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Evaluation of RIL Population Derived from Traditional and Modern Cultivar of Wheat (C 518/2* PBW 343) for Yield Potential under Drought Stress Conditions

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Abstract

Present study was carried out to assess the yield potential of C518 and their potential utility in context of drought tolerance when introgressed in to a modern day wheat variety (PBW 343). These two cultivars (PBW 343 and C 518) belongs to distinct adaptation groups, offer several morpho-physiological and biochemical contrasts. C518 is tall and adapted to low input rainfed conditions whereas PBW 343 is semi-dwarf and input responsive. 175 recombinant inbred lines (C 518/2* PBW 343) along with parents and checks were evaluated for drought tolerance in account of yield potential under irrigated and rainfed environments during 2013 to 2014. Water stress was created by withholding irrigation. Different drought tolerance indices viz., stress susceptibility index, relative drought index, mean productivity, stress tolerance index, geometric mean productivity, yield stability index, drought resistance index were evaluated based on grain yield under irrigated and rainfed conditions. Out of 175 inbred lines, seven lines recorded higher grain yield under irrigated as well as rainfed environments. STI, DRI and MP showed highly significant positive correlation with yield in both stress and non-stress environments and with other drought tolerance indices. Thus application of these indices could be appropriate while screening the varieties for drought tolerance and on the basis of theses indices, the inbred lines 108, 84, 80 and 32 were found tolerance lines with high yield under both environments better than the parents.

Keywords

Drought indices; Principal component analysis; Recombinant inbred lines (RILs); Stress tolerance index; Wheat

Abbreviations

Ys: Yield Under Stress Condition; Yp: Yield Under Non-Stress Condition; STI: Stress Tolerance Index; SSI: Stress Susceptibility Index; TOL: Tolerance; MP: Mean Productivity ; GMP: Geometric Mean Productivity; YSI: Yield Stability Index; RDI: Relative Drought Index; DRI: Drought Resistance Index

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Introduction

Wheat (*Triticum aestivum* L.) is an important food crop in the world and drought is one of the most common environmental stresses in agriculture [1,2]. In India, from 80% of the total cultivated wheat only one third is grown under full irrigation while the remaining receives only one to two irrigation in the crop season and hence water inadequacy is a critical factor for sustainable yield [3]. The unpredictability of duration and intensity of drought because of irregular rainfall patterns make the situation more intricate. Wheat crop can experience water deficit stress during growth and development in limited irrigation environments depending upon the water availability and in results of decline in yield productivity. In fact wheat crop often experiences drought in the post-anthesis and maturity period which most responsible plant behavior and development. Growing food demand and global warming would further drive wheat crop to heat and drought stress environments [4]. Therefore, in wheat breeding, drought tolerance has been a major objective in all breeding programs both nationally and internationally in order to improve crop productivity under water-limiting conditions [5]. There is a need for breeding approaches which couples higher yield and stress adaptation to combine higher yield potential and drought tolerance [5,6]. Fischer et al. [7] recommended relative drought index (RDI) as a positive indicator for stress tolerance. Rosielle and Hamblin [8] defined stress tolerance (TOL) as the differences in yield between water stressed and irrigated conditions and mean productivity (MP) as the average yield of genotypes under both these conditions. Since drought severity in field experiments vary over the years hence, some breeders use geometric mean productivity (GMP) to define the relative performance [9]. Fischer and Maurer [10] suggested the stress susceptibility index (SSI) for measurement of yield stability that perceives the changes in both potential and actual yields in under rainfed and irrigated environments. Clarke et al. [11] used SSI to evaluate drought tolerance in wheat genotypes and found year-to-year variation in SSI for genotypes. Guttieri et al. [12] evaluated yield potential by using SSI and suggested that an SSI >1 shows above-average susceptibility to drought stress. A yield stability index (YSI) was suggested by Bouslama and Schapaugh [13] in order to evaluate the stability of genotypes in the both stress (drought) and non-stress (irrigated) conditions. Stress tolerance index (STI) was defined as a useful tool for determining high yield and stress tolerance potential of genotypes under drought and irrigated conditions [9]. Prior to advent of present day semi-dwarf wheat in the 1960s, tall traditional cultivars were grown under rainfed conditions in the state. These cultivars (such as C306, C273, C518 and C591) were derived from landraces materials of this region. After the adaption of semi-dwarf, the tall traditional cutivars found very little use even as donors of traits in wheat breeding programme. Presently these materials have come under focus as a result of greater emphasis on breeding for abiotic stress tolerance with the aim of tall traditional cultivars C518 and their potential utility in context of drought tolerance when introgressed in to a modern day wheat variety (PBW 343). These two cultivars belonging to distinct adaptation groups, offer several morpho-physiological and biochemical contrasts. C518 is tall and adapted to low input rainfed conditions whereas PBW 343 is semi-dwarf and input responsive. The aim of the research reported in this

