Journal of Applied Biosciences 35: 2325- 2331
ISSN 1997–5902

The role of water deficit stress and water use efficiency on bread wheat cultivars

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Original submitted on 21st October 2010. Published online at www.biosciences.elewa.org on November 9, 2010

ABSTRACT
Objective: To study the effects of drought stress on yield and water use efficiency of three wheat cultivars under field condition.
Methodology and results: Two similar and concurrent experiments were carried out between 2007-2008 in the Dryland Agriculture Research sub-Institute Sararood and the Mahidasht Agricultural Research Center. The experiments were conducted based on split plot in a randomized complete block design with three replications. The main plots included drought stress treatments at 4 levels: I_1-drought stress at the start of stem elongation stage (31 Zadoks) through the ripening stage with irrigation after 80% depletion of soil moisture; I_2- drought stress at the start of boot stage (43 Zadoks) through the ripening stage with irrigation after 80% depletion of soil moisture; I_3- drought stress at the start of grain filling stage (70 Zadoks) through the ripening with irrigation after 80% depletion of soil moisture; and I_4- full irrigation (irrigation during growth period after 40% depletion of soil moisture). Subplots included cultivars treatments at 3 levels; Chamran (C_1), Marvdasht (C_2) and Shahriar (C_3). Results showed that yield, harvest index and water use efficiency were affected by drought stress (I_1 , I_2 and I_3), as plants in full irrigation treatment (I_4) produced the highest grain and biological yields, harvest index and water use efficiency. Water use efficiency varied from 0.66 to 1.34 kg.m^{-3} between irrigation regimes. Variation of grain yield and biological yield versus utilized water within 2 regions, in the form of linear regression, showed high correlation (R^2=0.71, R^2=0.82) between them, respectively, and that there was a correlation relationship between yield and water use efficiency.
Conclusion and application: The results of the present study showed that Sararood region wheat has higher economical yield, biological yield, and WUE than those of Mahidasht region. Despite the lower WUE in Mahidasht , its total water utilized amount was more than that of Sararood`s . Chamran cultivar (C_1) had higher yield stability than the others and its yield reduction under stress conditions was lower than others.
Keywords: Wheat, Water use efficiency, Drought stress, Correlation, Grain yield

INTRODUCTION
Wheat is the most basic calorie and protein source and one of the most important crops in the world especially in Iran. About 33 million ha of the world's wheat-cultivated lands, face drought damage of which is considerable at global level (Rajarm et al, 1995; Richards et al, 2001). Breeding programs are among the most efficient strategies in coping with water stress conditions in

arid and semi- arid regions. They introduce genotypes resistant to drought and to manage farming correctly (Frank & Blauer, 1996). Given limitation of water supply, Iran's near future conditions require change of irrigation programs by developing low irrigation methods and / or by culturing genotypes with high water use efficiency. Although water is considered as an input highly effective in increasing agricultural products, its utilization efficiency in production has no direct or linear correlation with increase in water use. (Gifford & Evans, 1981; Stewart & Nielsen, 1990). Water use efficiency is used in arid regions to evaluate produced crops for used water rate and is obtained through marketable yield or biomass over plant evapotranspiration (Hatfield et al, 2001; Allison & Jones, 2005). Ehdaie et al, (1991) reported genetic diversity for drought resistance or water use efficiency in wheat genotypes. In climatic arid- semiarid condition, wheat grain- filling period is concurrent with heat and drought period. Within such regions, focus of research is on selecting better early maturity cultivars with morphological and physiological characteristics commensurate to escape from end- season drought conditions, but little success has been attained in this field (Ehdaie et al, 1988). (Stanhill, 1986) introduced factors affecting water use efficiency by identifying these factors as water; carbon dioxide; temperature; plant species; plant photosynthetic pathway: stomatal plant behavior; leaf size, structure, and an array of soil characteristics. Presently, water may not be considered as a production limiting factor, but the necessity of revising irrigation and selection of better wheat genotypes to achieve cultivars having physiological and morphological characteristics suitable for higher efficiency of water utilization accompanied by high yield becomes important given prediction of near- future distribution of water supplies. The present research was done with the aim of studying the effect different moist conditions have on the yield and water use efficiency of three bread wheat cultivars in order to increase efficiency of water use and to increase production by the maximum amount of crops per unit irrigation. Also to identify resistant cultivars by eliminating irrigation or by deficit irrigating during growth stages which are less sensitivity to water stress.

