Research Article

Genetic evaluation of drought tolerance in maize (*Zea mays* L.) inbred lines using tolerance indices

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Abstract
Genetic evaluation based on drought tolerant indices was conducted under moisture stress and well watered conditions using 98 maize inbreds along with four checks by following RBD with two replications. STI, GMP and MP are the most appropriate indices which determine drought tolerance and they showed high heritability coupled with high genetic advance over per cent mean. STI, GMP, MP, HARM, DI and K2 exhibited positive and significant association with grain yield under stress situation. Path coefficient analysis showed that positive and direct affect of MP, SSPI, K1 and RDI on grain yield in stress thus, direct selection based on these indices could be advisable to improve drought tolerance. Mahalanobi's D^2 analysis had found out the occurrence of wide range of diversity among the inbreds selected for study. Eight different clusters were formed, in which cluster I had 69 inbreds whereas, cluster VI and VII were singletons', suggesting their uniqueness. Highest inter cluster distance was observed between cluster V and cluster VI where crossing can be recommended to develop drought tolerant heterotic hybrids. Mean of Stress tolerance index was high in cluster III it is comparable with tolerant check found in cluster V. Stress Tolerance Index was the major traits which contributed highest towards genetic diversity observed in the inbreds. Of the 98 inbreds considered for the evaluation, 30 inbreds showed minimum yield reduction (TOL) in stress condition. Among the 31 inbreds, MLB34, BLSB7-1, PDM 6572, PDM 6541and PDM 6529 were considered as tolerant based on Stress Susceptibility Index. Therefore, above study would serve the requirements for development of moisture stress tolerant hybrids by looking in to variability, character association, divergence and drought tolerant indices.

Key words
Maize, tolerant indices, diversity, variability, yield

Introduction

Maize is a major cereal crop grown for human food and feed for livestock. It also serves as raw material for agro based industries such as food, medicine and textile. Among various abiotic stress factors, drought is an important cause which can occur at any growth stage of the crop and is more sensitive to moisture stress at flowering and grain-filling periods that lead to a great yield loss with a range of 1–76% (Zarabi *et al.,* 2011). Development of plants which are highly tolerant to moisture stress can meet the demand of various industries including poultry in present days. Thus, it is necessity to identify selection indices that are able to distinguish high yielding maize line in stress situations. Selection for drought tolerance is not easy due to the happening of strong interactions between genotypes and the environment and restricted knowledge about the function and role of tolerance mechanisms.

Response of plants to moisture stress can be studied based on some selection indices, a mathematical relation between stress and non stress conditions (Fernandez, 1992). Moghaddam and Hadi-Zadeh (2002) found that stress tolerant index (STI) is an appropriate index to select tolerant maize cultivars under stressful and stress-free conditions. Khodarahmpour *et al*. (2011) reported that, indices such as, Stress Susceptibility Index (SSI), Stress Tolerant Index (STI) and

Geometric Mean Productivity (GMP) were the more accurate criteria for selection of drought tolerant genotypes. Rosielli and Hamblin (1981) demonstrated that, lower the STI, hybrid yield in normal irrigation and drought condition is close to each other or plant is resistant to drought.

In the above contest, the aim of present study was the genetic evaluation in terms of variability, characters association and divergence as well as evaluation of efficiency of drought tolerance indices in identification of lines which are agronomically superior under moisture stress situation.

Materials and methods

The present experiment was conducted at Department of Genetics and Plant Breeding, College of Agriculture, Dharwad, during Summer 2015. Evaluation was done using 98 inbreds and four checks (Bio9681-tolerant check, Super900M-suceptible check, PC3 & PC4 moderately tolerant checks) in two different experiments like, non stress and moisture stress by following Randomized Block Design with two replications. Non stress experiment was conducted by giving optimum irrigations whereas, in moisture stress field, irrigation was restricted at taseling stage to till harvest with single protective irrigation at fifteen days after taseling. Yield of five randomly selected plants of respective lines from two

