IDENTIFICATION OF DROUGHT TOLERANT WHEAT GENOTYPES BASED ON SEEDLING TRAITS

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ABSTRACT

Drought significantly reduces yield of many crop plants including wheat in the world. Identification of wheat genotypes that can thrive on limited water is vital to boost the wheat production of rainfed areas. Forty wheat genotypes were screened for drought tolerance using 0, 7.5, 15 and 22.5% Polyethylene Ethylene Glycol 6000 solutions at PMAS Arid Agriculture University, Rawalpindi, Pakistan during 2009-10. Data were recorded on various seedling parameters like germination percentage, germination rate index, root length, shoot length, coleoptile length and seedling vigor. The seedling traits showed a decreasing trend in response to increased concentrations of PEG 6000. Wheat genotype Lyalpur-73 was found the best for germination percentage (87.5). The genotypes C-591 had maximum germination rate index (2.4). Wheat genotypes Pasban 90 and WC-18 possessed maximum root length (9.9) and seedling vigor (7.4) respectively. The genotype Auqab-2000 showed maximum shoot length (8.3). Wheat genotypes Pak-81 along with CB 335 had maximum coleoptile length (1.9). Germination percentage and germination rate index showed positive correlation with all other traits. Root length showed positive association with shoot length and coleoptile length. While shoot length had positive correlation with coleoptile length and seedling vigour.

Key Words: **Water Stress, Wheat, Seedling Traits, Drought Tolerance, Controlled Conditions**

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INRODUCTION

Wheat (*T. aestivum* L.) supplies one-third of the world population with more than half of their calories and nearly half of their protein. The forecasted global demand for wheat in year 2025 may rise up to 750 million tons (Mujeeb-Kazi and Rajaram, 2002). The most threatening problem in wheat production is the shortage of water at the seedling stage, mid season water stress, terminal stress or a combination of any two or three. Various factors affect the yield of a crop like seed germination, seedling vigor, growth rate, and mean emergence time and desiccation tolerance (Crosbie *et al*., 1980; Noorka *et al*., 2007).

Selection for drought tolerance at early stage of seedlings is most frequently practiced using poly ethylene glycol (PEG 6000) in the medium (Rauf *et al.,* 2006). PEG 6000 molecules are inert, non ionic and virtually impermeable chains and have frequently been used to induce water stress without causing any significant physiological damage to crop plants (Carpita *et al*., 1979). PEG can be used to modify the osmotic potential of nutrient solution culture and can induce plant water deficit in a relatively controlled manner, appropriate to experimental protocols (Lagerwerff *et al.,* 1961). Earlier studies focusing on identification of the drought tolerant wheat genotypes using different concentrations of PEG 6000 have showed significant differences for different seedling traits (Rauf *et al.,* 2006; Singh *et al.,* 2008). Significant differences among the wheat genotypes have also been observed for cell membrane stability (CMS), number of tillers and 100-seed weight. A positive correlation was observed between CMS and number of tillers in wheat (Shafeeq *et al.,* 2006). The seedling traits when pooled together could discriminate between drought tolerant and susceptible genotypes (Noorka and Khaliq, 2007).

Identification of wheat genotypes that can tolerate limited water condition is vital to boost the wheat production which can be achieved only by exploring maximum genetic potential from available germplasm of wheat. Knowledge of character association for seedling traits under water deficit conditions is also important for understanding yield limiting factors. The present study was planned to identify wheat genotypes which could tolerate well under water stress conditions.

MATERIALS AND METHODS

This study was performed in the Research Laboratory of the Department of Plant Breeding & Genetics, Pir Mehr Ali Shah Arid Agriculture University, Rawalpindi, Pakistan during 2009-2010. The research material comprised of 40 different wheat genotypes of diverse nature i.e. local land races, old and new approved varieties etc. (Table 1). PEG 6000 solutions treatments i.e. 0, 7.5, 15 and 22.5% were used to induce water stress to different wheat genotypes. Seeds of each genotype were placed on moist germination papers and PEG solution treatments were applied on the paper to provide appropriate moisture stress for seed germination. The Petri plates were kept in growth chamber at 25 °C. Mean data were determined for germination percentage, germination rate index, root length, shoot length, coleoptile length and seedling vigour. Simple correlation coefficient between different traits was also computed.