MATERIAL AND METHODS

This research was conducted between 2007 and 2008 in the Sararood station of the Dryland Agriculture Research sub- Institute, Kermanshah, Iran which is (47°, 20′E; 34°, 20′ N), 1351 meter elevated from sea level, and also in the Mahidasht Research station of Kermanshah Agricultural Research Center, Iran which is (46°, 50′ E; 34°, 16′ N), 1380 meter elevated from sea level. Based on the Dumarten's climate classification method, the climate of both stations is cold semi-arid region. Soil type of Sararood station at test site was silty- clay – loam with EC= 1.3 $ds.m^{-2}$ and Ph=7.3. Mahidasht test site had loamy – clay texture with EC=1.4 $ds.m^{-2}$ and PH=7.5. The Main plots included four drought stress treatments, (I_1): Drought Imposed from onset of stem elongation stage (31 Zadoks) until maturity; (I_2): Drought Imposed from onset of Boot stage (43 Zadoks), (I_3): Drought Imposed from onset of grain- filling stage (70 Zadoks) and (I_4): full irrigation (test plots were fully irrigated during growth period and irrigation applied at 40% depletion of soil moisture until maturity). For I_1, I_2 and I_3 irrigation applied after 40% depletion of soil moisture before targeted growth stage and after that stage irrigation stopped. At the condition of 80% depletion of soil moisture, irrigation was applied until full maturity. The Subplots were three commercial cultivars, i.e.: Chamran(C_1) , Marvdasht (C_2), and Shahriar (C_3) and the planting date was 23rd November 2007. Based on soil analysis the required fertilizers were used as follows: 100 kg P_2O5/ha^{-1} and 60 kg N/ ha^{-1} prior to planting and 30 kg N/ ha^{-1} were used as topdressing in the tillering stage. Each plot consisted of 8 rows 20 cm apart and 4 meters long. One (1) and 2 meters distance was taken between test plots and blocks, respectively. The density was 400 seeds per square meter.

The first irrigation was carried out immediately after seed sowing. For each cycle of irrigation, water quantity was determined with respect to test plots areas and continuous measurement of test plots moisture with a WET HH_2 device. For the targeted growth stages, drought stress treatments were imposed through stopping irrigation and preventing rainfall from entering the plots by covering with rain-shelters. At the maturity stage, plants from 4th and 5th rows were harvested from each plot center. The grain yield, biological yield, and harvest index were measured. Water use efficiency (WUE) and evapotranspiration efficiency (ETE) were calculated using equation 1 and equation 2 based on Ehdaie & Waines, (1994), method respectively.

$$WUE\ (kg.m^{-3}) = \frac{Grain\ yield}{water\ used\ rate} \qquad (1)$$

$$ETE\ (kg.m^{-3}) = \frac{Biological\ yield}{water\ used\ rate} \qquad (2)$$

MSTATC and SPSS software were used to analyze the obtained data. Analysis of variance was performed on the targeted traits. Duncan's multiple range tests was used to compare means, and Excel software was used to construct diagrams.

