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Research Article

Evaluation of drought tolerance indices for identification of drought tolerant and susceptible genotypes in wheat (*Triticum aestivum* L.)

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Abstract
This experiment was designed to identify the drought tolerant and susceptible genotypes in wheat genotypes collected from different wheat breeding centre of India. The experiment was conducted in alpha lattice design under stress and non-stress conditions to estimate the drought tolerance indices. Nine drought tolerance viz., Tolerance index (TOL), Mean productivity (MP), Harmonic mean (HM), Stress susceptibility index (SSI), Yield index (YI), Relative drought index (RDI), Grain yield per plant under potential condition (Y_p), Grain yield per plant under stress condition (Y_s) were calculated. The indices were estimated based on grain yield under stress condition (Ys) and non-stress condition (Yp). These indices were subjected for analysis of variance, correlation coefficient analysis, cluster analysis. SSI is suggested as useful indicator for wheat breeding where the stress is severe; while MP, TOL and HM are suggested if the stress is less severe. Based on grain yield per plant twenty-one tolerant genotypes and eleven susceptible genotypes were identified. Identified tolerant and susceptible genotypes can be used for the development of mapping populations to identify QTLs for drought tolerance in wheat (*Triticum aestivum* L.).

Key words
Yield traits, Drought tolerance indices, Wheat (*Triticum aestivum* L.)

INTRODUCTION

Wheat is one of the most important cereal crop in terms of production and area. It has been grown in a wide range of arid and semi-arid areas, where drought occurs frequently because of rainfall fluctuations in rainfed regions (Mardeh *et al.* 2006), and water scarcity in irrigated regions. Drought stress tolerance is a complex trait that is obstructed by low heritability and deficiency of successful selection approaches. In addition, drought tolerance mechanism should be identified during the development of new cultivars in order to increase the productivity (Rajaram *et al.* 1996). Stable yield performance of genotypes under both favorable and drought stress conditions is vital for plant breeders to identify drought tolerant genotypes. Moreover, high-yielding genotypes under optimum conditions may not be drought tolerant; therefore, many studies preferred the selection under stress and non-stress conditions.

In wheat greater genetic variability can be explored with germplasm from its centres of origin and diversity.

In addition to cultivated wheat varieties and breeding lines, extensive variability for drought tolerance remains within wild relatives and landraces (Dodig *et al.* 2012). Manipulation of this diversity to improve drought tolerance among genotypes may be achieved through genetic modification and selection for adaptive mechanisms including drought escape, dehydration avoidance, and dehydration tolerance (Blum, 2011). Grain yield and its contributing traits are two important selection criteria in moisture deficit conditions. Drought stress reduces the grain yield and an average yield loss of 17% to 70% in grain yield has been estimated due to drought stress (Nouri-Ganbalani *et al.* 2011). An understanding of yield components of a wheat crop in a particular environment is the key for a successful breeding program. Yield component traits, such as days to heading, days to anthesis, days to maturity, grain filling duration, spikelets per spike, grains per spike, grain weight per spike (g), 1000-grain weight (g), grain yield per plant (g) influence the tolerance to drought in wheat (Passioura, 1977).

Drought is one of the most damaging abiotic stresses affecting agriculture. It is an important abiotic factor affecting the yield and yield stability of food cereals and acts simultaneously on many traits leading to a decrease in yield (Zhang *et al.* 2006). Breeding for tolerance to drought is complicated by the lack of fast, reproducible screening techniques and the inability to routinely create defined and repeatable water stress conditions where large populations can be evaluated efficiently (Ramirez and Kelly, 1998). Loss of yield is the main concern of plant breeders and they hence emphasize on yield performance under stress conditions. Thus, drought indices which provide a measure of drought based on loss of yield under drought conditions in comparison to normal conditions have been used for screening drought-tolerant genotypes (Mitra, 2001). Selection of wheat genotypes with better adaptation to water stress should increase the productivity of rainfed wheat (Rajaram, 2001). Several researchers have used different methods to evaluate genetic differences in drought tolerance. Drought susceptibility of a genotype is often measured as a function of the reduction in yield under drought stress (Ramirez and Kelly, 1998). Many studies have used drought indices to select stable genotypes according to their performance under non-stress and stress conditions (Mursalova *et al.* 2015). Several selection criteria have been proposed to select genotypes based on their performance in stress and non-stress environments. Fischer *et al.* (1998) suggested that the relative drought index (RDI) is a positive index for indicating stress tolerance. Rosielle and Hamblin (1981) defined tolerance index (TOL) as the differences in yield between stress and non-stress conditions and mean productivity (MP) as the average yield of genotypes under stress and non-stress conditions.