Table 1. ***List of wheat genotypes used in the study***

Sr.No.	Genotypes	Sr. No.	Genotypes
1	MH-97	21	WC-11
2	WC-10	22	Pak 81
3	LLR-1	23	GA-2002
4	LLR-20	24	Inqlab-91
5	Pasban 90	25	Bhakkar -2002
6	CB-335	26	WC-17
7	LLR-45	27	Rawal-87
8	WC-5	28	C-591
9	Margalla 99	29	WC-14
10	LLR-12	30	LLR-23
11	Chakwal 86	31	WC-2
12	CB-93	32	Altar-84
13	WC-15	33	WC-8
14	WC-18	34	Faisalabad-08
15	WC-16	35	Pavon-76
16	WC-6	36	Barani-83
17	LLR-25	37	Auqab-2000
18	WL-711	38	Lyalpur-73
19	Yecora 70	39	Chakwal-50
20	LLR-26	40	Blue silver

RESULTS AND DISCUSSION

Germination Percentage

Results showed that there was decrease in germination percentage at high concentration of PEG i.e. 22.5%. A perusal of Table III depicted that maximum germination (99.38%) was observed under control conditions followed by (90.63 %) in the treatment (T_1) where 7.5 % PEG was applied. The minimum germination (15 %) was observed in treatment (T_4) where 22.5 % PEG was applied. The genotype Lyalpur-73 showed maximum germination percentage (87.5 %) followed by Rawal-87 that showed 81.3 % germination (Table 2). The genotype LLR-25 showed minimum germination percentage i.e. 40.7 %. The present results are in accordance with findings of Rauf *et al*. (2006) and Ambawatia *et al.* (1995).

Germination Rate Index

Mean values regarding the germination rate index are displayed in Table II. The highest value of germination rate index was observed in control i.e. 2.91 which was followed by the treatment T_2 i.e. 2.21. The lowest value of GRI (1.34) was produced by treatment (T_4). The results are comparable with the findings of Baalbalki *et al.*, 1999 who reported that germination rate index was more sensitive to change in osmotic potential than germination percentage.

The genotype C-591 showed maximum germination rate index (GRI) of 2.4 followed by Chakwal 50 which had 2.2, while the genotype Altar-84 showed minimum germination rate index (0.5). Similar results were reported by Singh *et al.* (1994) and Akram *et al*. (1998).

Table 2. ***Mean values of various seedling traits for different wheat genotypes across four levels of Poly Ethylene Glycol***

Sr. No.	Genotypes	Germination Percentage	Germination Rate Index	Root Length (cm)	Shoot Length (cm)	Coleoptile Length (cm)	Seedling Vigour
1	Lyalpur-73	87.5	2.1	7.0	5.9	1.8	1232.0
2	Barani-83	68.8	2.0	7.1	6.3	1.3	1268.0
3	GA-2002	71.9	0.8	1.6	3.0	0.7	351.3
4	C-591	78.1	2.4	5.5	5.6	1.6	1077.0
5	Chakwal 86	59.4	1.3	5.8	4.8	1.2	918.4
6	Yecora 70	43.8	0.7	4.7	2.8	0.9	690.9
7	WL-711	75.0	1.8	5.3	4.6	1.1	918.3
8	Pavon-76	81.3	1.8	7.1	5.1	1.6	992.8
9	Blue silver	68.8	1.7	6.1	4.4	1.2	1027.0
10	Altar-84	62.5	0.5	5.8	4.0	1.1	956.9
11	Pak 81	65.6	2.0	7.5	6.4	1.9	1228.0
12	Pasban 90	75.0	2.3	9.9	8.1	1.8	1549.0
13	Inqlab-91	65.6	2.1	8.5	5.2	1.3	1155.0
14	Rawal-87	81.3	1.5	7.3	4.9	1.6	1025.0
15	MH-97	71.9	1.7	4.5	5.5	0.9	969.1
16	Margalla 99	75.0	1.7	7.2	6.4	1.4	1089.2
17	Chakwal-50	75.0	2.2	9.0	7.3	1.3	1440.2
18	Faisalabad-2008	62.5	1.1	8.7	4.4	1.2	1179.3
19	Auqab-2000	65.6	1.9	7.0	8.3	1.4	1182.3
20	Bhakkar -2002	81.3	2.1	7.5	4.6	1.5	1093.4
21	WC-2	56.3	1.6	1.2	5.0	1.3	520.9
22	WC-5	68.8	1.4	5.9	3.4	1.0	812.8
23	WC-6	62.5	1.6	5.9	3.6	1.0	780.9
24	WC-8	75.0	1.3	7.2	4.0	1.2	1068.0
25	WC-10	62.5	2.0	5.5	4.0	0.9	753.4
26	WC-11	50.0	1.6	8.0	4.4	0.8	909.1
27	WC-14	68.8	1.7	6.3	2.6	0.9	858.4
28	WC-15	50.0	1.1	2.4	1.5	0.5	336.6
29	WC-16	68.8	2.0	6.9	5.9	1.3	1132.0
30	WC-17	50.0	1.6	7.0	4.6	1.8	835.4
31	WC-18	75.0	1.9	9.6	7.4	1.3	1455.0
32	LLR-20	43.8	0.9	4.3	3.5	0.7	693.4
33	LLR-12	50.0	1.1	2.8	3.3	1.6	541.3
34	LLR-23	68.8	2.1	5.3	4.8	1.2	925.3
35	LLR-1	87.5	1.4	5.5	4.0	0.9	758.1
36	LLR-25	68.8	0.6	5.5	2.8	1.1	690.0
37	LLR-26	50.0	1.6	5.6	4.8	1.6	896.9
38	LLR-45	40.6	1.6	6.7	4.1	1.2	877.8
39	CB-93	75.0	1.4	8.2	4.4	1.1	1016.0
40	CB-335	56.3	1.0	8.8	3.9	1.9	1095.0

