Research Article

# Response of Spring Wheat (*Triticum aestivum* L.) to Induced Water Stress at Critical Growth Stages

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**Abstract** | The extent of yield reduction with water deficit depends not only on the magnitude of water deficit but also on the stage of plant growth at which it develops. A pot study was conducted during 2011-12 at College of Agriculture, Dera Ghazi Khan, to assess the effect of induced water stress on performance of different wheat varieties at critical growth stages. Three wheat varieties viz. Faisalabad-2008, Lasani-2008 and Kohistan-97 were manually sown in polythene lined pots. Five water stress treatments were created by withholding the irrigation for specified time at critical growth stages *viz.* tillering, booting, anthesis and milking (grain filling), whereas a well-watered treatment was also included during whole plant growth and development period. The results showed that water stress significantly reduced plant height, number of total tillers per plant, number of fertile tillers per plant, number of nodes per plant, spikelet per spike, number of grains per spike, 100-grain weight and dry matter per plant as compared with control. Wheat genotype Faisal-2008 exhibited comparatively more drought tolerance with less decrease in growth rate (18.70%); total dry matter (26.94%), 100-grain weight (23.45%) and grain yield (21.50%) as compared with all other treatments. It was concluded that water stress induced at grain filling stage showed a significant impact on wheat growth as compared with other growth stage stresses. Regarding genotypes, Faisal-2008 was least affected by water stress than other varieties.

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## Introduction

Wheat is the main source of food in Pakistan. It adds 13.1% to the value added in agriculture and 2.7 percent to Gross Domestic Product (GDP). Wheat was cultivated on 8805 thousand hectares, presenting a reduction of 3.6% over previous year area of 9132 thousand hectares (Govt. of Pakistan, 2011). Like some other crops, if wheat is subjected to many biotic and abiotic stresses, yield will be reduced. The abiotic stresses include drought, heat, water logged, soils and soils with toxic levels of boron. All of these can pose serious problem for wheat farmer, especially in the less-favoured growing environment (Yagoub and El Hwary, 2011).

Wheat is the crop cultivated in arid and semi-arid parts of the world. Increasing wheat production under abiotic stress situations has attained significant attention in current years, because wheat production even in areas with ideal growing circumstances does not meet the needs of the growing population. Drought resistance is a broad term and could refer to any type of drought resistance processes such as drought es-


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cape, dehydration avoidance, or dehydration tolerance. Breeding wheat for drought resistance is a difficult and long-term job. Existing varieties were developed by production testing in a wide range of environment from fully watered to severely water stressed. Possibly physiologically based screening and selecting methods can be used to improve selection of parental material or to rapidly screen large segregation populations to progress the level of drought resistance prior to yield testing (Bhutta, 2006).

Water stress is one of the most important abiotic stress factors which are frequently supplemented by heat stress in dry season (Dash and Mohanty, 2001). Water stress is main abiotic restraint on crop production and food security, and harmfully affects the socio-economic fabric of many developing countries. Water stress is the most severe restraint for production of crop. The problem of water stress is threatening in the developing countries of the worldwide where about 37% of the wheat growing areas are semi-arid having low water availability and act as a restraining factor for higher yield (Rajaram, 2001). In Pakistan, approximately 80% of agricultural land is watered (irrigated), while the rest 20% is rainfed (Khan et al., 2010).

The role of genotypes under stressful conditions is of immense significance for sustainable crop husbandry. A plant type with high efficiency under limited moisture supply can grow more quickly resulting in higher grain yields. Hence, the present study was contemplated to screen wheat varieties showing less reduction of yield and growth under drought in semi-arid conditions of Dera Ghazi Khan (D. G. Khan), Pakistan.

