RESEARCH ARTICLE

SABRAO Journal
of Breeding and Genetics
45 (3) 458-467, 2013

CHARACTER ASSOCIATION STUDIES OF SEEDLING TRAITS IN DIFFERENT WHEAT GENOTYPES UNDER MOISTURE STRESS CONDITIONS

M.I. KHAN[1], G. SHABBIR[1], Z. AKRAM[1], M.K.N. SHAH[1], M. ANSAR[2], N.M. CHEEMA[3] and M.S. IQBAL[1*]

[1] Department of Plant Breeding and Genetics, Pir Mehr Ali Shah Arid Agriculture University, Rawalpindi
[2] Department of Agronomy, Pir Mehr Ali Shah Arid Agriculture University, Rawalpindi
[3] Crop Sciences Institute, national Agricultural Research Institute, Islamabad
*Corresponding author's email: shahidkooria@gmail.com

SUMMARY

Wheat improvement in rainfed areas requires reliable assessment for drought tolerance. Forty three diverse wheat genotypes including local land races (LLR) were screened following completely randomized design under controlled condition at PMAS Arid Agriculture University Rawalpindi during 2011. Different concentrations of PEG-6000 were used to induce moisture stress at germination and seedling stage. Data revealed a decreasing trend in values for all traits with the increasing concentrations of PEG-6000. The genotypes showed higher values for germination percentage, germination rate index (GRI), root length, shoot length, coleoptile length, seedling vigor index, fresh root weight, dry root weight, fresh shoot weight and dry shoot weight under normal condition. The genotype, Faisalabad-2008 had the highest germination percentage (100) and germination rate index (17.73), Lasani-2008 showed maximum value for root length (18.28 cm), Chenab-70 attained maximum shoot length (12.05 cm) and dry root weight (0.169 g), LLR-14 showed maximum value for coleoptile length (4.08 cm), Pak-81 exhibited maximum value for seedling vigor index (1892.6) and dry shoot weight (0.251 g), 99FJ-03 showed the highest value for fresh root weight (0.269 g) and maximum fresh shoot weight (0.350 g) was observed for Seri-82. Whereas minimum germination percentage (72.50) and fresh shoot weight (0.212 g) was observed for LLR-21. The genotype LLR-17 showed minimum values for GRI (10.72) and fresh root weight (0.144 g), LLR-32 exhibited minimum root length (11.00 cm) and dry root weight (0.109 g), WC-25 attained minimum shoot length (7.64 cm) and minimum coleoptile length (2.41 cm) was recorded for Chakwal-50. LLR-29 and LLR-30 had minimum seedling vigor index (1288.5) and dry shoot weight (0.118 g) respectively. Correlation studies revealed considerable and positive correlation among seedling traits. Root length showed significant correlation with coleoptile length (0.80) and fresh root weight (0.82). Fresh root weight showed considerable correlation with fresh shoot weight (0.89) and dry shoot weight (0.90).

Keywords: Wheat, seedling traits, drought tolerance, osmotic stress, PEG-6000

Manuscript received: July 11, 2012; Decision on manuscript: May 25, 2013; Manuscript accepted: July 10, 2013.

Communicating Editor: Bertrand Collard

INTRODUCTION

Bread wheat (*Triticum aestivum* L.) is the most widely cultivated crop and provides more than half of the calories and almost half of the proteins to one-third of the world's population. The forecasted global wheat demand in the year 2020 may rise up to 750 million tons. To achieve this target, annual wheat production will have to be increased from 1.6 to 2.6 percent with global mean yield to be raised from 2.5 to 4 tons per hectare (Mujeeb-Kazi *et al.,* 2004). Several ecological factors influence plant growth and development and ultimately limit yield performance of crop (Keresa *et al.,* 2000). Abiotic stresses: like drought, soil salinity, nutrient imbalance and high temperatures; are the major environmental constraints for sustainable agricultural productivity in the world. For instance, about 45 % of the world's agricultural lands have been subjected to continuous or frequent drought (Bot *et al.,* 2000). Wheat grown in rainfed areas of Pakistan has low yield because of uneven and unpredictable rainfall pattern and temperature fluctuation. Presence of genetic variation in diverse wheat material and its evaluation is a pre-requisite in breeding programme for improvement in wheat production (Zeb *et al.,* 2009).