Root Length

Mean values regarding root length are given in Table 2. Reduction in root length was observed with an increase in concentration of PEG. The maximum root length (12.09) was recorded in control followed by the treatment T_2 (7.79) in which 7.5 % PEG was applied. The least root length (0.88) was observed in treatment T_4 in which 22.5 % PEG was applied. The genotypes Pasban-90 and WC-18 showed maximum root length i.e. 9.9 cm and 9.6 cm respectively. The genotype WC-2 showed minimum root length i.e. 1.2 cm. These results are similar to the findings of Rauf *et al.* (2006) and Singh *et al*. (1994).

Shoot Length

Mean values regarding shoot lengths are presented in Table 2. The shoot length decreased significantly by increasing moisture stress irrespective of genotypes. The highest shoot length (8.49 cm) was recorded in control followed by the treatment T_2 (6.16 cm). The least shoot length (0.66 cm) was recorded in treatment T_4 in which maximum amount of stress was applied. The genotypes Auqab-2000 and Pasban-90 showed maximum shoot length i.e. 8.3 cm and 8.1 cm, respectively. The genotype WC-15 showed minimum shoot length of 1.5 cm. These results are in corroboration with the findings of Akram *et al.* (1998) and Baalbaki *et al.* (1999).

Coleoptile Length

Mean values regarding coleoptile length (cm) are shown in Table 2. There was reduction in coleoptile length as concentration of PEG increased. Maximum value of coleoptile length (2.10 cm) was observed in control followed by treatment T_2 (1.52 cm). Minimum coleoptile length (0.243 cm) was observed in T_4 in which 22.5 % PEG was applied (Table 2).

Table 3. ***Mean values of various treatments of wheat genotypes under different stress levels***