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paper was to identify RILs combining drought tolerance with higher yield from the cross PBW 343 × C 518 based on tolerance indices to differentiate drought resistant inbred lines.

Materials and Methods

A Field experiment was carried out at experimental area of Department of Plant Breeding & Genetics, Punjab Agricultural University Ludhiana, Punjab, India (30^0-54' N and 75^0-48' E, 247 m altitude) during the 2012-13 and 2013-14 growing seasons. Plant material consisted of 175 recombinant inbred lines (C 518/2*PBW 343) along with 21 check cultivars viz. (PBW 343, PBW 621, C518, PBW 644, PBW 527, C306, C273, C591, C286, C281, C285, PBW 706, PBW 175, PBW 691, BWL 1856, HD 2967, Kirchauff, Babax, Excalibur, Gladius and Drysdale). The experimental design was 14 × 14 square lattice having 1m^2 plots with three replications. The drought environment was created by withholding irrigation and created temporary rain shelter over trails whenever required. Agrometerological data were recorded during crop season from Agrometerological station, PAU Ludhiana and is presented in Figure 1. Normal recommended agronomic practices for growing timely sown wheat crop was followed. Analysis of variance was computed by using SAS pro lattice (version 9.2). Correlation and Principal component analysis among different tolerance indices were analyzed by software JMP$^@$ SAS (version 12).

Calculation of drought tolerance indices

The grain yield/m^2 were recorded for each genotype under irrigated and rainfed environment and used to calculate the drought tolerance indices. The drought tolerance indices were calculated using the following formulas:

Stress Tolerance Index (STI): Drought tolerance indices were calculated based on grain yield over stress environment (drought) and non-stress environment (irrigated) by using the formula as below:

$$STI = \frac{Y_S * Y_p}{(\bar{Y}_P)^2} \quad [9]$$

Stress susceptibility index (SSI) = $\dfrac{1-\left(Y_S/Y_P\right)}{1-\left(\bar{Y}_S/\bar{Y}_P\right)}$ [10]

Tolerance (TOL) = $Y_P - Y_S$ [8]

Mean productivity (MP) = $\dfrac{(Y_S + Y_P)}{2}$ [8]

Geometric mean productivity (GMP) = $\sqrt{(Y_S * Y_P)}$ [9]

Yield stability index (YSI) = $\dfrac{Y_S}{Y_P}$ [13]

Relative drought index (RDI) = $\dfrac{\left(Y_S/Y_P\right)}{\left(\bar{Y}_S/\bar{Y}_P\right)}$ [7]

Drought resistance index (DRI) = $\dfrac{Y_S\left(Y_S/Y_P\right)}{(\bar{Y}_S)}$ [14]

Where;

Y_P : yield of each genotype in non- stressed (Irrigated) environment

Y_S : yield of each genotype in stressed (drought) environment

$\bar{Y}_P$: mean of yield of all genotypes under non- stressed (irrigated) environment

Result and Discussion

The 175 inbred lines of wheat along with 21 check cultivars were evaluated for drought tolerance indices under normal and drought environments. Analysis of variance showed that genotypes were significantly differed for grain yield in both irrigated as well as rainfed conditions (Table 1). These results indicated high diversity among the genotypes that may enable breeder to select genotypes under stress as well as non-stress environments for grain yield potential. Stress-environment decreased grain yield by 12.19% as compared to non-stress environment. Several other researchers also reported the similar kind of observations under stress and non-stress conditions for grain yield [15]. Out of 175 lines tested for grain yield, seven