Drought tolerance is a mechanism that relates to the ability of a crop to maintain yield stability under adverse climatic conditions (Tuberosa and Salvi, 2006). Various agronomic traits conferring tolerance to abiotic and biotic stresses found in wild type (*Aegilops tauschii*), have been transferred into modern wheat to improve its tolerance against stresses (Villareal and Mujeeb-Kazi, 2003). Under rainfed conditions, selection of genotypes based on better adaptability can help to increase wheat production (Rajaram, 2001). Various drought indices are used to estimate yield loss under moisture stress and normal conditions (Mitra, 2001; Noorka *et al.,* 2007). Genetic improvement in wheat crop for drought tolerance requires exploration of wide genetic diversity. Plant breeders have been continuously involved in finding suitable germplasm for drought tolerance to mitigate climatic risks (Mujeeb-Kazi and Kimber, 1985).

Screening and selection are thought to be important aspects of crop breeding programmes. For effective screening, assessment should be carried out under controlled environmental conditions. Large set of germplasm could be effectively screened within short time using *in vitro* screening methods (Kulkarni and Deshpande, 2007). *In vitro* studies include the use of stress inducing chemicals such as polyethylene glycol (PEG) for the identification of traits contributing to moisture stress tolerance and helps in the evaluation of drought tolerant genotypes (Galovic *et al.,* 2005). Genetic improvements of crops require further exploration of genetic variation and finding more possible components of drought tolerance (Dhanda *et al.,* 2004). Keeping in view the above scenarios, the present study was undertaken with the objective to screen and identify drought tolerant wheat genotypes under controlled conditions for arid regions of Pakistan.

MATERIALS AND METHODS

The present study was conducted using forty three diverse wheat genotypes collected from different research institutes and maintained in the department of Plant Breeding and Genetics. The genotypes (Table 1) were screened under *in vitro* conditions in the Department of Plant Breeding and Genetics, Pir Mehr Ali Shah, Arid Agriculture University Rawalpindi during the year 2011. The experiment was laid out under complete randomized design (CRD). PEG-6000 was used to induce moisture stress at germination and seedling stage of wheat genotypes. Seeds were placed between filter papers in petri plates to provide appropriate moisture stress. Different concentrations of PEG-6000 [T_1, Control (distilled water), T_2 (6 %), T_3 (12 %) and T_4 (18%)] were used to induce moisture stress. Distilled water and PEG solutions were applied (2 ml each) on alternate days for each genotype

Data were recorded regarding germination percentage (%), root length (cm), shoot length (cm), coleoptile length (cm), fresh root weight, dry root weight, fresh shoot weight and dry shoot weight while germination rate index and seedling vigour index were computed.

Data analysis

Data collected were statistically analyzed to ascertain differences amongst various wheat genotypes (Steel *et al.,* 1997). Simple correlation coefficients were measured for different seedling traits using STATIX 8.1 software.

Table 1. List of wheat genotypes used to study seedling traits maintained in the department.

No.	Name of Genotypes	No.	Name of Genotypes
1	LLR-29	23	WC-25
2	WC-22	24	Jauhar-78
3	C-591	25	Fareed-2006
4	LLR-17	26	Faisalabad-2008
5	Pak-81	27	Kohistan-97
6	Chenab-70	28	GA-2002
7	99FJ-03	29	Miraj-2008
8	Margalla-99	30	Seri-82
9	Chakwal-50	31	Bhakkar-2002
10	LLR-12	32	Rawal-87
11	LLR-30	33	Auqab-2000
12	LLR-13	34	Lasani-2008
13	LLR-22	35	Chakwal-86
14	LLR-32	36	Lyalpur-73
15	LLR-44	37	LLR-21
16	LLR-40	38	LLR-19
17	LLR-11	39	Maxipak-65
18	LLR-14	40	Chakwal-97
19	LLR-15	41	Shahkar-95
20	LLR-18	42	Bakhtawar-93
21	WC-23	43	Fakhre-Serhad
22	WC-24		

Table 2. Analysis of variance for mean squares of various seedling traits.