RESULTS AND DISCUSSION

The results obtained showed that in the Sararood region wheat had higher economical yield, biological yield, and WUE than in the Mahidasht region. Despite lower WUE in Mahidasht region, total water used, was higher in this region than that of Sararood region. More water utilization with lower efficiency in Mahidasht region was possibly due to undesirable climatic conditions. In this region there was higher heat which shortened the wheat reproductive process in addition to raising the evapotranspiration rate as a result grain yield suffered more fluctuation than that of Sararood region. The result of the works done by other researchers also showed that heat is a factor limiting growth and yield (Giunta et al, 1993), and that the hot condition makes the plants have early maturity (Guera & Antonini, 1996). In the Mahidasht region, occurrence of heat, especially at final growth stages, decreased the duration of the reproductive stage and grain- filling period. Moisture stress had a significant effect on grain yield so that the highest and lowest grain yield was achieved for treatment I_4 and I_1, respectively. Royo et al, (2000) reported that drought stress from flowering to maturity stages, especially associated with high temperature, shortened the grain- filling period in triticale and reduced grain weight. Singh and Patel, (1996) studied the effects of drought stress at different stages of tillering, flowering, and grain- filling of wheat varieties and the experiments results showed that drought stress affected plant biomass distribution, grain yield, fertile spike number, grain weight, grain number per spike, and grain filling strength. Also, occurrence of drought stress during wheat anthesis time decreased stem dry weight, grain number and weight, grain yield, biological yield, and harvest index (Gupta et al, 2001). This is in agreement with the present research where Moisture stress had a highly significant effect on WUE .The Variation trend of WUE was almost similar to that of grain yield and there was a correlation between them.

So it can be concluded that grain yield increased more intensely as water utilization increased in the unit area resulting in an increase in WUE. Under moist stress condition at stages after stem elongation (I_1), booting (I_2), and grain- filling (I_3), a decrease in WUE in the unit area reduced yield compared to the control condition (I_4) which resulted in a decrease in WUE. These results are in agreement with reports of Lie et al, (2000) who demonstrated that weight of wheat grains was dependent on speed and duration of grain growth period affected by assimilation. Drought stress decreases the rate of assimilation production due to closing stomata. Final grain weight was higher for well- irrigated plants than that of those under drought stress condition due to longer duration of grain- filling period.

For WUE, conflicting results have been reported, by researchers like (Johnson et al, 1990 and Karam et al 2003) who reported an increase in WUE as water utilization rate decreased while

Shangun et al, (2000); Oktem et al, (2003) reported an increase in WUE as water utilization rate increased. Such differences are due to different climatic and soil conditions, different methods of exercising water treatment, and different cultivars used in the different experiments. But, generally, any managerial efforts of reducing water loss through pathways other than transpiration, increasing leaf area index of crops increased surface absorbing sunlight, decreased evaporation rate from soil surface, and therefore raised WUE (Andrade et al, 2002).

The difference between these cultivars was highly significant for grain yield, harvest index, and WUE ($P \leq 0.01$) and significant for biological yield ($P \leq 0.05$). Given that the longer part of the growth period of late maturity cultivars, Shahriar cultivar (C_3) is concurrent with high temperatures, its low WUE is possibly due to more evapotranspiration caused by environment heat. In their studies on wheat, Fischer and Mourrer, (1978) reported that more late maturity plants flower more slowly and, under water stress conditions, late maturity has a negative relationship with WUE. Lack of a significant difference between treatments and test region in terms of ETE indicates that the biological yield of studied cultivars decreased proportionally as water utilization decreased. The highest and lowest rates of grain yield, harvest index, and biological yield were related to Chamran cultivar and Shahriar cultivar (C_3), respectively. Accounted for the highest yield among test cultivars, cultivar Chamran (C_1) had higher WUE than others and the difference increased as intensity of drought stress increased. Generally, the results showed that among other cultivars, Chamran cultivar (C_1) had more yield stability and its yield reduction was lower than that of others under less stressed conditions. So it can be said that Chamran cultivar (C_1) had more yield stability both under desirable and stress conditions. In this experiment , it was observed that compared to control treatment (I_4) , treatments (I_1) , (I_2) , and (I_3) had 47% , 37% , and 31% yield decrease , respectively , on one hand and 46% 28% and 15% WUE reduction , respectively. Such differences show that the cultivars used in the experiment were susceptible to water stress conditions and their grain yields decreased sharply as soil water content decreased. Given the WUE reduction in the treatments I_1 , I_2 , and I_3 in comparison with control treatment I_4 , it can be stated that deficit irrigation condition during growth period reduces WUE due to yield reduction, resulting in waste of large amount of water per unit area. Munes- Perea et al, (2007) reported that water use efficiency (WUE) is grain yield to water utilization ratio generally begin inversely proportional to these cultivars of drought stress, that is, 25% reduction in grain yield caused by drought stress begin expressed as drought intensity. Frahm et al, (2004) and Teran et al , (2002) reported that stress reduces (20% - 100%) overall plant growth or biomass yield, number of grains, harvest index , grain yield , grain weight , and grain quality in dry bean , which are in agreement with this study's results.