## Materials and Methods

The planned study was conducted to evaluate the performance of three local wheat varieties to induced water stress at different critical growth stages. For this purpose pot experiment was carried out at College of Agriculture, D. G. Khan. The experiment was laid out in Complete Randomized Design (CRD) in factorial arrangements having three replications. Average temperatures in the net house were 20 ± 8°C during the day and 13 ± 5°C at night time during the experimental period. The relative humidity remained between 60% (midday) to 85% (midnight). Light intensity ranged between 360 and 1500 μmol photon $m^{-2}$ $sec^{-1}$ depending upon the day and cloud conditions. Three local wheat varieties *viz.* Faisal-2008, Lasani-2008 and Kohistan-97 were sown manually on 25th November, 2011, in pots lined with polythene and each pot contained 5 plants. The pot size was 32.5cm diameter of opening, 37.5cm height, and 22.5cm lower side diameter with capacity of 25 kg of soil per pot i.e Medium texture soil belonging to Sandy Clay Loam. Water stress condition was produced by withholding the irrigation at critical growth stages viz. $T_1$: water stress at tillering on 19th December, 2011 (25 days after sowing), $T_2$: water stress at booting on 31st December, 2011 (37 day after sowing), $T_3$: water stress at anthesis on 1st February, 2012 (64 days after sowing), $T_4$: water stress at grain filling on 15th February, 2012 (78 days after sowing), whereas a well-watered treatment was also included during whole plant growth and development period; $T_0$: Control on 31st December, 2011. Gravimetric water contents were measured from the sample drawn from the pots. 44.32 g (gravimetric soil water content) measured once at the start of experiment. The pots in the respective treatment were re-irrigated when gravimetric water content in the test pot reaches 50% of the soil water contents. The same procedure was followed for creating water stress at other critical stages of plant growth. Water applied to each pot was 4 liters with six to seven days interval. The crop was harvested on 31st March, 2012 and growth and yield parameters of crop were noted by using standard procedures.

The data collected was analyzed for analysis of variance to determine the significance of treatment using MSTAT-C (Freed, 1986). The treatment means were compared by Duncan Multiple Range DMR test at 1% significance level (Steel et al., 1997).

## Results and Discussion

The highest plant height was attained in control treatment, however, when stress was induced then higher height attained by Faisal-2008 while lower height was attained by Kohistan-97 (Table 1). The result clearly showed that water stress at critical stages decreased plant height considerably. In term of percentage, higher reduction in plant height was in 30.23% in Lasani-2008 when water stress induced at anthesis while plant height decreased lower in Faisal-2008 which was 3.11 when water stress induced at booting stage of wheat. Plant height reduced under induced water stress which might be due to the difference in genetic character among different cultivars as well as influences plant growth with insufficient availability of nutrients having moisture stress. These results are in accordance with finding of Sarwar et al. (2010) and Thompson and Chase (1992) who reported that significant relationship exist between genotypes and irrigation levels. Similarly, Inamullah et al. (1999) also observed that plant height in wheat varieties reduced significantly under water stress when it was compared with irrigated.

Higher spike length was attained in control treatment, while when stress induced then higher spike length attained by Faisal-2008 while lower spike length was attained by Kohistan-97 (Table 1). Decrease in percentage is higher in 16.37% in Lasani-2008 when water stress was induced at anthesis while lower decrease was recorded in 2.56% when water stress induced at tillering stage of wheat in Faisal-2008. Higher tillers were counted in control treatment, while when stress induced then higher total tiller produced by Faisal-2008, while lower total tillers were produced by Lasani-2008. It is clear from the result that water stress at critical stages decrease total tillers. Number of total tillers reduces under induced water stress, higher reduction in number of tillers was in 27.22% in Faisal-2008 when water stress induced at stress at anthesis, while lower decrease was in Lasani-2008, 2.19% when water stress induced at booting stage of wheat. It is clear from the result that water stress at critical stages decrease spike length. Akram (2011) found that water stress treatments showed non-significant result for the spike length. Result from another study shows that spike length was decreased when plants subjected to water stress. These results of present study regarding spike length was also similar with the results of Rauf et al. (2006), Akram et al. (2004), Jaleel et al. (2008), and Mirbahar et al. (2009) that skipping irrigation at different crop growth stages does not significantly affect the spike length of the different varieties of wheat.

Higher fertile tillers were counted in control treatment, while when stress induced then higher fertile tiller gotten by Lasani-2008 while lower fertile tiller was counted in Kohistan-97 (Table 1). It is clear from the result that water stress at critical stages decreased fertile tillers. Number of fertile tillers reduces under induced water stress; higher reduction in number of fertile tillers was in 42.69% in Kohistan-97 when water stress induced at tillering, while lower decrease was in Lasani-2008, 3.36% when water stress induced at booting stage of wheat. Khan and Naqvi (2011) found that number of tillers in irrigated plants showed non-significant differences between genotypes. All wheat varieties showed non-significant differences. Al-Tabbal (2011) stated that there is significant difference in number of fertile tillers among water treatment means was observed. Highly significant difference was found among cultivars means for number of fertile tillers.