Drought indices which provide a measure of drought based on loss of yield under drought conditions in comparison to normal conditions have been used for screening drought tolerant genotypes (Mitra, 2001). These indices are either based on drought resistance or susceptibility of genotypes. Many studies have used drought indices to select stable genotypes according to their performance under favorable and stress conditions (Farshadfar *et al.* 2013; Mursalova *et al.* 2015). The relative yield performance of genotypes in drought stressed and non-stressed environments seems to be a common starting point in the identification of traits related to drought tolerance and the selection of genotypes for use in breeding for dry environments (Clarke *et al.* 1992). To differentiate drought resistant genotypes, several selection indices have been suggested on the basis of a mathematical relationship between non-stressed and stressed conditions (Huang, 2000). Tolerance index (TOL) Rosielle & Hamblin (1981), Mean productivity (MP) (Hossain *et al.* 1990), Harmonic mean (HM) (Kristin *et al.* 1997), Stress susceptibility index (SSI) (Fischer and Maurer, 1978), Yield Index (YI) (Lin *et al.* 1986), Yield Stability Index (YSI) (Bouslama and Schapaugh, 1984), Relative drought index (RDI) (Fischer *et al.* 1979), all of these have been employed under various conditions.

MATERIALS AND METHODS

The experiment was conducted in the experimental area of N.E. Borlaug Crop Research Centre (NEBCRC), G.B. Pant University of Agriculture and Technology. Pantnagar, Distt. U.S. Nagar, Uttarakhand during 2014-15 and 2015-16 *Rabi Season*. The Crop Research Centre is situated at 29^{0}N latitude, 79^{0}29' E longitude and at an altitude of 243.84 m above the mean sea level. Experiment was laid in the Alpha lattice design (Patterson and Williams, 1976). The randomization of 160 cultivars was done with Crop Stat v7.2 software. The design constitutes of 8x20 i.e. eight blocks each of 20 genotypes, planted in two environments; drought stress and non-stress condition with two replications. Each entry was planted two-meter-long, with three rows per plot. The plants were spaced 10 cm each other and rows were spaced 20 cm. The experimental material evaluated in two environments under drought stress and non-stress condition with two replications for 2 years 2014-15 and 2015-16. The plots were irrigated before sowing to ensure seed germination. In drought stress condition no irrigation was done during the crop season. In non-stress condition normal irrigations were given. Seventeen yield and yield contributing traits were recorded viz., Days to heading, Days to maturity, Days to anthesis, Grain filling duration, No. of tillers per plant, Flag leaf length (cm), Flag leaf width (cm), Flag leaf area (cm^2), Plant height (cm), Peduncle length (cm), Peduncle weight (g), Spike length (cm), No. of spikelets per spike, No. of grains per spike, Grain weight per spike (g), 1000-grain weight (g), Grain yield per plant (g). Analyses of variance (ANOVA) for the phenotypic data under drought stress and non-stress conditions in 2014-15 and 2015-16 crop seasons were performed using PROC GLM of SAS.

Calculations of drought tolerance indices

Drought tolerance indices were calculated using the following formulas:

1. Tolerance index (TOL) Rosielle & Hamblin (1981):

TOL = (Yp–Ys)

Yp and Ys were the yield of each cultivar under non-stressed and stressed condition, respectively.

2. Mean productivity (MP) (Hossain *et al.* 1990):

MP = (Ys+Yp)/2

Yp and Ys were the yield of each cultivar under non-stressed and stressed condition, respectively.

3. Harmonic mean (HM) (Kristin *et al.* 1997):

HM = 2(Yp*Ys)/(Yp+Ys)

Yp and Ys were the yield of each cultivar under non-stressed and stressed condition, respectively.