experiments were calculated and mean values were considered for calculation of fourteen different drought tolerant indices such as, Stress Susceptibility Index (SSI), Relative Drought Index (RDI), Stress Tolerance Index (STI), Geometric Mean Productivity (GMP), Tolerance (TOL), Mean productivity (MP), Golden Mean (GOL), Harmonic Mean (HARM), Yield Index (YI), Drought Resistance index (DI), Yield Stability Index (YSI), Stress Susceptibility percentage (SSPI), and Modified Stress tolerance Index (Ki STI, K1 & K2) have been calculated using following formulae. $1.SSI= (1-(Ys/Yp))/(1-(\bar{Y}s/\bar{Y}p))$; $2.RDI=(Ys/Yp)/ (\bar{Y}s/\bar{Y}p)$; $3.STI=(Ys \times Yp)/(\bar{Y}p2)$; $4.GMP=\sqrt{Ys \times Yp}$; $5.TOL=Ys-Yp$; $6.MP=(Ys+Yp)/2$; $7.GOL=Yp+Ys/Yp-Ys$; $8. HARM = 2(Yp)(Ys)/Yp+Ys$; $9.YI=(Ys)/(\bar{Y}s)$; $10.DI=(Ys \times (Ys/Yp))/\bar{Y}s$; $11. YSI=Ys/Yp$; $12. SSPI =(Yp-Ys/2(\bar{Y}p)) \times 100$; $13.KiSTI, K1=Yp2/\bar{Y}p2$; $14.K2=Ys2/\bar{Y}s2$. In the above formulas , Ys, Yp, $\bar{Y}s$ and $\bar{Y}p$ represent yield under stress, yield non-stress for each cultivar, yield mean in stress and non-stress conditions for all cultivars, respectively.

Data of drought tolerant indices was used to derive Genetic variability parameters such as, mean, Genotypic Variance (GV) and Phenotypic Variances (PV), Genotypic and Phenotypic coefficient of variances (GCV and PCV), Heritability (h^2) and Genetic Advance over percent Mean (GAM). Correlations and Path coefficients among yield and drought tolerant indices along with genetic diversity that exits among the inbreds were derived using WINDOSTAT v8.0 software and drawn the following results.

Results and discussion
Analysis of variance showed that grain yield per plant in non-stress and stress condition, and all drought tolerant indices were statistically significant at 5% level of significance, which confirmed the existence of high variation among inbred lines studied for drought tolerance and the inbreds considered were statistically significant with each other, similar results were also reported by Jahra and Jahad (2011). Genetic variability parameters shown in table 1 infers, narrow range of difference between genotypic and phenotypic variability for grain yield in moisture stress situation (948.71; 1050.37) similarly, for SSI (0.23; 0.43) and STI (1.99; 2.18). PCV was more compare to GCV for all the indices suggesting the influence of environment on the index. Grain yield in stress and other indices showed higher PCV while, RDI (18.49) and YSI (18.48) showed medium GCV.

Broad sense heritability of the traits considered was high (>60%) for all indices, which infers selection based on these indices can improve respective indices. Genetic advance as percent mean for grain yield (74.98%), SSI (72.60%), TOL

(89.42) and YSI (95.43) was high inferring high expression both additive and dominant effects.

To determine the most desirable stress tolerant criterion, the correlation coefficient between grain yield per plant in moisture stress and indices of stress tolerance were calculated and presented in table 2. A strong positive and significant association with grain yield in moisture stress was exhibited by RDI (0.602**), GMP (0.986**), MP (0.989**), GOL (0.603**), HARM (0.992**), DI (0.981**), YSI (0.602**), K1 (0.901**) and K2 (0.971**), it confirms selection based on these indices would enhance drought tolerance. Positive and highly significant correlation between grain yield under moisture stress and STI (0.960**) confirms selection for high STI should give positive responses in all stages of drought stress (Fernandez 1992).

Analysis of cause and effect relationship between dependent and independent variables determine the nature of relationship between the variables. Since, correlation coefficients may give misleading results because the correlation between two variables may be due to third factor. The traits with high positive correlation and but high direct effects are expected to be useful as selection criteria in selection programme. Highest positive and significant direct effect on grain yield in moisture stress situation was exhibited by MP (2.261) and SSPI (O.204) followed by RDI (0.003), K1 (0.004) and K2 (0.004) each (Table 3) thus, selection can be done theses indices for improvement of drought tolerance in the maize inbreds.

Development of superior hybrids for moisture stress situation requires selection of superior inbreds which possess higher directional dominance, genetic diversity and allelic differentiation for most of the traits. In the present study we identified seven different clusters (Fig. 1) out of 98 inbreds and four checks based on drought tolerant indices and yield in stress as well as non stress plots. Cluster one had highest number (69) of lines followed by cluster two with 17 lines whereas, cluster six (PDM 4511) and seven (PDM 4121) were solitary showing highest divergence among the inbreds studied. Selection of parent for hybrid breeding can be possible based on inter cluster distance (Table 4), in this contest, highest inter cluster distance was observed between cluster five and six (13.64) followed by cluster four and five (12.88), it means hybridization between these two clusters can give highly heterotic drought tolerant hybrids.