Higher number of nodes was counted in control treatment, while when stress induced then higher total tiller attained by Lasani-2008, while lower number of nodes was counted in Kohistan-97 (Table 1). Number of nodes decreased in term of percentage was higher (18.69%) in Lasani-2008 when water stress induced at anthesis stage, on the other hand lower decrease was 2.68% in Kohistan-97 when water stress induced at tillering (Table 1).

Higher spikelet per spike was counted in control treatment, while when stress induced then higher spikelet per spike gotten by Faisal-2008, while lower spikelet per spike was counted in Kohistan-97 (Table 2). It is clear from the result that water stress at critical stages decrease spikelet per spike. In term of percentage decrease, higher decrease was recorded in Lasani-2008 which is 17.48% when water stress induced at anthesis stage, whereas lower decrease in spikelet per spike was found in Faisal-2008 which is 0.33% when water stress induced at grain filling stage. The decrease in number of spikelets per spike under water stress could be due to less spikelets primordial being formed during tillering or may be credited to floret death at the terminal and basal ends of the spike during stem extension. These result are in accordance with study of Sarwar et al. (2010) stated that irrigation treatments affect the number of spikelets per spike significantly.

Higher number of grain per spike were counted in control treatment, while when stress induced then higher number of grain per spike produced by Faisal-2008, while lower number of grain per spike was produced by Kohistan-97 (Table 2). Number of grains per spike decreased under induced water stress. Percentage decrease was higher in Kohistan-97 33.48% when water stress induced at grain filling, while lower decrease was in Kohistan-97 3.40% when water stress induced at booting stage. Number of grains decreased because of dehydration of pollen grains. Moreover, pollen grains germination tube growth down to the ovary and ovule was badly affected and finally number of grain per spike was reduced. Khanzada et al. (2001)

**Table 1:** *Performance of three local wheat varieties to induced water stress at critical growth stages*

| Water Stress Treatments | Variety | Plant Height (cm) | Spike Length (cm) | Total Tillers | Fertile Tillers | Number of Nodes |
|---|---|---|---|---|---|---|
| Control | $V_1$ | 64.33±1.50 | 10.83±0.25 | 9.37±0.24 | 7.63±0.77 | 4.28±0.15 |
| | $V_2$ | 73.88±2.48 | 11.55±0.25 | 8.70±0.38 | 6.55±0.59 | 4.55±0.11 |
| | $V_3$ | 63.66±1.15 | 11.10±1.12 | 8.47±0.17 | 6.77±0.44 | 4.11±0.11 |
| WS at Tillering | $V_1$ | 55.02±0.87 ( 85.52) | 10.55±0.22 (97.44) | 7.23±0.21 (77.13) | 6.10±0.58 (79.94) | 3.55±0.11 (82.94) |
| | $V_2$ | 52.74±0.48 (71.39) | 9.88±0.22 (85.55) | 6.82±0.54 (78.39) | 4.63±0.64 (70.68) | 4.22±0.22 (92.74) |
| | $V_3$ | 52.24±0.28 (82.07) | 10.33±0.38 (93.06) | 7.70±0.59 (90.90) | 3.88±0.23 (57.31) | 4.00±0.00 (97.32) |
| WS at Booting | $V_1$ | 62.32±2.03(69.89) | 10.44±0.40 (96.39) | 8.67±0.96 (92.52) | 5.66±1.07 (74.18) | 3.75±0.12 (87.61) |
| | $V_2$ | 60.10±2.81(81.36) | 10.55±0.40 (91.34) | 8.51±0.53 (97.81) | 6.33±0.19 (96.64) | 4.11±0.22 (90.32) |
| | $V_3$ | 57.77±1.85(90.74) | 10.22±0.58 (92.07) | 8.04±0.41 (94.92) | 6.44±0.59 (95.12) | 3.77±0.11 (91.72) |
| WS at Anthesis | $V_1$ | 56.22±1.98 (87.39) | 9.88±0.61 (91.22) | 6.82±0.87 (72.78) | 5.77±0.73 (75.62) | 3.78±0.22 (88.31) |
| | $V_2$ | 51.27±5.53 (69.40) | 9.66±0.61 (83.63) | 7.68±0.74 (88.27) | 5.00±0.84 (76.33) | 3.70±0.15 (81.31) |
| | $V_3$ | 61.23±1.49 (96.19) | 10.21±0.44 (91.98) | 7.90±0.45 (93.27) | 6.09±0.54 (89.95) | 3.66±0.38 (89.05) |
| WS at Grain Filling | $V_1$ | 58.66±1.35 (91.18) | 9.66±0.33 (89.19) | 8.45±0.66 (90.18) | 6.00±0.19 (78.63) | 3.66±0.19 (85.51) |
| | $V_2$ | 58.77±3.38 (79.77) | 9.66±0.33 (83.63) | 7.98±1.00 (91.72) | 5.96±0.30 (90.99) | 3.89±0.11 (85.49) |
| | $V_3$ | 60.88±0.29 (95.64) | 8.67±0.33 (78.10) | 7.19±0.25 (84.88) | 6.22±0.29 (91.87) | 3.89±0.11 (94.64 ) |