Source	df	GP	GRI	RL	SL	CL	SVI	FRW	DRW	FSW	DSW
Genotypes	42	308.733**	25.007**	30.348**	9.194**	1.080**	17834**	0.0086**	0.00156**	0.0137**	0.0125**
Treatment	3	57.996 ns	13.178**	12.388**	1.243 ns	0.169*	15725**	0.00015ns	0.0003 ns	0.0008 ns	0.0005ns
Error	126	29.052	1.462	1.463	0.635	0.051	11930	0.00033	0.00015	0.0004	0.00027

**Highly significant at $P < 0.01$, * = Significant at $P < 0.05$, ns = Not significant
GP = Germination percentage, GRI = Germination rate index, RL = Root length, SL = Shoot length, CL = Coleoptile length
SVI = Seedling vigor index, FRW = Fresh root weight, DRW = Dry root weight, FSW = Fresh shoot weight, DSW = Dry shoot weight

Table 3. Mean values of various wheat genotypes for seedling traits under different moisture stress levels.

Parameters	Treatments				LSD
	T1	T2	T3	T4	($P < 0.05$)
Germination percentage	86.863 a	86.206 ab	84.883 ab	84.345 b	2.3004
Germination rate index	15.056 a	14.421 b	14.076 bc	13.765 c	0.5161
Root length	14.79 b	14.60 b	14.44 b	15.65 a	0.5163
Shoot length	10.12 a	9.83 ab	9.72 b	9.90 ab	0.3402
Coleoptile length	3.23 a	3.21 a	3.17 ab	3.09 b	0.0965
Seedling vigor index	1662.01 a	1645.11 ab	1633.22 ab	1598.1 b	46.617
Fresh root weight	0.200 a	0.204 a	0.203 a	0.203 a	0.0077
Dry root weight	0.137 a	0.136 a	0.135 a	0.130 b	0.0052
Fresh shoot weight	0.287 a	0.277 ab	0.262 b	0.251 c	0.0085
Dry shoot weight	0.186 a	0.186 a	0.181 a	0.179 a	0.0070

Table 4. Mean values for various traits of wheat genotypes under different moisture stress levels tested at PMAS-Arid Agriculture University Rawalpindi during 2011.

No.	GP	GRI	RL	SL	CL	SVI	FRW	DRW	FSW	DSW
1	76.50 klm	11.85 defg	11.75 cde	7.71 h	2.52 lmno	1288.5 g	0.150 f	0.120 hi	0.213 d	0.121 e
2	77.00 klm	13.23 cd	12.02 bcde	9.00 defg	2.67 jklmno	1422.6 efg	0.160 f	0.116 hi	0.217 cd	0.122 e
3	96.43 abc	17.28 ab	17.50 a	11.50 ab	3.96 abc	1842.3 abc	0.241 bcde	0.146 cdefg	0.342 ab	0.245 ab
4	74.75 lm	10.72 g	11.65 cde	7.88 gh	2.36 o	1330.8 g	0.144 f	0.119 hi	0.215 d	0.121 e
5	89.10 cdefg	15.89 b	16.81 a	11.47 ab	3.47 efgh	1892.6 a	0.249 abcd	0.157 abcde	0.346 ab	0.251 a
6	95.00 abcd	17.22 ab	17.66 a	12.05 a	3.45 efgh	1879.9 a	0.248 abcd	0.169 a	0.340 ab	0.245 ab
7	86.61 efghi	15.96 b	17.25 a	10.61 bc	3.43 gh	1795.0 abc	0.269 a	0.168 ab	0.342 ab	0.238 abc
8	93.93 abcde	15.87 b	16.96 a	11.27 ab	3.60 defgh	1786.9 abc	0.258 abc	0.158 abcd	0.331 ab	0.243 ab
9	76.25 klm	11.51 efg	11.25 e	7.81 h	2.41 o	1405.7 efg	0.154 f	0.114 i	0.225 cd	0.131 de
10	80.75 hijkl	11.07 fg	11.35 de	8.43 efgh	2.8 ijklm	1350.6 g	0.162 f	0.117 hi	0.218 cd	0.122 e
11	75.75 klm	11.63 defg	11.02 e	8.13 fgh	2.61 klmno	1404.4 efg	0.165 f	0.116 i	0.223 cd	0.118 e
12	86.25 fghij	16.36 ab	18.00 a	10.99 ab	4.05 ab	1810.7 abc	0.247 abcd	0.152 bcdef	0.332 ab	0.241 abc
13	75.75 klm	11.39 efg	13.22 bc	8.58 efgh	2.82 ijkl	1430.8 efg	0.161 f	0.118 hi	0.214 d	0.128 de
14	78.75 jklm	12.66 cdef	11.00 e	7.74 h	2.75 ijklmn	1393.7 fg	0.149 f	0.109 i	0.221 cd	0.149 d
15	77.50 klm	12.80 cde	12.00 bcde	9.10 def	2.46 no	1415.9 efg	0.163 f	0.117 hi	0.227 cd	0.120 e
16	74.75 lm	11.58 defg	12.25 bcde	8.53 efgh	2.61 klmno	1412.9 efg	0.152 f	0.110 i	0.212 d	0.121 e
17	87.50 defgh	16.77 ab	17.87 a	11.51 ab	3.75 bcdef	1814.0 abc	0.242 bcde	0.146 cdefg	0.330 ab	0.234 abc
18	90.25 cdef	16.59 ab	17.68 a	11.53 ab	4.08 a	1815.7 abc	0.234 cde	0.138 fg	0.338 ab	0.238 abc
19	77.68 klm	11.22 efg	13.50 b	8.38 efgh	3.00 i	1422.9 efg	0.157 f	0.112 i	0.218 cd	0.128 de
20	78.25 klm	11.09 fg	11.48 de	8.46 efgh	2.61 klmno	1414.6 efg	0.155 f	0.110 i	0.226 cd	0.122 e
21	77.14 klm	12.60 cdef	12.17 bcde	8.54 efgh	2.82 ijkl	1386.8 fg	0.163 f	0.117 hi	0.228 cd	0.124 e
22	76.50 klm	11.73 defg	13.63 b	8.32 efgh	2.92 ijk	1406.3 efg	0.160 f	0.114 i	0.244 c	0.128 de
23	77.43 klm	11.33 efg	13.29 bc	7.64 h	2.75 ijklmn	1388.1 fg	0.149 f	0.116 hi	0.219 cd	0.130 de
24	98.75 ab	16.65 ab	18.26 a	10.86 bc	3.62 defgh	1831.1 abc	0.240 bcde	0.147 cdefg	0.322 b	0.219 c
25	92.68 abcdef	16.76 ab	16.70 a	11.34 ab	3.45 fgh	1810.8 abc	0.237 bcde	0.1407 efg	0.341 ab	0.234 abc
26	100.00 a	17.73 a	16.90 a	11.07 ab	3.64 defgh	1779.7 abc	0.267 a	0.158 abcd	0.347 ab	0.225 bc