Means of all indices and yield across seven clusters has been depicted in table 5. According to Fernandez (1992), higher values of STI, GMP, MP and lower value of SSI are indicative of drought

stress tolerance. In this study inbreds of cluster three (PDM-6547, PDM-6572, PDM-6528, HKI-163, MLB34, PC3 and PC4) had exhibited lowest mean value for Stress Susceptibility Index (0.53) therefore, lines from this clusters can serve as source for drought tolerance. Higher mean values of STI (7.44), GMP (159.23) and MP (231. 69) was noted in the cluster five consisting of checks for moderate drought tolerance (Super 900 M and Bio 9681) similarly higher and comparable mean values on STI (4.51), GMP (123.20) and MP (180.63) were observed for cluster three (PDM-6547, PDM-6572, PDM-6528, HKI-163, MLB34, PC3 and PC4), showing comparable drought tolerance as like checks.

Emphasis should be laid on characters contributing maximum D^2 values for choosing the cluster for the purpose of further selection and choice of parents for hybridization. The contribution of each character towards total genetic diversity was shown in Fig 2. Highest contribution towards divergence in this regard was put forth by grain yield per plant in moisture stress situation (40.21%) followed by Stress Tolerance Index (16.13%) whereas, least contribution towards divergence was exerted by TOL (0.00%) and RDI (0.89%).

Thirty diverse inbreds has been selected based on minimum yield reduction (TOL) under moisture stress, in comparison with non stress yield data and moderately drought tolerant checks yield data. Drought tolerant indices for these thirty inbreds have been showed in table 6. More index value of GOL indicates that yield value in drought pressure is close to yield potential and the studied inbred was damaged lesser. Inbreds PDM 6521 (27.57), PDM 6541(33), PDM 6547 (27), MLB 34 (38.57) and BLB7-1 (31.52) had showed high values of GOL. These results were supported by Moradi *et al.* (2012). Lower TOL index shows most tolerant inbreds, in our study, inbred MLB 34 (9) and BLB7-1 (6.34) had low TOL index suggesting their tolerance to moisture stress. Stress Susceptibility Index value in between 0.1-0.6 is considered as tolerant thus, inbreds MLB34 (0.28), BLSB7-1 (0.31), PDM 6572 (0.37), PDM 6541 (0.22) and PDM 6529 (0.29) were considered as moisture stress tolerant. Similar findings were also reported by Zahra Khodarahmpour and Jahad (2011).

The inbred considered for the study had showed occurrence of wide variability and genetic divergence, a prime necessary for and breeding or crop improvement activities. Drought tolerant indices are unique because they are not or least influenced by environmental factors thus; selections based on such indices would give most successful results. Based on lower SSI and higher STI, GMP and MP as well as minimum yield

reduction in stress field (TOL), we would suggest inbreds PDM 6521, PDM 6541, PDM 6547, MLB 34, BLB7-1, BLSB7-1, PDM 6572 and PDM 6529 would be best source for development drought tolerant varieties, synthetics and Single Cross hybrids.

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Table 1. Genetic variability parameters of drought tolerant indices and yield in stress as well as non stress condition

Genetic parameter	GYPP (MS)	GYPP (ww)	SSI	RDI	STI	GMP	TOL	MP	GOL	HARM	YI	DI	YSI	SSPI	K1	K2
Mean	58.40	80.42	1.02	0.99	1.62	67.91	22.02	98.61	11.32	66.53	1.00	0.77	0.72	13.69	1.16	1.26
PV	889.74	1050.37	0.43	0.06	2.18	920.20	271.35	1986.71	128.14	942.65	0.26	0.24	0.03	104.89	0.87	1.63
GV	807.57	948.71	0.23	0.034	1.99	854.00	158.01	1843.88	44.80	871.28	0.23	0.20	0.01	61.08	0.78	1.46
PCV	51.07	40.30	64.49	24.98	91.22	44.67	74.80	45.20	100.01	46.14	51.06	64.24	25.01	74.80	80.75	101.60
GCV	48.66	38.30	47.67	18.49	87.26	43.03	57.08	43.54	59.14	44.36	48.64	59.07	18.48	57.08	76.45	96.19
h² (Broad Sense)	0.90	0.90	0.54	0.54	0.91	0.92	0.58	0.92	0.35	0.92	0.90	0.84	0.54	0.58	0.89	0.89
Gen.Adv as % of Mean 5%	95.50	74.98	72.60	28.20	171.97	85.40	89.74	86.42	72.04	87.86	95.43	111.91	28.12	89.73	149.10	187.61