4. Stress susceptibility index (SSI) (Fischer and Maurer, 1978):

SSI = 1–(Ys/Yp)/SI, while SI=1–(Ȳs/Ȳp)

Whereas SI is stress intensity and Ȳs and Ȳp are the means of all genotypes under stress and well water conditions, respectively.

5. Yield Index (YI) (Lin *et al.* 1986):

YI = (Ys/Ȳs)

Ys is the yield of each cultivar under stressed condition. Ȳs is the means of all genotypes under stress.

6. Yield Stability Index (YSI) (Bouslama and Schapaugh, 1984):

YSI = (Ys/Yp)

Yp and Ys were the yield of each cultivar under non-stressed and stressed condition, respectively.

7. Relative drought index (RDI) (Fischer *et al.* 1979):

RDI= (Ys/Yp)/(Ȳs/Ȳp)

Yp and Ys were the yield of each cultivar under non-stressed and stressed condition, respectively. Ȳs and Ȳp are the means of all genotypes under stress and well water conditions, respectively.

RESULTS AND DISCUSSIONS

Analysis of variance of both years and pooled for drought tolerance indices are presented in (**Tables 1, 2 and 3**). There is a general agreement that the modern high yielding wheat cultivars are more adapted to favorable growing conditions, while old cultivars and landraces have more stable yield under drought stress conditions (Blum, 1996, Mardeh *et al.* 2006). Ceccarelli (1989) reported a 25-61% superiority of landraces over modern genotypes under stress conditions and 6-18% superiority of modern genotypes over landraces under non-stress conditions. In the present study analysis of variance results were found significant differences among genotypes for tolerance index, mean productivity, harmonic mean, stress susceptibility index, yield index, yield susceptibility index, relative drought index, grain yield per plant under stress and non-stress conditions. The similar findings were also given by (Golabadi *et al.* 2006; Fard and Sedaghat, 2013) reported significant differences for tolerance index, mean productivity, stress susceptibility index, yield susceptibility index for genotypes assessed under stress and non-stress condition.

Table 1. Analysis of variance of drought tolerance indices in wheat genotypes during 2014-15

Sources of variation	DF	TOL	MP	HM	SSI	YI	YSI	RDI	Yp	Ys
Replication	1	12.78**	2.59**	3.86**	7.35**	0.15**	0.16**	0.22**	0.03ns	11.56**
Blocks(rep)	14	0.49ns	2.05**	2.09**	0.30ns	0.03**	0.00ns	0.00ns	1.94**	2.41**
Treatments	159	0.75**	7.15**	7.42**	0.50**	0.11**	0.01**	0.01**	6.33**	8.35**
Error	145	0.45	0.27	0.28	0.20	0.00	0.00	0.00	0.32	0.44

** = Significant at 1% level, * =Significant at 5% probability level, ns = Non-Significant

Table 2. Analysis of variance of drought tolerance indices in wheat genotypes during 2015-16

Sources of variation	DF	TOL	MP	HM	SSI	YI	YSI	RDI	Yp	Ys
Replication	1	0.26ns	0.08ns	0.14ns	0.22ns	0.00ns	0.00ns	0.00ns	0.00ns	0.30ns
Blocks(rep)	14	0.96*	1.23**	1.30**	0.53**	0.02**	0.01**	0.01**	1.35**	1.60**
Treatments	159	0.90**	6.78**	7.18**	0.72**	0.11**	0.01**	0.02**	5.57**	8.44**
Error	145	0.51	0.33	0.34	0.23	0.00	0.00	0.00	0.43	0.49

** = Significant at 1% level, * =Significant at 5% probability level, ns = Non-Significant

Table 3. Pooled analysis of variance of drought tolerance indices in wheat genotypes during 2014-15 and 2015-16