27	95.18 abc	17.56 ab	18.00 a	11.55 ab	3.77 abcde	1814.4 abc	0.242 bcde	0.153 abcdef	0.339 ab	0.235 abc
28	77.00 klm	11.41 efg	13.03 bcd	9.32 de	2.92 ijk	1421.2 efg	0.159 f	0.117 hi	0.226 cd	0.130 de
29	96.43 abc	16.80 ab	16.81 a	11.22 ab	3.65 defgh	1824.7 abc	0.239 bcde	0.149 cdefg	0.320 b	0.228 bc
30	96.43abc	16.37 ab	17.91 a	10.86 bc	3.51 defgh	1722.4 bc	0.256 abcd	0.148 cdefg	0.350 a	0.245 ab
31	78.93 jklm	12.37 cdefg	12.48 bcde	8.31 efgh	2.97 ij	1389.2 fg	0.148 f	0.117 hi	0.218 cd	0.129 de
32	92.93abcdef	16.68 ab	16.84 a	10.83 bc	3.69 cdefg	1884.8 a	0.255 abcd	0.1513 bcdef	0.345 ab	0.235 abc
33	96.25 abc	16.16 ab	17.28 a	11.46 ab	3.61 defgh	1791.7 abc	0.241 bcde	0.155 abcde	0.330 ab	0.227 bc
34	93.50 abcdef	16.43 ab	18.28 a	11.21 ab	3.82 abcd	1859.0 ab	0.218 e	0.133 gh	0.335 ab	0.233 abc
35	96.43 abc	16.74 ab	17.73 a	12.00 a	3.68 cdefg	1827.8 abc	0.234 cde	0.142 defg	0.343 ab	0.229 abc
36	92.68 abcdef	16.23 ab	17.55 a	10.64 bc	3.47 efgh	1719.6 bc	0.261 ab	0.158 abcd	0.330 ab	0.233 abc
37	72.50 m	11.61 defg	11.50 de	8.33 efgh	2.42 o	1372.2 g	0.164 f	0.120 hi	0.212 d	0.121 e
38	77.00 klm	12.13 defg	12.23 bcde	9.86 cd	2.77 ijklmn	1432.4 efg	0.163 f	0.120 hi	0.229 cd	0.124 e
39	82.68 ghijk	13.86 c	13.00 bcd	8.17 fgh	2.75 ijklmn	1548.7 de	0.152 f	0.118 hi	0.230 cd	0.136 de
40	95.18 abc	16.89 ab	17.26 a	11.41 ab	3.33 h	1808.0 abc	0.232 de	0.159 abc	0.327 ab	0.227 bc
41	79.11 ijklm	11.83 defg	11.75 cde	8.94 defg	2.50 mno	1530.0 ef	0.158 f	0.114 i	0.227 cd	0.137 de
42	91.25 bcdef	16.05 ab	17.48 a	11.60 ab	3.40 gh	1691.3 cd	0.251 abcd	0.159 abcd	0.336 ab	0.242 abc
43	95.00 abcd	17.40 ab	17.24 a	11.25 ab	3.62 defgh	1861.6 ab	0.259 abc	0.163 abc	0.344 ab	0.251 a
LSD ($P < 0.05$)	7.5424	1.6921	1.6929	1.1153	0.3164	152.84	0.0254	0.0172	0.0279	0.0231
SE	3.8113	0.8551	0.8554	0.5636	0.1599	77.234	0.0128	0.0086	0.0141	0.0117