Table 2. Correlation coefficients between yield per plant in stress and among the drought tolerant indices in maize inbreds

Traits*	SSI	RDI	STI	GMP	TOL	MP	GOL	HARM	YI	DI	YSI	SSPI	K1	K2	GYPP (MS)
GYPP (ww)	-0.239	0.240*	0.932**	0.967**	0.386**	0.962**	0.316**	0.953**	0.913**	0.823**	0.240	0.386**	0.970**	0.893**	0.913**
SSI	1.000	-1.000	-0.445*	-0.470**	0.772**	-0.483**	-0.907**	-0.510**	-0.601**	-0.723**	-1.000	0.772**	-0.247	-0.538**	-0.601**
RDI		1.000	0.446**	0.471**	-0.771**	0.485**	0.909**	0.511**	0.602**	0.724**	1.000	-0.771**	0.248	0.539**	0.602**
STI			1.000	0.970**	0.113	0.970**	0.462**	0.970**	0.960**	0.918**	0.446**	0.113	0.972**	0.991**	0.960**
GMP				1.000	0.139	0.999**	0.511**	0.998**	0.986**	0.938**	0.471**	0.139	0.948**	0.960**	0.986**
TOL					1.000	0.122	-0.649**	0.092	-0.023	-0.200	-0.772**	1.000	0.339**	-0.006	-0.023
MP						1.000	0.530**	0.999**	0.989**	0.945**	0.484**	0.122	0.945**	0.963**	0.989**
GOL							1.000	0.540**	0.629**	0.760**	0.906**	-0.649**	0.287**	0.559**	0.630**
HARM								1.000	0.992**	0.952**	0.511**	0.092	0.937**	0.965**	0.992**
YI									1.000	0.981**	0.602**	-0.023	0.902**	0.971	1.000
DI										1.000	0.724**	-0.200	0.819**	0.952**	0.981**
YSI											1.0000	-0.772**	0.248	0.539**	0.602**
SSPI												1.000	0.339**	-0.006	-0.023
K1													1.000	0.936**	0.901**
K2														1.000	0.971**

*, ** Significant at 5 and 1 per cent level, respectively   *Abbreviated forms of indices shown in Materials and Method

Table 3. Direct (Diagonal) and indirect effects (off diagonal) of independent variables on drought tolerant indices in maize inbreds

Traits*	GYPP (WW)	RDI	STI	GMP	MP	GOL	HARM	YI	DI	YSI	SSPI	K1	K2
GYPP (ww)	**-1.307**	-0.315	-1.219	-1.264	-1.2583	-0.4136	-1.2462	-1.1932	-1.0767	-0.3143	-0.5048	-1.2685	-1.1674
RDI	0.001	**0.003**	0.001	0.002	0.002	0.003	0.002	0.002	0.002	0.003	-0.002	0.001	0.002
STI	-0.007	-0.003	**-0.007**	-0.007	-0.007	-0.003	-0.007	-0.007	-0.007	-0.003	-0.001	-0.007	-0.007
GMP	-0.016	-0.008	-0.016	**-0.017**	-0.017	-0.009	-0.017	-0.016	-0.016	-0.008	-0.002	-0.016	-0.016
MP	2.177	1.097	2.194	2.260	**2.261**	1.200	2.259	2.236	2.137	1.096	0.278	2.136	2.177
GOL	0.000	0.000	0.000	0.000	0.000	**0.000**	0.000	0.000	0.000	0.000	0.000	0.000	0.000
HARM	-0.005	-0.003	-0.005	-0.005	-0.005	-0.003	**-0.005**	-0.005	-0.005	-0.003	-0.001	-0.005	-0.005
YI	-0.007	-0.005	-0.007	-0.008	-0.008	-0.005	-0.008	**-0.008**	-0.008	-0.005	0.000	-0.007	-0.008
DI	-0.008	-0.007	-0.008	-0.009	-0.009	-0.007	-0.009	-0.009	**-0.009**	-0.007	0.002	-0.008	-0.009
YSI	-0.001	-0.004	-0.002	-0.002	-0.002	-0.003	-0.002	-0.002	-0.003	**-0.004**	0.003	-0.001	-0.002
SSPI	0.079	-0.157	0.023	0.028	0.025	-0.132	0.019	-0.005	-0.041	-0.157	**0.204**	0.069	-0.001
K1	0.003	0.001	0.004	0.003	0.003	0.001	0.003	0.003	0.003	0.001	0.001	**0.004**	0.003
K2	0.003	0.002	0.004	0.004	0.004	0.002	0.004	0.004	0.003	0.002	0.000	0.003	**0.004**
GYPP(MS)	0.913	0.603	0.961	0.987	0.989	0.630	0.993	1.000	0.982	0.602	-0.024	0.902	0.971
Partial R²	-1.193	0.002	-0.007	-0.016	2.236	0.000	-0.005	-0.008	-0.009	-0.002	-0.005	0.003	0.004