Sources of variation	DF	TOL	MP	HM	SSI	YI	YSI	RDI	Yp	Ys
Treatment	159	1.31^{**}	13.72^{**}	14.40^{**}	1.06^{**}	0.23^{**}	0.02^{**}	0.03^{**}	11.51^{**}	16.59^{**}
Year	1	0.30^{ns}	16.41^{**}	17.49^{**}	0.75^{ns}	0.26^{**}	0.01^{ns}	0.02^{ns}	14.15^{**}	18.62^{**}
Rep.(Year)	2	6.52^{**}	1.34^{*}	2.00^{**}	3.78^{**}	0.08^{**}	0.08^{**}	0.11^{**}	0.01^{ns}	5.93^{**}
Blocks	7	0.77^{ns}	0.44^{ns}	0.52^{ns}	0.42^{ns}	0.01^{*}	0.00^{ns}	0.01^{ns}	0.34^{ns}	0.93^{**}
Treatment x Year	159	0.40^{ns}	0.30^{ns}	0.29^{ns}	0.19^{ns}	0.00^{ns}	0.00^{ns}	0.00^{ns}	0.47^{**}	0.33^{ns}
Error	311	0.47	0.29	0.31	0.21	0.00	0.00	0.00	0.37	0.45

** = Significant at 1% level, * =Significant at 5% probability level, ns = Non-Significant

TOL=Tolerance index, MP=Mean productivity, HM=Harmonic mean, SSI=Stress susceptibility index, YI=Yield index, RDI=Relative drought index, Y_p=Grain yield per plant under potential condition, Y_s= Grain yield per plant under stress condition

The estimates of simple correlation coefficients between nine drought tolerance indices during 2014-15 are given in (**Table 4**). The grain yield under stress condition exhibited highly significant positive correlation with yield index (1.000), harmonic mean (0.994), mean productivity (0.990), grain under potential condition (0.956), stress susceptibility index (0.782), yield susceptibility index (0.782), relative drought index (0.782). The grain yield under stress condition exhibited a highly significant negative correlation with tolerance index (-0.548). The estimates of simple correlation coefficients between nine drought tolerance indices during 2015-16 are given in (**Table 5**). The grain yield under stress condition exhibited a highly significant positive correlation with yield index (1.000), harmonic mean (0.994), mean productivity (0.991), yield under potential condition (0.954), relative drought index (0.828), stress susceptibility index (0.826), and yield susceptibility index (0.826). The grain yield under stress condition exhibited a highly significant negative correlation with tolerance index (-0.681). The estimates of pooled correlation coefficients during 2014-15 and 2015-16 between nine drought tolerance indices are given in (**Table 6**). The grain yield under stress condition exhibited a highly significant positive correlation with harmonic mean (0.966), mean productivity (0.965), yield index (0.958), yield under potential condition (0.948), stress susceptibility index (0.748), relative drought index (0.751) and yield susceptibility index (0.748). Correlation coefficient analysis showed a high positive correlation between grain yield and the drought indices. We observed that the mean productivity, geometric mean productivity and stress tolerance index are the best indices for selecting drought-tolerant lines. SSI is suggested as useful indicator for wheat breeding where the stress is severe; while MP, TOL and HM are suggested if the stress is less severe. Therefore, plant breeders should pay attention to severity of drought stress when selecting drought-tolerant wheat lines (Ali and El-Sadek, 2016). Mean productivity, yield index and yield susceptibility index were strongly correlated with yield under both conditions. Similar findings were given by (Mohammadi *et al.* 2003; Mardeh, 2006), all these parameters to be suitable for discriminating the best genotypes under stress and stress conditions. Yield susceptibility index was a more useful selection criterion to discriminate drought tolerant from drought susceptible genotypes (Mohammadi *et al.* 2010). In wheat, stress susceptibility index and grain yield were used as stability parameters to identify drought tolerance genotypes (Bansal and Sinha, 1991). It was interesting to note a positive correlation between SSI and Yp indicating that the stress susceptibility was positively correlated with non-stressed yield (Fischer and Wood 1979; Ceccarelli and Grando, 1991).