Experimental results showed that under drought stress conditions, wheat cultivars WUEs were significantly lower than under non- stress conditions (control). Under control (I_4) conditions , WUE mean was 1.288 kg.m^{-3} for all cultivars , but equal to 0.70 , 0.93 , and 1.11 kg.m^{-3} for stress treatments I_1 , I_2 , and I_3 , respectively . Interaction effect of water stress and cultivar on harvest index and WUE was highly significant ($P \leq 0.01$) . The highest and lowest rates of WUE and harvest index were observed with Chamran cultivar (C_1) and treatment I_4 and Shahriar cultivar (C_3) and treatment I_1, respectively. Percent variations of WUE were different for each cultivar in control treatment (I_4) and stress treatment (I_1 , I_2 , I_3) as follows : for treatments I_1 , I_2 , and I_3 , respectively , 1.13 , 1.28 , 1.81 for Chamran cultivar (C_1) ; 1.18 , 1.41 , 1.80 for Marvdasht cultivar (C_2) ; and 1.17 , 1.44 , 1.83 for Shahriar cultivar (C_3).

Correlation between water used and biological yield is lower than that with grain yield, indicating higher effect of water used on grain yield. The results obtained show that grain yield reduces with a decrease in water amount used. Changes in grain yield versus water used in 2 regions, in the form of linear regression show high correlation (R2

= 0.71) between these 2 variables. Regression coefficient is 0.011 between grain yield and ET, for which Singh et al., (1980) and Deju & Jingwen, (1993) obtained coefficients 0.013 and 0.010, respectively. The relationship between biological yield and amount of water plant used shows that in 82% of cases, there is desirable correlation between yield and ET changes in which case curve slope equals to 0.037. With regression coefficient of 0.048 and R^2 between and 0.91 until 0.98 and R^2 = 0.96, Gajeri & Prihar (1983) and Deju & Jingwen (1993), respectively, found a highly strong relationship between yields and ET with different irrigation regimes.(Table 1,2)

Table 1: Effect of cultivar and deficit Irrigation on grain yield and traits evaluated In two regions Sararood and Mahydasht .

Water stress	GY ($kg.h^{-1}$)	BY ($kg.h^{-1}$)	HI (%)	WUE ($kg.m^{-3}$)	ETE ($kg.m^{-3}$)
I_1	3576 d	10600 c	32.90 d	0.7083 d	3.566 a
I_2	4210 c	12440 b	34.71 c	0.9378 c	2.343 a
I_3	4607 b	11780 b	40.208	1.106 b	2.286 a
I_4	6632 a	13690 a	49.41 a	1.288 a	2.482 a
Cultivar					
C_1	4.999 a	12610 a	40.27 a	1.082 a	2.806 a
C_2	4849 a	12230 ab	39.68 b	1.014 b	2.611 a
C_3	4428 B	11520 b	37.36 c	0.9342 c	2.590 a
Experimental location					
Mahydasht	4639 b	11956 a	38.51 b	0.992 b	2.618 a
Sararood	4873 a	12280 a	40.08 a	1.028 a	2.720 a

Mean followed by similar letters in each column are not signitifinty different at 5% probability level using Duncan`s Multiple Range Test. GY: grain yield; BY: biological yield; HI: harvest index; WUE: water use efficiency: ETE: evapotranspiration efficiency; I1, I2, I3 and I4.