Rsquare = 1.0000, residual effect =sqrt(1- 1.0000)   *Abbreviated forms of indices shown in Materials and Method

Table 4. Intra (Diagonal) and inter cluster (Above diagonal) distances based on Mahalanobis D^2 mean values

Groups	Group. 1	Group. 2	Group. 3	Group. 4	Group. 5	Group. 6	Group. 7
Group.1	**3.85**	5.96	6.33	7.05	11.53	7.38	10.30
Group.2		**4.00**	9.23	8.17	12.88	5.83	7.27
Group.3			**3.30**	8.77	7.37	10.04	12.54
Group.4				**5.72**	12.78	8.73	12.04
Group.5					**2.42**	13.64	14.42
Group.6						**0.00**	8.17
Group.7							**0.00**

Table 5. Cluster means for the various drought tolerant indices considered for diversity analysis

Traits*	GYPP(WW)	GYPP(MS)	SSI	RDI	STI	GMP	TOL	MP	GOL	HARM	YI	DI	YSI	SSPI	K1	K2
Group.1	59.88	79.98	0.91	1.03	1.49	68.84	20.09	99.87	12.14	67.80	1.03	0.80	0.75	12.49	1.05	1.16
Group.2	26.14	44.92	1.30	0.89	0.35	33.74	18.79	48.60	7.37	32.12	0.45	0.29	0.64	11.68	0.35	0.21
Group.3	113.81	133.63	0.53	1.18	4.51	123.20	19.81	180.63	19.44	122.69	1.95	1.67	0.86	12.32	2.80	3.85
Group.4	38.73	105.13	2.31	0.51	1.21	63.06	66.39	91.30	2.26	55.62	0.66	0.26	0.37	41.28	1.73	0.49
Group.5	142.81	177.75	0.71	1.11	7.44	159.23	34.94	231.69	10.38	158.18	2.45	1.98	0.81	21.72	4.89	6.00
Group.6	18.50	57.50	2.47	0.45	0.31	32.56	39.00	47.25	1.97	27.91	0.32	0.10	0.32	24.25	0.52	0.10
Group.7	11.00	18.25	1.46	0.83	0.06	14.17	7.25	20.13	4.05	13.72	0.19	0.12	0.60	4.51	0.06	0.04

*Abbreviated forms of indices shown in Materials and Method

Table 6. Drought tolerant indices of top 31 inbreds selected based on minimum yield reduction in moisture stress situation

INBRED	GYPP(WW)	GYPP(MS)	SSI	RDI	STI	GMP	TOL	MP	GOL	HARM	YI	DI	YSI	SSPI	K1	K2
PDM-4061	80.50	118.50	1.17	0.94	2.80	97.67	38.00	139.75	05.24	95.87	1.38	0.94	0.68	23.63	2.17	1.90
PDM-4191	85.00	96.50	0.44	1.21	2.41	90.55	11.50	133.25	17.58	90.34	1.46	1.28	0.88	07.15	1.44	2.13
PDM-4201	57.00	88.00	1.28	0.89	1.47	70.80	31.00	101.00	04.78	69.13	0.98	0.63	0.65	19.27	1.20	0.95
PDM-4211	78.00	97.00	0.71	1.11	2.22	86.92	19.00	126.50	10.30	86.35	1.34	1.08	0.80	11.81	1.46	1.79
PDM-4491	62.00	89.50	1.12	0.95	1.63	74.48	27.50	106.75	05.55	73.23	1.06	0.74	0.69	17.10	1.24	1.13
PDM-4791	67.50	83.50	0.69	1.12	1.65	75.04	16.00	109.25	10.37	74.58	1.16	0.94	0.81	09.95	1.08	1.34
PDM-6505	59.50	99.50	1.47	0.82	1.73	76.68	40.00	109.25	04.30	73.99	1.02	0.63	0.60	24.87	1.53	1.06
PDM-6508	54.50	63.00	0.49	1.19	1.01	58.59	8.50	86.00	14.04	58.44	0.93	0.81	0.87	05.28	0.62	0.88
PDM-6515	76.00	102.00	0.93	1.02	2.28	88.04	26.00	127.00	06.87	87.08	1.30	0.97	0.74	16.17	1.61	1.70
PDM-6516	82.00	122.50	1.21	0.92	2.94	100.19	40.50	143.25	05.12	98.17	1.40	0.94	0.67	25.18	2.32	1.98
PDM-6518	62.00	70.68	0.45	1.21	1.28	66.19	8.68	97.34	15.82	66.04	1.06	0.93	0.88	05.39	0.77	1.13
PDM-6528	112.00	136.00	0.64	1.13	4.47	123.42	24.00	180.00	10.33	122.84	1.92	1.58	0.82	14.92	2.86	3.68
PDM-6529	96.50	104.50	0.29	1.27	3.00	100.41	8.00	148.75	27.57	100.32	1.65	1.53	0.92	04.97	1.71	2.78
PDM-6541	87.00	92.50	0.22	1.29	2.36	89.71	5.50	133.25	33.00	89.66	1.49	1.40	0.94	03.42	1.32	2.22
DM-6547	131.00	148.50	0.42	1.22	5.70	139.36	17.50	205.25	27.75	138.98	2.24	1.99	0.89	10.88	3.42	5.03
PDM-6547	116.50	131.50	0.41	1.22	4.51	123.77	15.00	182.25	16.70	123.54	1.99	1.77	0.89	09.33	2.68	3.99
PDM-6550	53.88	72.00	0.94	1.02	1.16	62.19	18.13	89.88	07.54	61.46	0.92	0.70	0.74	11.27	0.81	0.88

