable segregants (Frova *et al*., 1999) (Table.4). For the expression of maximum yield, all genes which contribute to yield should have a positive heterosis for the exploitation of hybrid vigor in the development of hybrids (Table. 4). The major traits which have a genetic contribution to yield showing significant effects are cob weight, 100 kernel weight, number of kernels per row, number of kernel rows per cob, single plant yield. All these traits were showing positive heterosis in the superior F1 hybrids developed. Not much variation was noticed in normal irrigated or induced moisture stress developed hybrids in terms of hybrid vigor. This has lead to the selection of a particular hybrid which performs well in both conditions. Evaluation of hybrids in F2 generation becomes necessary to consider whether a hybrid can be used on a commercial basis or could be utilized in a breeding program. The hybrids can be evaluated based on their mean value and degree of heterosis.

For cob weight, 100 kernel weight, number of kernels per row, and single plant yield the hybrid L5XT3 recorded the highest value under normal irrigated condition. This shows that genes contributing these traits were able to express better in this hybrid. The specific combining ability of this hybrid is better. While comparing the induced moisture stressed field, the variation observed is due to the impact of stress condition. In a stressed situation certain genes are expected to express well resulting in overdominance of the genes related to drought resulting in another hybrid to express better. In induced moisture stress the hybrid which performed best was L6 X T2. While comparing both hybrids L6XT2 AND L5XT3, the parents involved were different in both. For obtaining good specific combining crosses, good combiners should come together, but this is not a rule for all crosses. It is not possible to pick up a good general combiner for all the characters because the combining ability of the parents is not consistent for all the yield components (Jaiswal *et al.*, 2013 ; Akbar *et al*. 2009). Sometimes two poor combiners may yield good specific combination due to epistatic gene action. The crosses with poor combiners will yield transgressive segregants in segregating generations.

In both induced moisture stress and normal irrigation, the hybrid L5 X T3 (IBET IE 1253-8 X UMI 61) recorded positive significant values for grain yield per plant and was the best hybrid for both conditions. While considering the various traits in both conditions of induced stress and normal irrigation, the hybrid L5 X T3 expresses a positive significant value for grain yield per plant, which can happen only when the genes which contribute to maximum yield are expressed well in the hybrid along with the desirable environmental effects. The hybrid L5 X T3 (IBET IE 1253-8 X UMI 61) did not show a wide difference in grain yield of 6.4t/ha, 6t/ha for irrigated and induced stress conditions respectively. In the L5 X T3 hybrid both the parents has positively significant gca effects for most of the traits. After subsequent selection in advanced generations, the suggested crosses may be utilized to develop the inbred with better contribution towards seed yield. The understanding of gene action is essential for formulating effective procedure for the improvement of any crop species (Aminu *et al.,* 2014).

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