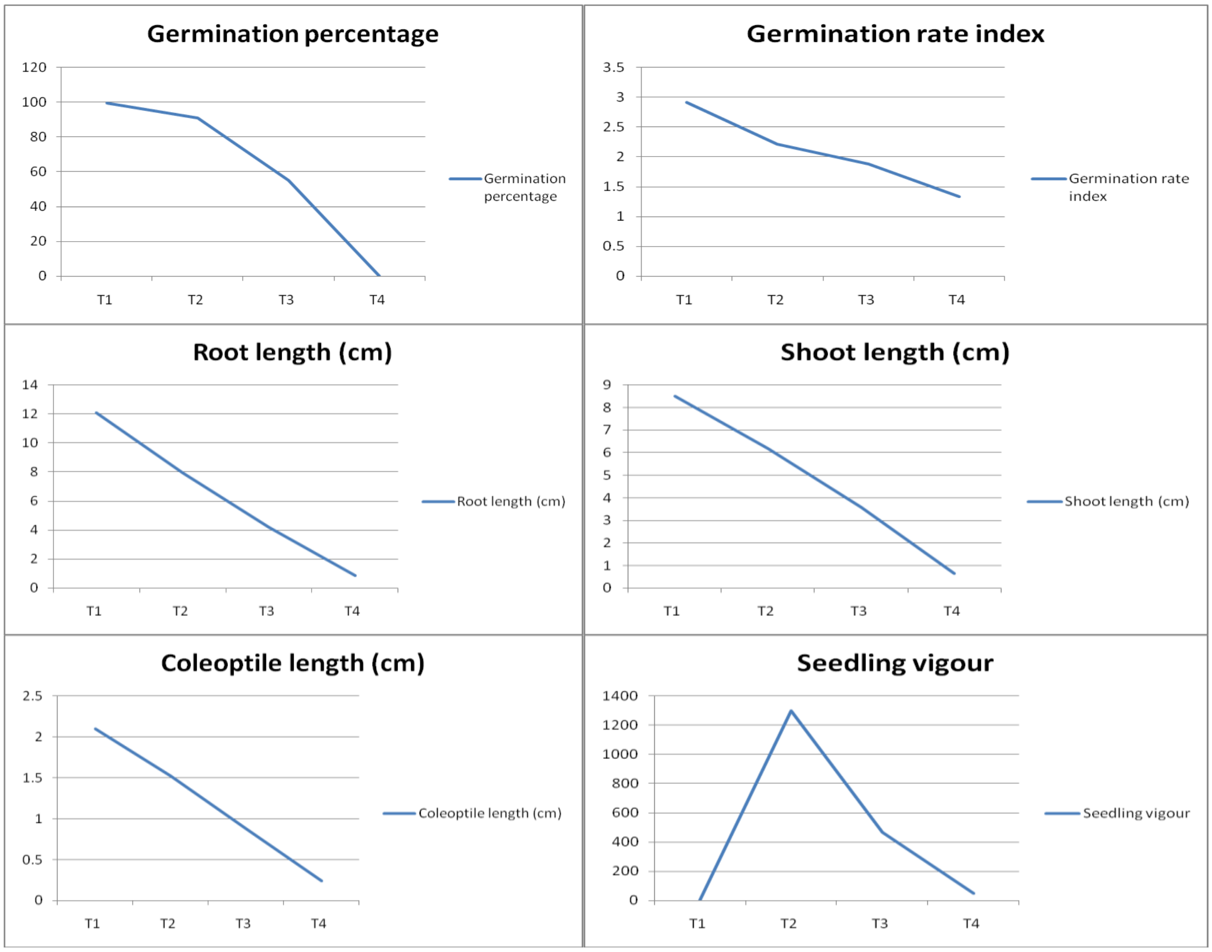
PEG levels	Germination percentage	Germination rate index	Root length (cm)	Shoot length (cm)	Coleoptile length (cm)	Seedling vigour
T_1 (0)	99.38	2.91	12.09	8.49	2.10	2024.
T_2 (7.5%)	90.63	2.21	7.97	6.16	1.52	1298
T_3 (15%)	55.00	1.88	4.19	3.57	0.88	467.4
T_4 (22.5%)	15.0	1.34	0.88	0.66	0.24	46.46

Two genotypes Pak-81 and CB 335 showed maximum coleoptile length of 1.9 cm. The genotype WC-15 showed minimum coleoptile length of 0.5 cm (Table 2). Similar results have already been reported by Boubaker and Hammouda (1997).

Seedling Vigour

The highest value of seedling vigour (2024) was observed in case of control, followed by T_2 with mean value of 1298 (Table II). The least value of seedling vigour (46.46) was recorded in case of T_4 in which maximum amount of stress was plasticized. The highest value of seedling vigour (1549.2) was shown by genotype Pasban-90, followed by WC-18 with mean value of 1455.5. Lowest value of seedling vigour (336.6) was shown by genotype WC-15.

Results revealed that response of all parameters become decreased by increasing PEG concentrations (Fig. I). Lyalpur-73 showed maximum value of germination percentage. The highest germination rate index was observed for C-591. Root length and shoot length were the highest for wheat genotypes Pasban-90 and Auqab-2000, respectively. Coleoptile length and seedling vigour were maximum in Pak-81 and Pasban-90, respectively. Early vegetative growth is a critical factor in wheat productivity under moisture stress conditions. Seedling germination and seedling vigor may lead to early vegetative growth. A deep and voluminous root system should permit seedlings to extract soil moisture in a greater soil volume. The influence of root architecture on yield and other agronomic traits, especially under stress conditions, has been widely reported in all major crops (Passioura, 1972; Ludlow and Muchow, 1990; Tuberosa *et al.,* 2002; de Dorlodot *et al.,* 2007). Rapid early development of leaf area and above-ground biomass, denoted as early vigor, contributes to a high yield due to shading of the soil surface, thereby reducing evaporation of water from the soil and leaving more water available for the crop. Greater early vigor can increase the crop's seasonal water use efficiency by as much as 25% (Siddique *et al.,* 1990), and it is recognized as a trait to select for to improve yield under water stress (Richards, 2000; Botwright *et al.,* 2002; Richards *et al.,* 2002). In more favorable environments, high early vigor may be beneficial by increasing seedling competitiveness against weeds, resulting in less need for herbicide use (Lemerle *et al.,* 2001). The genotypes excelling in various seedling



traits can be further used in hybridization programme for wheat improvement targeted for development of drought tolerant cultivars for rainfed areas of Pakistan.