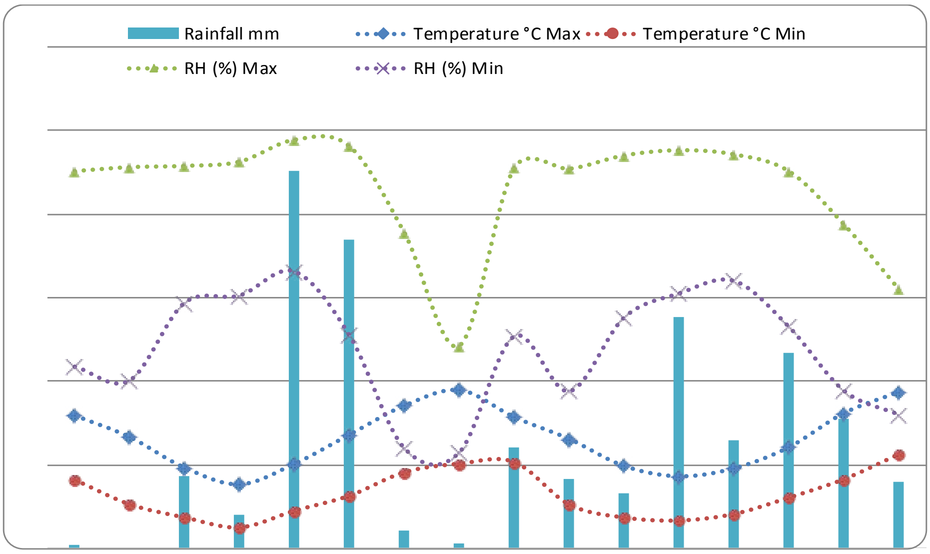

Figure 1: Agrometerological data during crop seasons 2012-13 and 2013-14.

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Table 1: Analysis of variance for grain yield under irrigated and rainfed conditions.

		Mean square of characters	
Source of variation	**DF**	**Grain Yield (Irrigated)**	**Grain Yield (Rainfed)**
Replication	2	87.24	0.00952
Block within rep (adj)	39	1388.89	0.00669*
Treatment (unadj)	195	18100	0.01391
Treatment (adj)	195	16809.2**	0.0129**
Intra Block Error	351	919.64	0.00317
Randomized complete Block Error	390	966.56	0.00352
Total	587	6655.27	0.00699
Efficiency relative to RCBD		101.67	105.5
R^2		0.917	0.729
CV (%)		12.92	23.21

Table 2: Various drought indices of selected inbred lines along with check cultivars under irrigated and rainfed environments.