Table 6. Contd.,

INBRED	GYPP(WW)	GYPP(MS)	SSI	RDI	STI	GMP	TOL	MP	GOL	HARM	YI	DI	YSI	SSPI	K1	K2
PDM-6554	81.67	108.50	0.89	1.04	2.60	94.09	26.84	135.92	07.47	93.11	1.40	1.06	0.76	16.68	1.83	1.96
PDM-6563	94.50	110.50	0.49	1.19	3.08	102.07	16.00	149.75	22.83	101.65	1.62	1.40	0.87	09.95	1.92	2.62
PDM-6567	74.50	85.00	0.45	1.21	1.86	79.52	10.50	117.00	21.31	79.30	1.28	1.12	0.88	06.53	1.12	1.64
PDM-6571	77.50	90.00	0.50	1.19	2.04	83.47	12.50	122.50	16.68	83.19	1.33	1.15	0.86	07.77	1.25	1.76
PDM-6572	118.00	131.50	0.37	1.24	4.56	124.55	13.50	183.75	20.39	124.36	2.02	1.81	0.90	08.39	2.69	4.09
PDM-6573	83.50	105.00	0.75	1.09	2.58	93.63	21.50	136.00	08.76	93.02	1.43	1.14	0.79	13.37	1.71	2.05
PDM-6576	48.00	97.00	1.84	0.68	1.36	68.20	49.00	96.50	02.98	64.17	0.82	0.41	0.50	30.47	1.46	0.68
MLB-28-1	68.00	96.50	1.08	0.97	1.93	80.97	28.50	116.25	05.90	79.71	1.16	0.82	0.70	17.72	1.44	1.37
MLB33-1	73.50	110.50	1.22	0.92	2.39	90.12	37.00	128.75	05.00	88.27	1.26	0.84	0.67	23.00	1.90	1.59
MLB34	110.50	119.50	0.28	1.27	3.89	114.88	9.00	170.25	38.57	114.75	1.89	1.75	0.92	05.60	2.21	3.62
BLSB7-1	65.67	72.00	0.31	1.26	1.39	68.74	6.34	101.67	31.52	68.65	1.12	1.03	0.92	03.94	0.81	1.27
BLSB8-1	100.00	117.50	0.55	1.17	3.45	108.29	17.50	158.75	16.76	107.83	1.71	1.47	0.85	10.88	2.14	2.97
HKI-163	110.00	131.00	0.51	1.18	4.32	119.87	21.00	175.50	23.90	119.25	1.88	1.60	0.86	13.06	2.77	3.59

*Abbreviated forms of indices shown in Materials and Method

Figure 1. Touchers method of clustering pattern of 98 inbreds and four checks considered for diversity analysis in maize inbreds