Fig. 1. Graphs depicting response of studied seedling traits to different stress levels of PEG 6000

Correlation Studies

Simple correlation coefficient was calculated among all the characters (Table IV) and described as follows. Germination percentage showed a positive correlation with germination rate index while it shows a very strong positive correlation with root length, shoot length, coleoptile length and seedling vigour. Positive correlation showed that an increase in germination percentage would cause an increase in these parameters. These results are supported by the findings of Khan *et al.* (2002). Results of correlation analysis showed that germination rate index exhibited a positive association with all other parameters i.e. root length; shoot length, coleoptile length and seedling vigour. It showed that an increase in germination rate index will cause an increase in root length, shoot length, coleoptile length and seedling vigour. These results are in accordance of Singh *et al*. (1994).

Table 4. ***Correlation coefficient among various seedling traits of different wheat genotypes***

	Germination percentage	Germination rate index	Root length	Shoot length	Coleoptile length
Germination rate index	0.0523				
Root length	0.7992*	0.0582			
Shoot length	0.8152*	0.0520	0.8407*		
Coleoptile length	0.8524*	0.0431	0.8540*	0.8646*	
Seedling vigour	0.8508*	0.0620	0.9424*	0.9087*	0.8700*

* Significant at P < 0.05 level

Root length shows a strong correlation with shoot length and coleoptile length. Root length exhibited a very strong correlation with seedling vigour. A positive association indicated that increase in root length will also increase shoot length, root length and seedling vigour. These results are supported by the findings of Khan *et al.* (2002) and Baalbaki *et al*. (1999). Shoot length showed a positive and strong correlation with coleoptile length, while it exhibited a very strong correlation with seedling vigour. The findings infer that increase in shoot length will also cause an increase in these parameters. These results are supported by Akram *et al*. (1998). A strong and positive correlation was observed between coleoptile length and seedling vigour (Table IV). It showed that increase in seedling vigour will cause an increase in coleoptile length. These results are supported by Singh *et al.* (1994).

Germination percentage showed a positive correlation with germination rate index while it showed a very strong positive correlation with root length, shoot length, coleoptile length, and seedling vigor. These results are supported by the findings of Khan *et al*. (2002). Germination rate index exhibited a positive association with all other parameters i.e. root length, shoot length, coleoptile length and seedling vigor. These results are in accordance of Singh *et al*. (1994). While root length showed a strong correlation with shoot length and coleoptile length. Root length exhibited a very strong correlation with seedling vigor. These results are supported by the findings of Khan *et al.* (2002) and Baalbaki *et al*. (1999). On the other hand shoot length showed a positive and strong correlation with coleoptile length, while it exhibited a very strong correlation with seedling vigor. It means that increases in shoot length will also cause an increase in these parameters. These results are supported by Akram *et al.* (1998). A strong and positive correlation was found between coleoptile length and seedling vigor. These results are supported by Singh *et al*. (1994).

CONCLUSION AND RECOMMENDATIONS

The present study has helped to identify genotypes that can prove to be useful source for these traits. The genotypes identified include Pasban 90 and WC-18 (root length and seedling vigor), Pak-81 and CB 335 (coleoptile length). Drought tolerant traits like coleoptiles length and root length possessed by these genotypes can be incorporated into other high yielding and well adapted wheat varieties to get maximum plant population and yield under low moisture levels such as rainfed areas of Pakistan. These genotypes can also be utilized to develop mapping populations for seedling traits like root length and coleoptile length.

REFERENCES

Akram, H.M., N. Ahmed, A. Ali and A. Yar. 1998. Effect of stress on germination and seedling growth of wheat cultivars. J. Agric. Res. 36 (3): 217-222.

Ambawatia, G.R., T.R. Sahu, D.C. Garg and R.A. Khan. 1995. Germinability and early seedling growth of wheat genotypes under artificial moisture stress. Crop Res. Hisar. 9(1): 7-11.