*WS = Water Stress; V1 = Faisal-2008, V2 = Lasani-2008, V3 = Kohistan-97; Values in parenthesis indicates % of respective control; Average of three replications ± Standard Error (S.E)*

**Table 2:** *Performance of three local wheat varieties to induced water stress at critical growth stages*

| Water Stress Treatments | Variety | Spikelet/Spike | Grains/Spike | Grain Yield / plant (g) | 100 Grains Weight (g) | Dry matter / plant (g) |
|---|---|---|---|---|---|---|
| Control | $V_1$ | 12.25±0.46 | 26.52±1.09 | 8.52±0.63 | 3.94±0.09 | 27.73±1.92 |
| | $V_2$ | 12.30±0.41 | 27.87±0.73 | 8.33±0.86 | 3.62±0.19 | 25.82±0.93 |
| | $V_3$ | 12.10±0.17 | 26.50±2.67 | 5.95±0.99 | 4.14±0.05 | 26.43±1.33 |
| WS at Tillering | $V_1$ | 11.91±0.45 (97.22) | 24.52±1.01 (92.45) | 7.39±0.33 (86.61) | 3.81±0.10 (96.70) | 27.56±0.80 (99.38) |
| | $V_2$ | 11.92±0.48 (96.91) | 24.63±1.78 (88.37) | 7.39±0.77 (88.71) | 3.48±0.13 (96.13) | 24.89±1.88 (96.39) |
| | $V_3$ | 11.54±0.40 (95.37) | 25.60±1.39 (96.60) | 5.74±0.09 (96.47) | 3.36±0.12 (81.15) | 25.43±0.66 (95.87) |
| WS at Booting | $V_1$ | 11.88±0.54 (96.97) | 24.62±1.24 (92.83) | 6.79±0.29 (79.69) | 3.72±0.05 (94.41) | 22.83±3.08 (82.32) |
| | $V_2$ | 10.98±0.56 (89.26) | 24.01±3.33 (86.14) | 5.76±0.50 (69.14) | 3.55±0.04 (98.06) | 23.26±3.00 (90.00) |
| | $V_3$ | 10.31±0.08 (85.70) | 20.49±1.07 (97.32) | 5.64±0.52 (94.78) | 3.48±0.11 (84.05) | 23.90±1.59 (90.42) |
| WS at Anthesis | $V_1$ | 11.69±0.77 (95.42) | 22.13±2.55 (83.44) | 5.99±0.29 (70.30) | 3.65±0.19 (92.63) | 24.29±1.73 (87.59) |
| | $V_2$ | 10.15±0.86 (82.52) | 19.18±5.36 (68.81) | 4.87±0.45 (58.46) | 3.22±0.60 (88.95) | 18.28±2.24 (70.99) |
| | $V_3$ | 11.40±0.21 (94.21) | 20.05±2.37 (75.66) | 4.80±0.80 (80.67) | 3.28±0.03 (79.22) | 21.24±3.32 (81.04) |
| WS at Grain Filling | $V_1$ | 12.21±0.53 (99.67) | 12.58±0.50 (47.74) | 4.46±0.23 (52.34) | 2.55±0.30 (64.97) | 23.01±2.60 (82.97) |
| | $V_2$ | 11.64±0.51 (94.36) | 21.59±1.06 (77.46) | 3.60±0.25 (43.21) | 2.55±0.27 (70.44) | 18.43±0.14 (71.37) |
| | $V_3$ | 11.60±0.35 (95.86) | 17.63±4.76 (66.52) | 4.51±0.15 (75.79) | 2.72±0.13 (65.70) | 15.36±1.44 (58.11) |

*WS = Water Stress; V1 = Faisal-2008, V2 = Lasani-2008, V3 = Kohistan-97; Values in parenthesis indicates % of respective control; Average of three replications ± Standard Error (S.E)*

reported that water stress at vegetative and reproductive stages caused a significant decrease in number of grains per spike in wheat. Moghaddam et al. (2011) found that the minimum number of grains per spike was found with the no irrigation before grain filling treatment. Irrigation and no irrigation treatment before stem elongation had non-significant difference in grains per spike.