RILs	**Yp**	**Ys**	**STI**	**SSI**	**RDI**	**DRI**	**TOL**	**MP**	**GMP**	**YSI**
108	393.3	383.3	2.942	0.208	1.11	1.879	10	388.33	388.3	0.975
84	403.3	373.3	2.938	0.61	1.054	1.739	30	388.33	388.04	0.926
80	353.3	346.7	2.39	0.155	1.117	1.711	6.67	350	349.98	0.981
32	360	340	2.388	0.456	1.076	1.615	20	350	349.86	0.944
47	353.3	333.3	2.298	0.464	1.074	1.582	20	343.33	343.19	0.943
30	356.7	326.7	2.273	0.69	1.043	1.505	30	341.67	341.34	0.916
41	346.7	323.3	2.187	0.552	1.062	1.517	23.33	335	334.8	0.933
RILs Min	76.7	50	0.069	0.052	0.537	0.16	-33.33	63.33	61.91	0.467
RILs Max	403.3	383.3	2.729	4.096	1.307	1.828	153.33	388.33	388.3	1.137
RILs Mean	226.4	198.8	0.889	0.981	1.003	0.865	27.61	212.58	211.76	0.872
Checks	**Yp**	**Ys**	**STI**	**SSI**	**RDI**	**DRI**	**TOL**	**MP**	**GMP**	**YSI**
BWL 1856	520	460	4.33	0.886	1.017	1.991	60	490	489.08	0.885
HD 2967	493.3	433.3	3.869	0.934	1.01	1.862	60	463.3	462.33	0.878
PBW 644	440	400	3.186	0.698	1.045	1.779	40	420	419.52	0.909
PBW 621	426	383.3	2.956	0.77	1.034	1.687	42.7	404.65	404.09	0.9
PBW 706	423.5	381.7	2.926	0.758	1.036	1.683	41.8	402.6	402.06	0.901
GLADIUS	446.7	310	2.507	2.35	0.798	1.053	136.7	378.35	372.12	0.694
PBW 691	410	333.3	2.474	1.437	0.935	1.326	76.7	371.65	369.67	0.813
PBW 527	335.5	286.7	1.741	1.117	0.982	1.199	48.8	311.1	310.14	0.855
PBW 175	313.3	296.7	1.683	0.407	1.089	1.375	16.6	305	304.89	0.947
PBW 343	363.3	226.5	1.489	2.892	0.717	0.691	136.8	294.9	286.86	0.623
C 591	250	210	0.95	1.229	0.966	0.863	40	230	229.13	0.84
C 286	253	207	0.948	1.396	0.941	0.829	46	230	228.85	0.818
C 518	260	215.5	1.014	1.314	0.953	0.874	44.5	237.75	236.71	0.829
C 273	223.5	186.7	0.755	1.264	0.96	0.763	36.8	205.1	204.27	0.835
C 306	213.3	183	0.707	1.091	0.986	0.768	30.3	198.15	197.57	0.858
BABAX	206	130	0.485	2.833	0.726	0.401	76	168	163.65	0.631
EXCALIBUR	193.3	130	0.455	2.515	0.773	0.428	63.3	161.65	158.52	0.673
KIRCHAUFF	170	143.3	0.441	1.206	0.969	0.591	26.7	156.65	156.08	0.843
C 281	165.3	143.3	0.429	1.022	0.997	0.608	22	154.3	153.91	0.867
DRYSDALE	183.3	116.7	0.387	2.79	0.732	0.363	66.6	150	146.26	0.637
C 285	163	125	0.369	1.79	0.882	0.469	38	144	142.74	0.767

superior inbred lines were found higher grain yield over other lines under both stress and non- stress conditions. Drought indices which provide a measure of drought tolerance based on yield loss under drought conditions in comparison to normal conditions have been used for screening drought tolerant genotypes [16].

Evaluation of inbred lines on the basis of tolerance indices

Drought tolerance can only be evaluated, if drought stress causes significant reduction in yield [17]. Various drought tolerance indices were estimated for grain yield under rainfed with relation to performance under irrigated conditions and their values are presented in Table 2.

Stress Tolerance Index (STI) is a useful tool for determining stress tolerance potential and high yield of a genotype. Among the RILs the range of STI was 0.069 to 2.729 with an average of 0.889, whereas parents PBW 343 and C 518 had 1.489, 1.014 respectively. Line 108 showed higher STI value 2.94 followed by 84, 80, 32, 47, 30 and 41 (2.938, 2.39, 2.388, 2.298, 2.273 and 2.187 respectively).

RILs showed higher STI value either of parents indicating that inbred lines improved for drought resistance on at par or either of parents. Among the check cultivars higher STI value was recorded for BWL 1856 (4.33) followed by HD 2967, PBW 644, PBW 621, PBW 706, Gladius, PBW 527 and PBW 175 (3.86, 3.18, 2.95, 2.92, 2.50, 2.47,1.74 and 1.68 respectively). Among the RILs the range of SSI was 0.052 to 4.096 with an average of 0.981, whereas parents 343 and C 518 showed 2.892, 1.314 respectively. Line 80 recorded lowest SSI value (0.155) followed by 108, 32, 47, 41, 84 and 30 (0.208, 0.456, 0.464, 0.552, 0.610 and 0.690 respectively). Among the check cultivars, lowest SSI value was recorded for PBW 175 (0.407) followed by PBW 644, PBW 706, PBW 621, BWL 1856, HD 2967 (0.698, 0.758, 0.770, 0.886, 0.934 respectively). Thus, stress susceptibility index is independent of yield potential and drought intensity, and is potentially useful for comparisons of drought susceptibility of genotypes between drought and irrigated experiments, since larger values of SSI indicate greater drought susceptibility. On the basis of SSI, PBW 343 showed greater drought susceptibility followed by Babax (2.833), Drysdale (2.790), Excalibur (2.515) and Gladius (2.507). Similarly, Drought response indices (DRI) were calculated for stress condition. Genotypes with high DRI, low SSI and high grain yield performed consistently across the stress environments. Among the RILs the range of DRI was recorded 0.160 to 1.828 with an average of 0.865, whereas parents PBW 343 and C 518 showed 0.691, 0.874 respectively. Among the checks, highest RDI value was recorded for BWL 1856 (1.991) followed by HD 2967, PBW 644, PBW 621, PBW 706, PBW 175, PBW 691 and Gladius (1.862, 1.779, 1.687, 1.683, 1.375, 1.326 and 1.053 respectively). This indicates that greater DRI value have better yield under both the environments. Similarly for MP, GMP greater values considered for higher mean yield under both environments, based on these indices inbred lines 108, 84, 80, 32, 47 and 30 showed greater values as higher than either of parents PBW 343 and C 518 (Figure 2).