Table 4. Simple correlation coefficient analysis between drought tolerance indices in wheat genotypes during 2014-15

	TOL	MP	HM	SSI	YI	YSI	RDI	Yp	Ys
TOL	**1.000**	-0.427^{**}	-0.452^{**}	-0.923^{**}	-0.548^{**}	-0.919^{**}	-0.922^{**}	-0.280^{**}	-0.548^{**}
MP		**1.000**	1.000^{**}	0.693^{**}	0.990^{**}	0.694^{**}	0.693^{**}	0.988^{**}	0.990^{**}
HM			**1.000**	0.712^{**}	0.994^{**}	0.714^{**}	0.712^{**}	0.983^{**}	0.994^{**}
SSI				**1.000**	0.781^{**}	0.999^{**}	0.999^{**}	0.575^{**}	0.782^{**}
YI					**1.000**	0.782^{**}	0.781^{**}	0.956^{**}	1.000^{**}
YSI						**1.000**	0.998^{**}	0.577^{**}	0.782^{**}
RDI							**1.000**	0.575^{**}	0.782^{**}
Yp								**1.000**	0.956^{**}
Ys									**1.000**

** = Significant at 1% probability level, r=0.230, * = Significant at 5% probability level, r=0.164

Table 5. Simple correlation coefficient analysis between drought tolerance indices in wheat genotypes during 2015-16

	TOL	MP	HM	SSI	YI	YSI	RDI	Yp	Ys
TOL	**1.000**	-0.575**	-0.599**	-0.953**	-0.681**	-0.953**	-0.952**	-0.430**	-0.681**
MP		**1.000**	0.999**	0.746**	0.991**	0.745**	0.748**	0.986**	0.991**
HM			**1.000**	0.766**	0.994**	0.766**	0.768**	0.980**	0.994**
SSI				**1.000**	0.826**	0.999**	0.999**	0.628**	0.826**
YI					**1.000**	0.826**	0.828**	0.954**	1.000**
YSI						**1.000**	0.999**	0.628**	0.826**
RDI							**1.000**	0.631**	0.828**
Yp								**1.000**	0.954**
Ys									**1.000**

** = Significant at 1% probability level, r=0.230, * = Significant at 5% probability level, r=0.164

Table 6. Pooled correlation coefficient analysis between drought tolerance indices in wheat genotypes during 2014-15 and 2015-16

	TOL	MP	HM	SSI	YI	YSI	RDI	Yp	Ys
TOL	**1.000**	-0.533**	-0.543**	-0.597**	-0.569**	-0.600**	-0.598**	-0.476**	-0.571**
MP		**1.000**	0.959**	0.735**	0.965**	0.734**	0.735**	0.924**	0.965**
HM			**1.000**	0.741**	0.965**	0.740**	0.741**	0.923**	0.966**
SSI				**1.000**	0.746**	0.697**	0.694**	0.673**	0.748**
YI					**1.000**	0.757**	0.757**	0.906**	0.958**
YSI						**1.000**	0.693**	0.673**	0.748**
RDI							**1.000**	0.676**	0.751**
Yp								**1.000**	0.948**
Ys									**1.000**

** = Significant at 1% probability level, r=0.230, * = Significant at 5% probability level, r=0.16

TOL=Tolerance index, MP=Mean productivity, HM=Harmonic mean, SSI=Stress susceptibility index, YI=Yield index, RDI=Relative drought index, Y_p=Grain yield per plant under potential condition, Y_s= Grain yield per plant under stress condition