Higher grain yield per plant was weighted in control treatment, while when stress induced then higher grain yield per plant attained by Faisal-2008, while lower grain yield per plant was attained by Lasani-2008 (Table 2). In term of percentage higher decrease was recorded in 56.79% when water stress induced at grain filling stage, while lower decrease 3.53% in Kohistan-97 when water stress induced at tillering. Grain yield might be reduced under induced water stress because of reduction in translocation from the leaves, and as water stress hastens the maturation and in addition to that decreases in photosynthesis caused lower grain yield. Khan and Naqvi

(2011) found that there is non-significant differences for grain yield among all genotypes under water stress conditions. Araus et al. (2003) verified that water stress in different wheat growing stages caused significant reductions in grain yield. Moreover, the effects of water stress caused by the severity of the stress and the developmental phase at which the plant faces water stress.

Higher 100-grain weight was weighted in control treatment, while when stress induced then higher 100 grain weight attained by Faisal-2008, while lower 100-grain weight was attained by Lasani-2008 (Table 2). The 100-grain weight in percentage higher decrease was recorded in Faisal-2008 which is 35.03 % when water stress induced at grain filling, while lower decrease was in 1.94% when water stress induced at tillering. Higher 100-grain weight with full irrigations might be due to the more translocation of photosynthates towards grain due to the sufficient amount of water in root zone. On the other hand plants having limited supply of water had produced lighter grain which might be due to the less availability of nutrients from soil solution. These results are also in agreement with Qadir et al. (1999) who observed that 1000-grain weight of wheat was reduced mainly due to increasing water stress. Kazmi et al. (2003) observed that water stress shriveled the grains and its degree depends on variety and water stress condition prevailed. The shriveling affect the weight of grains and final yield of crop is also affected.

Higher total dry matter was produced in control treatment, while when stress induced then higher total dry matter gotten by Faisal-2008, while lower dry matter was produced by Lasani-2008 (Table 2). Dry matter production was decreased by water stress. In term of percentage, higher decrease was noted 41.89% in Kohistan-97 when water stress induced at grain filling, while lower decrease was noted in Faisal-2008 which is 0.62% when water stress induced at tillering stage of wheat. Impact of different abiotic stresses including water stress is frequently perceived through dry weight production. Since, desiccation tolerance is accomplished by different metabolic activities that include the synthesis of osomotically active substances, specific proteins and by-products. According to Naserian et al. (2007) in irrigated conditions no significant differences were found in wheat varieties but in rainfed condition significant difference were found in wheat varieties. Moghaddam et al. (2011) found that highest grain yield produced at all irrigation treatment, while with applications of water stress treatment it was found that the dry matter production decreased by 10% at no irrigation before stem elongation, by 26% at no irrigation before flowering, and by 36% at no irrigation before grain filling.

## Conclusions

The results showed that water stress significantly reduced all parameters as compared with control. Wheat cultivar Faisal-2008 showed relatively more tolerance to drought with minimum reduction in growth rate (18.70%), total dry matter (26.94%), 100-grain weight (23.45%) and grain yield (21.50%) as compare with all other treatments. It was concluded that water stress induced at grain filling stage showed a significant impact on wheat growth as compared with other growth stage stresses. Regarding genotypes, Faisal-2008 was least affected by water stress than other varieties

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## References

- Araus, J. L, J. Bor., P. Stedut., D. Villega., C. Royo. 2003. Breeding cereal for Mediterranean conditions: ecophysiological clues for biotechnology application. Ann. Appl Biol. 142: 129-141
- Akram, H. M., M. S. Iqbal, M. Saeed, A. Yar, A. Ali and K. A. Sahi. 2004. Drought tolerance studies of wheat genotypes. Pak. J. Biol. Sci. 7:88-92
- Akram, M. 2011. Growth and yield components of wheat under water stress of different growth stages. Bangladesh j. Agril. Res. 36 (3):455-468
- Al-Tabbal J. A. 2011. Effect of water stress on the yield and yield component of durum wheat cultivars (*Triticum turgidum* L.var.durum). Int. J. acad. Res. 3 (6): 98-113
- International wheat production statistics. 2010. http://blog.econsultant.com/top-wheat-producing-countries-in-the-world
- Freed, R. 1986. Micro-computer program for the design, management and analysis of agronomic research experiments (MSTAT-C). Michigan State University, East Lansing, Michigan, USA.
- Bhutta, W. M. 2006. Role of some agronomic

traits for grain yield production in wheat (*Triticum aestivum* L.) genotypes under drought conditions. Revista UDO Agricola 6(1): 11-19