Correlation analysis among the tolerance indices

Correlation among various drought indices were observed and presented in Table 3. Under stress environment, grain yield (Ys) was found significant positive correlation with STI, RDI, DRI, MP, GMP, YSI (0.962, 0.440, 0.973, 0.985, 0.988, 0.440 respectively) whereas, it was significant negative correlated with SSI (-0.440). Grain yield in irrigated condition (Yp) showed significant positive correlation with STI, DRI, TOL, MP and GMP (0.962, 0.845, 0.311, 0.987, and o.983 respectively), Positive relationship between MP and STI with yield under both environments would be more effective criteria in identifying high yielding genotypes. Farshadfar et al. [18] also reported similar results for correlations of grain yield with MP and STI under both stress and non-stress environments. Stress tolerance index (STI) showed positive significant correlation with RDI, DRI, MP and YSI. Mean productivity (MP) was found significantly and positively correlated with STI, DRI, RDI and TOL, and negatively correlated with SSI. Relative drought index (RDI) had significant positive correlation with STI, YI, YSI, MP, GMP and DRI and strong negatively correlated with SSI (-1.00). Absolute correlations of RDI with SSI and YSI with SSI indicated mathematical similarity in their

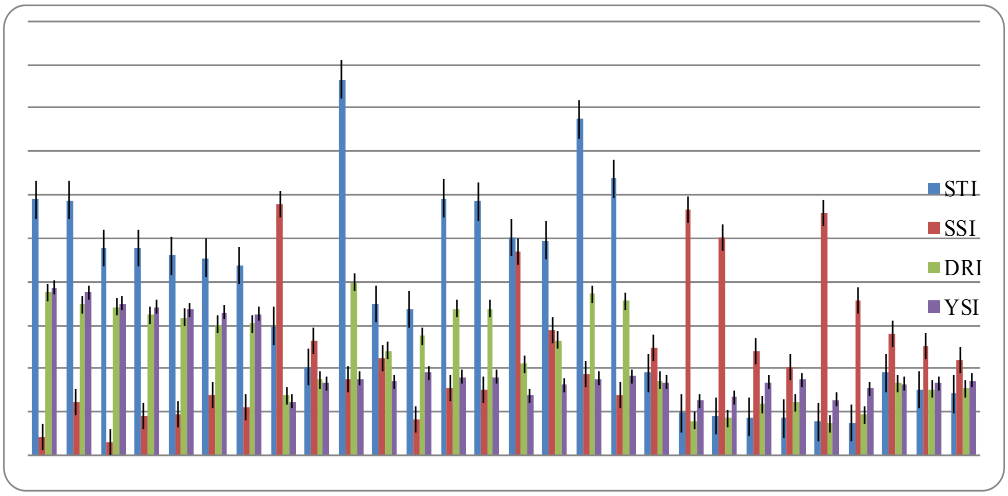

Figure 2: Different drought indices showed variability in inbred lines along with check cultivars.

Table 3: Correlation among different tolerance indices under both irrigated and rainfed environments.