The genetic divergence among 160 wheat genotypes was studied by employing Non-hierarchical Euclidean cluster analysis for nine drought tolerance indices; pseudo-F-test revealed that thirteen cluster agreements were the most appropriate for this material. The distribution of 160 wheat genotypes into thirteen clusters is given in (**Table 7**). The highest number of genotypes appeared in cluster I (66 genotypes) followed by cluster III (34 genotypes), cluster II (20 genotypes), cluster VIII (15 genotypes), cluster VII (13 genotypes) and cluster VII (5 genotypes). Cluster IV, cluster V, cluster IX, cluster X, cluster XI, cluster XII, cluster XIII with 1 genotype had minimum number of genotypes among all the clusters. The estimates of intra and inter-cluster distance for thirteen clusters are presented in (**Table 8**). The highest intra-cluster values were found in cluster VII (7.696) followed by cluster VIII (5.999), cluster III (5.375), cluster VI (3.545), cluster II (3.919) and cluster I (3.311). The maximum inter-cluster distance were recorded between cluster IV and cluster X (237.054), cluster II and cluster VII (197.868), cluster VIII and cluster XI (150.198), cluster XI and cluster XIII (146.297), cluster IV and cluster XI (133.961), cluster II and cluster VIII (122.526), cluster II and cluster XIII (199.626), cluster XI and cluster XII (115.130), cluster VII and cluster X (114.388) and cluster II and cluster IV (110.525). The cluster means for nine drought tolerance indices are presented in (**Table 9**). The genotypes of cluster XIII took maximum mean value for tolerance index (2.435) followed by cluster XII (2.710), cluster III (1.855) and cluster VIII (1.820). The genotypes of cluster XI (13.265) contained maximum mean value for mean productivity followed by cluster II (12.582) and cluster X (10.615). The cluster XI (13.935) showed a highest cluster mean for yield under potential condition followed by cluster II (12.958), cluster X (10.890) and cluster I (10.074). The genotypes occurring in cluster XI (12.595) produced the highest cluster mean for yield under stress condition followed by cluster II (12.206) and cluster X (10.340), while, the lowest mean was recorded in cluster VII (4.575) for this trait. Based on cluster analysis, cluster II, cluster VII and cluster XI are most important. Because cluster II and cluster XI containing maximum number of tolerant genotypes; cluster VII containing maximum number susceptible genotypes. Hybridization between the genotypes of cluster II and cluster VII, cluster XI and cluster VII will produce recombinant lines for improvement of drought tolerance in wheat breeding programs. Zadfar *et al.* (2014) studied cluster analysis of 8 drought tolerance indices which categorized 15 cultivars into 3 significant clusters. Cluster 1 included only 2 cultivars while, cluster 2 was consist of 7 cultivars, mean while other cultivars were belonged to cluster 3. Group number 3 was the most tolerant in contrast two other groups. Based on grain yield per plant under both the conditions twenty one tolerant genotypes namely; DBW 39, FLW 13, FLW 7, HD 2833, HD 3093, HI 1500, HI 617, HW 2004, HW 2005, HW 2066, HW 4002, HW 4008, HW 4029, HW 4215, Lok 1, Lok 65, MACS 2496, RAJ 4037, SOKOLL, SSRT 14, VJ 99 were selected and eleven susceptible genotypes using same criteria namely; DBW 14, DBW 28, DBW 88, HD 2824, HD 2877, NW 1014, PBW 343, PBW 373, RAJ 4083, UP 2828, MACS 6272 were identified. Identified tolerant and susceptible genotypes can be used for development of mapping populations to map the QTLs for drought tolerance in wheat (*Triticum aestivum* L.).

Table 7. Clustering pattern of 160 wheat genotypes for drought tolerance indices across the years

Cluster No.	Number of Genotypes	Genotypes
I	66	WH 1080, BWL 1793, MHW 4213, HD 2987, FLW 3, HD 3123, BERKUT, HD 2643, BWL 0814, DRYSDALE, HD 3059, HD 3118, HD 3091, NW 2036, AUS30518, DBW 77, SSRW35, SSRT17, HALNA, UP 2691, HW 2036, HD 2985, PBN 142, HD 2864, HD 2687, HD 3086, AUS30354, DHARWAR DRY, KRICHAUFF, HD 3043, SILVERSTAR, BWL 1771, PBW 550, HW 2039, SB187,RAJ 3765, HW 1105, HW 4022, HW 4218, IEPACA RABBE, WH 711, NACOZARI F 76, HI 1544, CETTIA, HD 3122, PBW 502, SERI M 82, HD 2932, RAC875, HI 1531, HW 5209, HW 4209, MACS 6273, AUS30355, HARTOG, PASTOR, SB044, SB169, SB025, HUW510, DBW 50, LOVE-HH-129, HD 3076, VJ10, HD 3121 and GLADIUS
II	20	FLW 13, VJ99, HW 2004, HW 2066, HW 2005, HI 617, Lok 1, HW 4002, SOKOLL, HD 2833, HW 4008, MACS 2496, RAJ 4037, HW 4029, FLW 7, Lok 65, HD 3093, SSRT14, DBW 39 and HI 1500
III	34	FLW 12, BACANORA 88, HW 4009, SSRT02, BAVIACORA M 92, WH 730, SB057, HD 3090, SB062, SB053, AUS30523, IC 532653, SB003, SB109, SB010, HI 1563, OTHERY EGYPT, PBW 175, BARKARE, WH 157, BWL 9022, VOROBEY, K 1016, EXCALIBUR, BWL 0924, HW 2009, HW 4202, NP 846, WH 542, DBW 58, NI 5439, SSRW47, HW 3620 and SSRT65
IV	1	BAW898
V	1	KUKRI
VI	5	Chirya 7, IC 252803 CK9, GRANERO INTA, RAJ 4120 and VJ01
VII	13	DBW 88, MACS 6272, PBW 343, HD 2877, RAJ 4083, UP 2828, PBW 373, NW 1014, DBW 14, HD 2824, SITTELLA, BABAX and DBW 28
VIII	15	PBN 51, WH 147, WYALKATCHEM, HD 3070, SB165, ATTILA, SB069, Lok 45, VJ30, WH 1021, TACUPETO F2001, HW 4219, SSRT09, HD 2733 and JANZ
IX	1	TEPOKO
X	1	C 306
XI	1	HW 4215
XII	1	SSRT16
XIII	1	HD 2967