GP = Germination percentage, GRI = Germination rate index, RL = Root length, SL = Shoot length, CL = Coleoptile length
SVI = Seedling vigor index, FRW = Fresh root weight, DRW = Dry root weight, FSW = Fresh shoot weight, DSW = Dry shoot weight, SE = Standard error

RESULTS AND DISCUSSION

Analysis of variance inferred significant difference for various traits among moisture stress treatments (Table 2). Considerable variation among the wheat genotypes were found for all traits. Data in the (Table 3) revealed that genotypes showed higher values for germination percentage (86.863), germination rate index (15.056), root length (15.79 cm), shoot length (10.12 cm), coleoptile length (3.23 cm), seedling vigor index (1662.01), dry root weight (0.137 g), fresh shoot weight (0.287 g) under normal condition (control, distilled water) while decreasing trend was observed for all traits with increasing concentrations of poly ethylene glycol except for fresh root weight and dry shoot weight. The genotype, Faisalabad-2008 exhibited the highest value for germination percentage (100) and germination rate index (17.73), Lasani-2008 showed maximum value for root length (18.28 cm), Chenab-70 attained maximum for shoot length (12.05 cm) and dry root weight (0.169 g), LLR-14 showed maximum value for coleoptile length (4.08 cm), Pak-81 exhibited maximum value for seedling vigor index (1892.6) and dry shoot weight (0.251 g), 99FJ-03 showed maximum value for fresh root weight (0.269 g) and maximum fresh shoot weight (0.350 g) was observed for Seri-82 (Table 4). The present study depicted that moisture stress may affect seed germination by decreasing water uptake by the seed because the activity and events normally associated with germination get either delayed or proceed at a reduced rate.

Basra *et al.* (2003) reported that if germination rate index was higher, then it indicates earlier and rapid germination. Earlier findings revealed that root length and shoot length decreased with the increase in osmotic stress in wheat (Dhanda *et al.,* 2004; Kamran *et al.,* 2009). Earlier studies also revealed that significant differences were obtained among various wheat genotypes for coleoptile length at different levels of osmotic stresses (Shahryari *et al.,* 2008). The results of Hafid *et al.* (1998) showed that genotypes with high seedling vigor index also had better germination percentage, root length and shoot length. Basra *et al.* (2005) reported increased root and shoot fresh weights that might be due to early emergence and seedling establishment in treated seeds. Achakzai (2009) reported that in relation to various levels of induced water stress, dry root weight significantly decreased which supported our findings. Mahmood *et al.* (2004) reported similar results in wheat genotypes based on genotypic response in respect of shoot fresh weight to various water stress treatments. Ahmad *et al.* (2007) reported reduced dry shoot weight under water stress conditions for various genotypes which supported our results. It was concluded that wheat genotypes respond differently under different moisture stress conditions. Germination and seedling traits were also affected due to osmotic stress.