Eighty 80% moisture depletion from stem elongation to end season; 80% moisture depletion from boot stage to end season ;80% moisture depletion from grain filling to end season ; and 40% moisture depletion during growing season(Control);C1,C2 and C3: Chamran, Marvdasht and Shahriar cultivars.

Table 2: Coefficients of correlation between different traits on two regions.

Traits	GY	BY	HI	WUE	ETE	TWE
GY	1					
BY	0.606**	1				
HI	0.930**	0.585**	1			
WUE	0.884**	0.578**	0.901**	1		
ETE	0.421**	-0.309**	-0.405**	-0.644**	1	
TWE	0.549**	0.242**	0.551**	0.520**	0.580**	1

Ns, * and **: not significant, significant at 5% and 1% levels, respectively. GY: grain yield; BY: biological yield; HI: harvest index; WUE: water use efficiency: ETE: evapotranspiration efficiency; TWE: total water used

CONCLUSION

The results of the present study showed that Sararood region wheat has higher economical yield, biological yield, and WUE than those of Mahidasht region. Despite the lower WUE in Mahidasht , its total water utilized amount was more than that of Sararood`s . Chamran cultivar (C_1) had higher yield stability than the others and its yield reduction under stress conditions was lower than others. In regions facing water shortage, irrigation deficit method can be on appropriate management regime to increase WUE and cultivated area. Under drought and aridity conditions, irrigation deficit technique can increase the crop economic profit by maximizing crop production per unit of irrigation water. The fundamental aim of irrigation deficit technique is to increase WUE with irrigation adequacy increase (English , 1990 ; Krida & Kanber , 1999) .

REFERENCES:

Allison, E. and C Jones. 2005. Plant water relations. Montana State University. Extension paper No. 4481-5.P.7.

Andrade, F. H. Echarte, L., Rizzalli, R, Della Maggiora, A and Casanovas, M. 2002. Kernel number predication in maize under nitrogen or water stress. Crop Sci. 42: 1173-1179.

Deju, Z. and jingwen, L.1993.The water use efficiency of winter wheat and maize on a salt- affected soil in the Huang Huai Hai river plain of China.Agri.Water manage.23:62-82.

Ehdaie, B., A, E, Hall, G, D, Farquhar, H, T, Ngugen. and J. G. Waines. 1991. Water use efficiency and carbon isotope discrimination in wheat. Crop Sci. 31: 1282-1288.

Ehdaie, B., and Waines, J. G. 1994. Growth and transpiration efficiency of near isogenic lines for height in spring wheat. Crop Sci. 34: 1443-1451

Ehdaie, B., J. G. Waines. and A, E, Hall. 1988. Differential responses of landrace and improved spring wheat genotypes to stress environment. Crop Sci. 28: 838-848.

English, M. 1990. Deficit irrigation. I. An analytical frame work. J. irrig. Drainage ASCE, 116:399-412.

Fischer R. A, Maurrer. 1978. Drought resistance in spring wheat cultivars. I. grain yield responses. Aust. J. Agric. Res. 29:897-912.

Frahm, M. A., Rosas, J. C., Mayek-Perez, N., lopez-Salinas, E., Acosta- Gallegos, J. A., J. D. Kelly. 2004. Breeding beans for resistance to terminal drought in the lowland tropics. Euphytica. 136:223-232.

Frank, A.B and A, Blauer. 1996 . Temperature, nitrogen and carbon dioxide effects on spring wheat development and Spikelets number . Crop Sci . 36: 659-665.

Gajeri, P. R. and prihar, S. S . 1983. Effect of small irrigation a mounts on the yield of wheat. Agri. Water Manage. 6: 31-41.

Gifford, R.M. and L.T. Evans . 1981 . photosynthesis carbon partitioning , and yield . annu . Rev . plant physiology . 32: 485-509.

Giunta, F., Motzo, R., and Deidda, M. 1993. Effect of drought on yield and yield components of durum wheat and triticale in Mediterranean environment. Field Crop Res. 33: 339-499.