- Dash, S and N. Mohanty. 2001. Evaluation of assays for the analysis of thermotolerance and recovery potentials of seedlings of wheat (*Triticum aestivum* L.) cultivars. J. Plant. Phys. 158 (9): 1153-165
- Government of Pakistan. 2011. Economic Survey of Pakistan. Ministry of finance. http://www.finance.gov.pk/survey/chapter_11/02Agriculture.pdf.
- Inamullah, Z. A. Swati, A. Latif and Siraj-u-Din. 1999. Evaluation of lines for drought tolerance in wheat (*Triticum aestivum* L.). Scientific Khyber. 12 (2): 39-48
- Jaleel, C. A., R. Gopi, B. Sanker, M. Gomathinayagam and R. Panneerselvam. 2008. Differential responses in water use efficiency in two varieties of *Catharanthus roseus* under drought stress. Comp. Rend. Biol. 331:42-47
- Kazmi, R. H., M. Q. Khan and M. K. Abbasi. 2003. Effect of water stress on the performance of wheat grown under controlled conditions at Rawalakot, Azad Jamu and Kashmir. Sarhad J. Agric. 19 (1): 61-68
- Khan, A. J., F. Azam and A. Ali. 2010. Relationship of morphological traits and grain yield in recombinant inbred wheat lines grown under drought conditions. Pak. J. Bot. 42 (1): 259-267
- Khan, N. and F. N. Naqvi. 2011. Effect of water stress in bread wheat hexaploids. Curr. Res. J. Biol. Sci. 3 (5): 487-498
- Khanzada, B., S., A. Ala, M. Y. Ashraf, M. U. Shirazi, S. M. Alam, R. Ansari, M. Ali, Mukhtiar Ali, S. M. Mujataba and M. A. Khan. 2001. Effect of water stress on yield and yield components of different Guar (*Cyamopsis tetragonaloba* L.) genotypes. Pak. J. Biol. Sci. 4 (4): 371-374
- Moghaddam, H A., M. Galavi., H. R. Fanaei., S. H. A. Koohkan and O. Poodineh. 2011. Effects of deficit irrigation on grain yield and some morphological traits of wheat cultivars in drought - prone conditions. Int. J. Agri. Sci. 1 (4): 249-257
- Mirbahar, A. A., G. S. Markhand, A. R. Mahar. 2009. Effect of water stress on yield and yield component of wheat (*Triticim aestivum* L) varieties. Pak. J. Bot. 41: 1303 1310
- Naserian B., A. A. Asadi., M. Rahimi., and M. R. Aradkani. 2007. Evaluation of wheat cultivar and mutants for morphological and yield trait and comparing of yield components under irrigated and rainfed conditions. Asian J. Pl. Sci. 6 (2): 214-224
- Qadir, G., M. Saeed and M. A. Cheema. 1999. Effect of water stress on growth and yield performance of four wheat cultivars. Pak. J. of Bio. Sci. 2 (1): 236-239
- Rauf, M. Munir, M. Hussan, M. Ahmad and M. Afzal. 2006. Performance of wheat genotypes under osmatic stress at germination and early seedling growth stage. Afr. J. Biotech., 6 (8):971-975.
- Sarwar, N., M. Maqsood, K. Mubeen, M. Shehzad, M. S. Bhullar, R. Qamar and N. Akbar. 2010. Effect of different levels of irrigation on yield and yield components of wheat cultivars. Pak. J. Agri. Sci. 47 (3): 371-374
- Steel, R. G. D., J. H. Torrie and D. Dickey, 1997. Principles and Procedures of Statistics: Abiometrical Approach. 3rd ed. McGraw Hill Book Co., New York
- Thompson, J. A. and D. L. Chase. 1992. Effect of limited irrigation on growth and yield of semi dwarf wheat in Southern New South Wales. Aust. J. Exp. Agri., 32(6): 725-730.
- Rajaram, S. 2001. Prospects and promise of wheat breeding in 21st century. Euphytica, 119: 3-15.
- Yagoub, S. O. and A. El Hwary. 2011. Effect of Different Irrigation Intervals on Wheat (*Triticum aestivum* L) in Semiarid Regions of Sudan. J. Sci. and Tech. 12(3): 75-83.