Baalbaki, R.Z., R.A. Zurayk, M.M. Bliek and S.N. Talhouk. 1999. Germination and seedling development of drought tolerant and susceptible wheat under moisture stress. J. Seed Sci. Technol. 27 (1): 291-302.

Botwright, T.L., A.G. Condon, G.J. Rebetzke and R.A. Richards. 2002. Field evaluation of early vigor for genetic improvement of grain yield in wheat. Aust. J. Agric. Res. 53: 1137–1145

Boubaker, M. and M. Ben Hammouda. 1997. Screening durum wheat for drought tolerance at the seedling growth stage. Agric. Mediterranea. 127(3): 267-274.

Crosbie, T.M., J.J. Mock and O.S. Smith. 1980. Comparison of gains predicted by several selection methods for cold tolerance traits of two maize populations. Crop Sci. 20: 649-655.

Carpita, N., D. Sabularse, D. Mofezinos and D. Delmer. 1979. Determination of the pore size of cell walls of living plant cells. Sci. 205: 114-1147.

de Dorlodot, S., B. Forster, L. Page, A. Price, R. Tuberosa and X. Draye. 2007. Root system architecture: opportunities and constraints for genetic improvement of crops. Trends Pl. Sci. 12: 474-481.

Khan., M.Q., S. Anwar and M.I. Khan. 2002. Genetic variability for seedling traits in wheat (*T. aestivum* L.) under moisture stress conditions. Asian J. Pl. Sci. 1(5): 588-590.

Lagerwerff, J.V., G. Ogata and H.E. Eagle. 1961. Control of osmotic pressure of culture solutions with polyethylene glycol. Sci. 133(3463): 1486-1487.

Lemerle, D., G.S. Gill, C.E. Murphy, S.R. Walker, R.D. Cousens, S. Mokhtari, S.J. Peltzer, R. Coleman and D.J. Luckett. 2001. Genetic improvement and agronomy for enhanced wheat competitiveness with weeds. Aust. J. Agric. Res. 52: 527-548.

Ludlow, M.M. and R.C. Muchow. 1990. A critical evaluation of traits for improving crop yields in water limited environments. Adv. Agron. 43: 107-153.

Mujeeb-Kazi, A. and S. Rajaram. 2002. Transferring alien genes from related species and genera for wheat improvement. *In:* Bread wheat improvement and production, FAO. pp. 199-215.

Noorka, I.R. and I. Khaliq. 2007. An efficient technique for screening wheat (*Triticum aestivum* L.) germplasm for drought tolerance. Pak. J. Bot. 39(5): 1539-1546.

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

Passioura, J.B. 1972. The effect of root geometry on the yield of wheat growing on stored water. Aust. J. Agric. Res. 23: 745-752.

Rauf, M., M. Munir, M. Hassan, M. Ahmad and M. Afzal. 2006. Performance of wheat genotypes under osmotic stress at germination and early seedling growth stage. Afr. J. Biotech. 6: 971-975.

Richards, R.A. 2000. Selectable traits to increase crop photosynthesis and yield of grain crops. J. Exp. Bot. 51: 447–458.

Richards, R.A., G.J. Rebetzke, A.G. Condon and A.F. van Herwaarden. 2002. Breeding opportunities for increasing the efficiency of water use and crop yield in temperate cereals. Crop Sci. 42: 111–121

Shafeeq, S., M. Rahman and Y. Zafar. 2006. Genetic variability of different wheat (*Triticum aestivum* L.). Pak. J. Bot. 38: 1671-1678.

Siddique, K.H.M., D. Tennant, M.W. Perry and R.K. Belford RK. 1990. Water use and water use efficiency of old and modern wheat cultivars in a Mediterranean type environment. Aust. J. Agric. Res. 41: 431–447.

Singh, G.P., H.B. Chaudhary, Y. Rajbir and S. Tripathi. 2008. Genetic analysis of moisture stress tolerance in segregating populations of bread wheat (*T. aestivum* L.). Indian J. Agric. Sci. 78(10): 848-852.

Singh, G., V. Bhalla and G. Singh. 1994. Differential response of wheat genotypes to moisture stress for seed germination and early seedling growth. Indian. J. Agric. Res. 28 (2): 99-104.

Tuberosa, R., S. Salvi, M.C. Sanguineti, P. Landi, M. Maccaferri and S. Conti. 2002. Mapping QTLs regulating morphophysiological traits and yield: case studies, short communications and perspectives in drought stressed maize. Ann. Bot. 89: 941-963.