Guera, A. F., and Antonini, J. C. D. 1996. Time for stopping irrigation on wheat crop. Pesquisa Brasileira. 31: 823-828.

Gupta, N. K., Gupta, S., and Kumar, A. 2001. Effect of water stress on physiological attributes and heir relationship with growth and yield of wheat cultivars at different stages. Wheat, Barley and Triticale Abstracts. 18. 497.

Hatfield, J.T.J. Saauer and J.H. Pruger . 2001. Managing soils to achieve greater water use efficiency. A. Review. Agron. 93:271-280.

Johnson, D. A., K. H. Asay, L. L. Tieszen, J. R. Ehleringer, and P. G. Jefferson. 1990. Carbon isotope discrimination: potential in screening cool- season grasses for water- limited environments. Crop Sci. 30-338-343.

Karam, F., Breidy, J. Stephn, C. and Rouphael, J. 2003. Evapotranspiration, yield and water use efficiency of drip irrigated corn in the Bekaa Valley of Lebanon. Agriculture Water Management. 63:125-137.

Kirda, C. & kanber, R. 1999. Water No longer a plentiful resource, should be used sparingly in irrigated agriculture. In: C. kirda, P. Moutonnet, C. Hera and D. R. Nielsen, eds. Crop Yield Response to Deficit Irrigation, Dordrecht, The Netherlands, Kluwer Academic Publishers.

Lie, A. G, Hou, V. S, Wall. G. W. Trent, A, Kimball and Printer, P. J. 2000. Free- air CO_2 enrichment and drought stress effect on grain filling rate and duration in spring wheat. Crop Sci. 40: 1263-1270.

Munez-Perea, C. G., R. G. Allen, D. T. Westermann, J. L. Wright and S. P. Singh. 2007. Water use efficiency among drybean Landraces and cultivars in drought-stressed and non-stressed environments. Euphytica, 155: 393-402

Oktem, A., Simsek, M. and oktem, A. G. 2003. Deficit irrigation effects on sweet corn (Zea mays saccharata sturt) with drip irrigation system in a semi- arid region. I. water yield relationship. Agriculture Water Management. 61: 63-74.

Rajaram ,S., Braun , H.J ., Van Ginlel , M ., and Tigerstedet , P.M.A. 1995 . CIMMYT`S a approach to breed for drought tolerance. Euphytica. 92 (1-2): 147: 153.

Richards, R.A., condon, A. G., and Rebetzke, G. J. 2001. Traits to improve yield in dry environments. PP. 88-100. In: Reynolds, M.P., Ortiz- Monasterio .J.I., and MCNab,A. (eds) . Application of physiology in wheat Breeding . Mexico, O.F.CIMMYT.

Royo, C. Abaza, M, Blanco, R, Garcia delMoral, L. F. 2000. Triticale grain growth and morphometry as affected by drought stress, late sowing and sirnlated drought stress. Aust. J. Plant Physiol. 27:1051-1059.

Shangguan, Z. P, Shao, M. A, Dyckman S, J. 2000. Nitrogen nutrition and water stress effects on leaf photosynthetic gas exchange and water use efficiency in winter wheat. Environmental and experimental botany. 44:141-149.

Singh, G., Singh, P. N. and Bhushan, L. S. 1980. Water use and wheat yields in northern India under different irrigation regimes. Agri. Water Manage. 3: 107-114

Singh, J and A, L, Patel. 1996. Dry matter distribution different parts of wheat under water stress at various growth stage. Field Crop. Abstracts. Vol. 49. No. 11.P:10-16.

Stanhill, G. 1986. Water use efficiency. Adv. Argon. 39: 53-85.

Stewart, B.A ., and D.R . Nielsen . 1990 . Irrigation of Aricultural crops . ASA . No . 30 . Madison , Wisconsin .

Tera`n H., S. P. Singh. 2002. Comparison of sources and lines selected for drought resistance in common bean. Crop Sci. 42: 64-70.