Correlation coefficients

Correlation analysis revealed that germination percentage exhibited significant and positive correlation with root length (0.73), shoot length (0.70), coleoptile length (0.71), fresh root weight (0.75), fresh shoot weight (0.77), dry root weight (0.69), dry shoot weight (0.80), germination rate index (0.78) and seedling vigor index (0.72) (Table 5) which indicated that by increasing these attributes, germination percentage will increase. Correlation coefficients depicted that root length showed highly positive and significant association with shoot length (0.79), coleoptile length (0.80), fresh root (0.82) and shoot weight (0.86), dry root (0.71) and shoot weight (0.84), germination rate index (0.79) and seedling vigor index (0.76). Shoot length showed significant correlation with dry shoot weight (0.82) coleoptile length (0.74), germination rate index (0.76) and seedling vigor index (0.76).

Coleoptile length exhibited positive and highly significant correlation with fresh root weight (0.78), fresh shoot weight (0.81) and dry root weight (0.0.69) and dry shoot weight (0.84). Fresh shoot weight showed significant correlation with dry shoot weight (0.93) and dry shoot weight had positive correlation with GRI (0.87). While positive and highly significant correlation was observed between fresh shoot weight and dry shoot weight (0.93).

Table 5. Correlation coefficients among various traits of different wheat genotypes under *in vitro* conditions during 2011.

	GP	RL	SL	CL	FRW	FSW	DRW	DSW	GRI
RL	0.73 **								
SL	0.70 **	0.79 **							
CL	0.71 **	0.80 **	0.74 **						
FRW	0.75 **	0.82 **	0.79 **	0.78 **					
FSW	0.77 **	0.86 **	0.83 **	0.81 **	0.89 **				
DRW	0.69 **	0.71 **	0.69 **	0.69 **	0.89 **	0.80 **			
DSW	0.80 **	0.84 **	0.82 **	0.84 **	0.90 **	0.93 **	0.81 **		
GRI	0.78 **	0.79 **	0.76 **	0.79 **	0.80 **	0.82 **	0.71 **	0.87 **	
SVI	0.72 **	0.76 **	0.76 **	0.76 **	0.78 **	0.83 **	0.69 **	0.84 **	0.73 **

These findings led to conclusion that the desireable traits possessed by different genotypes can be used for the development of drought tolerant wheat material. These results were also supported by the findings of Khan *et al.* (2002) that germination percentage exhibited positive and significant correlation with root length, coleoptile length, fresh shoot weight, dry shoot weight, fresh root weight and dry root weight. Rakesh *et al.* (1998) reported similar results that supported our present findings. Similarly, Rauf *et al.* (2007), Noorka *et al.,* (2007), Ahmad *et al.,* (2013) reported that genotypes showed variable response for drought related traits under different stress levels.

CONCLUSION

The present study inferred that in general seedling traits showed a decreasing trend with increasing PEG concentrations. However genotypes which showed slight reduction for the trait under moisture stress condition may be useful for wheat improvement in breeding programmes. Furthermore, significant and positive correlation among various seedling traits revealed that by improving dry shoot weight will improve the overall performance of the crop. The genotypes with improved traits may be used as parents in wheat breeding for moisture stress conditions.

REFERENCES

Achakzai AKK (2009). Effect of water stress on imbibition, germination and seedling growth of maize cultivars. *Sarhad J. Agric*. 25(2): 165-172.

Ahmad F, Rahmatullah, Aziz T, Maqsood MA, Tahir MA, Kanwal S (2007). Effect of silicon application on wheat (*Triticum aestivum* L.) growth under water deficiency stress. *Emir. J. Food Agric.* 19 (2): 01-07.

Ahmad M, Shabbir G, Minhas NM, Shah MKN (2013). Identification of drought tolerant wheat genotypes based on seedling traits. *Sarhad J. Agric.* 29(1): 21-27.

Basra SMA, Farooq M, Khaliq A (2003). Comparative study of pre-sowing seed enhancement treatments in fine rice (*Oryza sativa* L.). *Pak. J. Life Soc. Sci*. 1: 5-9.

Basra SMA, Anwar S, Afzal I, Shafique M, Haq A, Majeed K (2005). Effect of different seed invigoration techniques on wheat (*Triticum aestivum* L.) seeds sown under saline and non-saline conditions. *J. Seed Technol.*

Bot AJ, Nachtergaele FO, Young A, (2000). Land resource potential and constraints at regional and country levels.World Soil Resources Reports 90. Land and Water Development Division, FAO, Rome.