	Ys	Yp	STI	SSI	RDI	DRI	TOL	MP	GMP	YSI
Ys	1	0.944**	0.962**	-0.440**	0.440**	0.973**	-0.02	0.985**	0.988**	0.440**
Yp	0.944**	1	0.962**	-0.137^{NS}	0.137^{NS}	0.845**	0.311**	0.987**	0.983**	0.137^{NS}
STI	0.962**	0.962**	1	-0.259**	0.259**	0.898**	0.145*	0.976**	0.976**	0.259**
SSI	-0.440**	-0.137^{NS}	-0.259**	1	-1.000**	-0.617**	0.853**	-0.288**	-0.306**	-1.000**
RDI	0.440**	0.137^{NS}	0.259**	-1.000**	1	0.617**	-0.853**	0.288**	0.305**	1.000**
DRI	0.973**	0.845**	0.898**	-0.617**	0.617**	1	-0.244**	0.920**	0.927**	0.617**
TOL	-0.020^{NS}	0.311**	0.145*	0.853**	-0.853**	-0.244**	1	0.151*	0.133^{NS}	-0.853**
MP	0.985**	0.987**	0.976**	-0.288**	0.288**	0.920**	0.151*	1	1.000**	0.288**
GMP	0.988**	0.983**	0.976**	-0.306**	0.305**	0.927**	0.133^{NS}	1.000**	1	0.305**
YSI	0.440**	0.137^{NS}	0.259**	-1.000**	1.000**	0.617**	-0.853**	0.288**	0.305**	1

Table 4: First two principal components for grain yields and stress indices under irrigated and rainfed conditions.

Variable	PC1	PC2	PC3
Yp	0.318	0.316	0.115
Ys	0.358	0.147	-0.094
STI	0.342	0.22	-0.317
SSI	-0.297	0.363	-0.318
RDI	0.297	-0.363	0.338
DRI	0.367	0.026	-0.266
TOL	-0.125	0.571	0.703
MP	0.342	0.234	0.011
GMP	0.341	0.224	0.003
YSI	0.298	-0.363	0.306
Eigenvalues	7.32	2.57	0.086
Cumulative %	73.23	99	99.8

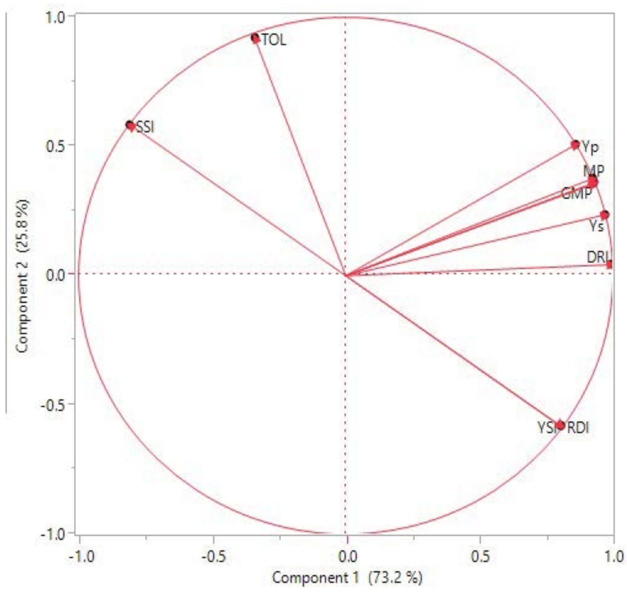

Figure 3: Biplot analysis for drought tolerance indices using two principal components.

formulae. So, these indices cannot be a proper index for selecting the genotypes which have a high yield in normal and drought stress environments [19].

Principal component analysis

The first two factors in the principal component analysis showed 99.0 % total variation (Table 4). The first PC explained 72.2% grain yield whereas the second contributed 25.8 %. The maximum contribution by individual for first factor was by DRI followed by STI and MP.

Therefore it reflects high grain yield as well as stress tolerance. The relationships among different indices are graphically displayed in a biplot of PCA1 and PCA2 (Figure 3). The angle direction between the attribute vectors illustrated the strength and the direction of correlation between any two attributes [9]. Significant positive correlation was observed between yield (Ys) with DRI, GMP, STI and MP and significant negatively correlated with SSI. These observations were conformity with correlation results indicating that DRI, STI, and MP could be reliable selection criteria for drought tolerance as reported by Abdi et al. and Mohammadi et al. [20,21].

It is concluded that, among the various tolerance indices, STI, DRI and MP showed strong correlation between them so on the basis of these, inbred lines 108, 84, 80 and 32 were found most tolerance lines as compared to other lines and better than parents as well as check cultivars. These RILs can be used as genetic material for further breeding programme and identify QTLs for drought tolerance traits.

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