Clustering by Tocher Method

CLUSTER 1: PDM-6508, MLB-28-1, PDM-6515, MLB-33-1, PDM-6505, PDM-4491,PDM-4201, PDM-6565, BLSB-4, PDM-6561, PDM-6549, PDM-6507, PDM-4791, PDM-4641, PDM-4011, PDM-6550, PDM-6560, PDM-6510, PDM-4381, BLSB12-1, PDM-4591, PDM-4031, PDM-4741, PDM-6555-2, PDM-6559, PDM-4001, PDM-6567, PDM-6564, PDM-6508, PDM-4721, PDM4731-2, PDM-4231, PDM-4171, PDM-4091, BLSB-7-1, PDM-6535, PDM-6556, PDM-6571, PDM-6576, MBSB3-1, PDM-6553, PDM-4161, PDM-4351, PDM-4281, PDM-4471, PDM-6571, PDM-6505, PDM-6546, PDM-4191, PDM-4211, PDM-6573, PDM-6554, PDM-6518, PDM-6541, BML-10, PDM-6566, PDM-4061, PDM-4611, PDM-6548, PDM-6574, PDM-6563, PDM-6514, PDM-

CLUSTER 2: PDM-4111, PDM-4341, PDM-6552, PDM-4701, PDM-4661, PDM-6558, PDM-6542, PDM-7071, PDM-4041, PDM-6522, PDM-4711, PDM-6503, PDM-4691-1, PDM-4311, PDM-4321, PDM-4241 and PDM-6506