Dhanda, SS, Sethi GS, Behl RK (2004). Indices of drought tolerance in wheat genotypes at early stages of plant growth. *J. Agron. Crop Sci.* 190: 6-12.

Galovic V, Kotaranin Z, Dencic S (2005). *In vitro* assessment of wheat tolerance to drought. *Genetika* 37(2): 165-171.

Hafid, REL, Smith DH, Karrou M, Samir K (1998). Physiological responses of spring durum wheat cultivars to early-season drought in a mediterranean environment. *Annals of Botany* 81: 363-370.

Kamran M, Shahbaz M, Ashraf M, Akram NA (2009). Alleviation of drought induced adverse effects in spring wheat (*Triticum aestivum* L.) using proline as a pre-sowing seed treatment. *Pak. J. Bot*. 41 (2): 621-632.

Keresa, S, Baric M, Sarcevic H, Marchetti S, Dresner G (2000). Callus induction and plant regeneration from immature and mature embryos of winter wheat (Triticum aestivum L.) genotypes. Plant Breeding Sustaining the Future. XVIth EUCARPIA congress, Edinburgh, Scotland.

Khan MQ, Anwar S, Khan MI (2002). Genetic variability for seedling Traits in wheat (*Triticum aestivum* L.) under moisture stress conditions. *Asian J. Plant Sci.* 1(5): 588-590.

Kulkarni M, Deshpande U (2007). *In vitro* screening of tomato genotypes for drought resistance using polyethylene glycol. *Afr. J. Biotech*. 6(6): 691-696.

Mahmood S, Hussain, A, Tabassum Z, Kanwal F (2004). Comparative performance of *Brassica napus* and *Eruca sativa* under water deficit conditions: An assessment of selection criteria. *J. Res. Sci.* 14(4): 439-446.

Mitra J (2001). Genetics and genetic improvement of drought resistance in crop plants. *Curr. Sci.* 80: 758-762.

Mujeeb-Kazi A, Kimber G (1985). The production, cytology and practicality of wide hybrids in the Triticeae. *Cereal Res. Comm.* 13:111-134.

Mujeeb-kazi A, Delgado A, Cortes A, Cano S, Rosas V, Sanchez J (2004). Progress in exploiting *Aegilops tauschii* for wheat improvement. *Ann. Wheat Newsl.* 50: 79-88.

Noorka IR., Khaliq I, Kashif M (2007). Index of transmissibility and genetic variation in spring wheat seedlings under water deficit conditions. *Pak. J. Agri. Sci*. 44(4): 604-607.

Rajaram S (2001). Prospects and promise of wheat breeding in the 21st century. *Euphytica* 119: 3-15.

Rakesh V, Sethi SS, Vashnavi R (1998). Relative drought tolerance of rye-introgressed bread wheat (*Triticum aestivum* L.) genotypes in osmoticum. *Annals Biols. Ludhiana* 14(2): 169-173.

Rauf M, Munir M, Hassan M, Ahmed M, Afzal, M (2007). Performance of wheat genotypes under osmotic stress at germination and early seedling growth stage. *Afr. J. Biotech*. 6: 971-975.

Shahryari R, Gurbanov E, Gadimov A, Hassanpanah D (2008). Tolerance of 42 bread wheat genotypes to drought stress after anthesis. *Pak. J. Biol. Sci.* 11: 1330-1335.

Steel RGD, Torrie JH, Dikey DA (1997). Principles and procedures of statistics: A biometrical approach, 3rd ed. McGraw Hill Book Co., New York.

Tuberosa R, Salvi S (2006). Genomics-based approaches to improve drought tolerance of crops. *Trends Pl. Sci*. 11(8): 405-412.

Villareal RL, Mujeeb-Kazi A, (2003). Genetic diversity and wheat improvement for sustainable agriculture. In: Agronomy Abstract. American Society of Agronomy, Madison, WI.

Zeb B, Khan IA, Ali S, Bacha S, Mumtaz S, Swati ZA (2009). Study on genetic diversity in Pakistani wheat varieties using simple sequence repeat (SSR) markers. *Afr. J. Biotech.* 8 (17): 4016-4019.