Table 8. Estimates of average intra-and inter-cluster distances for 13 clusters of drought tolerance indices across the years

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII
I	**3.311**	37.867	13.544	26.188	7.553	7.525	78.493	32.419	15.832	7.868	53.286	26.202	36.266
II		**3.919**	78.615	110.525	58.813	53.465	197.868	122.526	82.953	16.002	7.392	97.674	119.626
III			**5.375**	8.447	7.930	9.891	44.777	12.979	8.137	31.176	97.652	12.653	21.199
IV				**0.000**	13.757	19.831	21.407	6.240	8.517	50.218	133.961	19.909	22.512
V					**0.000**	3.946	60.981	20.806	10.377	20.069	74.459	18.411	35.618
VI						**3.545**	69.019	24.987	14.600	18.116	69.112	19.011	34.909
VII							**7.696**	21.944	44.419	114.388	237.054	62.374	44.979
VIII								**5.999**	16.365	59.042	150.198	21.974	20.328
IX									**0.000**	35.744	98.753	22.436	31.062
X										**0.000**	29.075	47.828	59.353
XI											**0.000**	115.130	146.297
XII												**0.000**	12.793
XIII													**0.000**

Table 9. Cluster means of drought tolerance indices in wheat genotypes across the years

	TOL	MP	HM	SSI	YI	YSI	RDI	Yp	Ys
I	0.926	9.611	9.578	6.138	1.081	0.909	1.066	10.074	9.147
II	0.753	12.582	12.566	6.373	1.442	0.944	1.108	12.958	12.206
III	1.855	8.409	8.283	5.420	0.884	0.802	0.942	9.332	7.478
IV	1.795	7.275	7.150	5.265	0.755	0.780	0.920	8.170	6.375
V	1.235	8.840	8.810	5.880	0.970	0.875	1.025	9.455	8.225
VI	1.402	9.185	9.129	5.811	1.001	0.862	1.009	9.883	8.486
VII	1.697	5.425*	5.261*	4.982*	0.542*	0.737*	0.866**	6.273*	4.575*
VIII	1.820	7.130	6.991	5.257	0.735	0.779	0.912	8.038	6.220
IX	1.535	8.275	8.200	5.630	0.890	0.840	0.980	9.040	7.495
X	0.550*	10.615	10.605	6.405**	1.220	0.945**	1.115**	10.890	10.340
XI	1.335	13.265**	13.235**	6.135	1.490**	0.910	1.070	13.935**	12.595**
XII	2.710	8.730	8.490	5.020	0.875	0.745	0.875	10.080	7.375
XIII	2.435**	7.975	7.700	5.015	0.805	0.740	0.870	9.200	6.760

** Highest Mean Value, * Lowest Mean Value

TOL=Tolerance index, MP=Mean productivity, HM=Harmonic mean, SSI=Stress susceptibility index, YI=Yield index, RDI=Relative drought index, Y_p=Grain yield per plant under potential condition, Y_s= Grain yield per plant under stress condition

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