CLUSTER 3: PDM-6547-2, PDM-6572, PDM-6528, HKI-163, MLB34, PC3, PC4 and PDM-6547-1

CLUSTER 4: PDM-4511, PDM-6543, MLB-32-1 and PDM-6544

CLUSTER 5: SUPER 900M and Bio9618 (check hybrids)
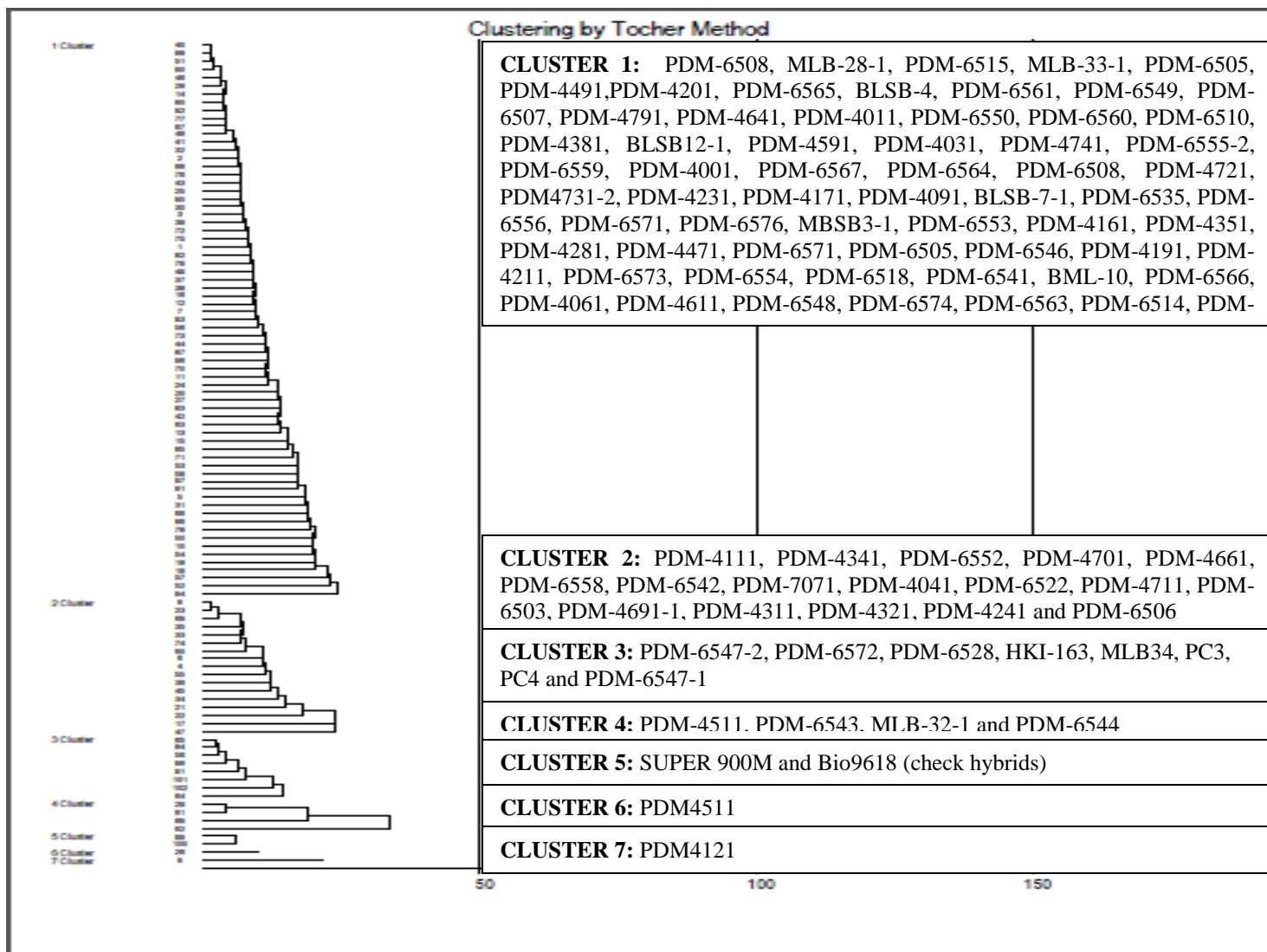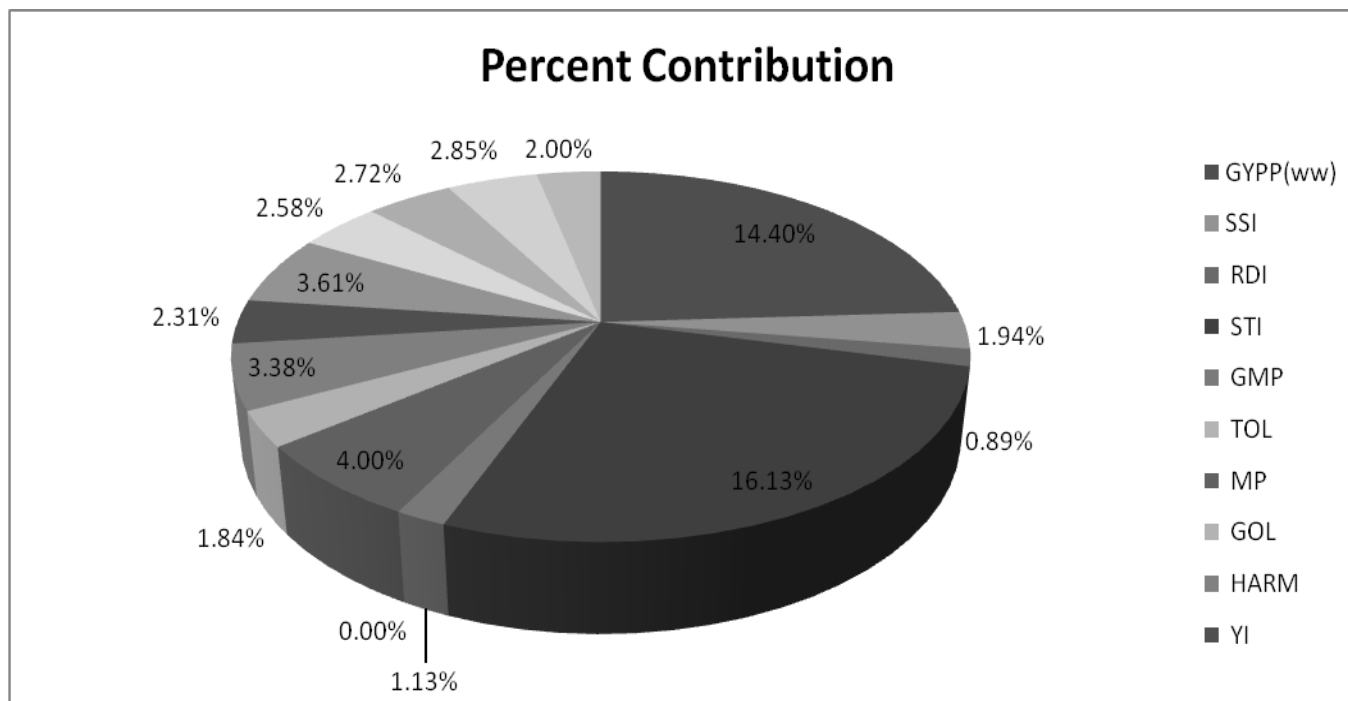
CLUSTER 6: PDM4511

CLUSTER 7: PDM4121

Fig. 2. Per cent contribution of various drought tolerant indices and yield parameters towards divergence in the maize inbreds

GYPP (WW)- Grain Yield Per Plant in well watered experiment; SSI- Stress Susceptibility Index; RDI- Relative Drought Index; STI-Stress Tolerance Index; GMP- Geometric Mean Productivity; TOL- Tolerance; MP-Mean Productivity; GOL- Golden Mean; HARM- Harmonic Mean; YI- Yield Index