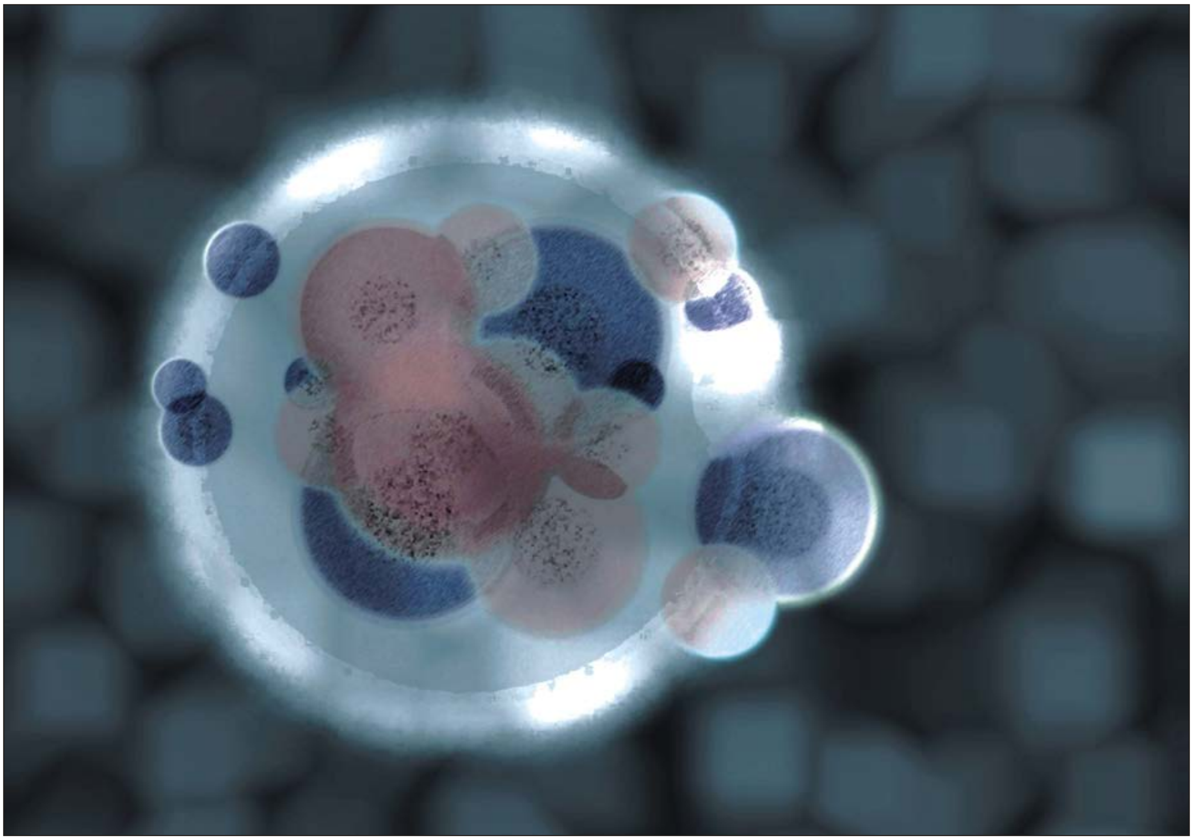

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Water Use Efficiency in Wheat Grown Under Drought Conditions

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Abstract: The effect of irrigation regimes on wheat productivity and Water Use Efficiency (WUE) was investigated under subtropical arid conditions. Results showed that irrigation regimes significantly affected grain, straw and biological yields/ha. Grain, straw and biological yields were significantly increased as the volume of irrigation water increased. Irrigation regime of 9750 $m^3 ha^{-1}$ recorded the highest WUE for grain, straw and biological yields.

Key words: Wheat, Gemmiza 5, irrigation, drought, yield, water use efficiency

INTRODUCTION

Kingdom of Saudi Arabia lies in the subtropical arid zone of the northern hemisphere, extending from Northern Africa, Saudi Arabia and Iran to Mongulia (Al-Taher, 1992). The dryness of air reaching Saudi Arabia and the consequent lack of cloud insulation produces high temperatures. The high temperature increases the evaporative losses from open water surfaces to 3600 mm, against an annual precipitation of less than 100 mm (Al-Barrak, 1993). This amount of rainfall is insufficient to sustain agricultural production which results using high amount of irrigation water for crop production. One of most important environmental factors determining crop growth and yield is water stress, which plays a very important role inhibiting crop yields. Water shortage which dramatically appeared in recent year in Saudi Arabia is a serious inconsistency aspect in the use of water resources worldwide. Therefore, crop production under irrigation in Saudi Arabia is severely constrained by water limitation in water resources (Rogers and Lydon, 1994)

Recently, numerous studies dealing with crop production and water use efficiency under irrigation showed that proper irrigation intervals can increase crop yield, by improving soil water condition and their water use efficiency water (Richards *et al*., 2002; Deng *et al*., 2002; Zhang *et al*., 2004, 2006; Wichelns, 2002; Kirnak *et al*., 2002).

Wheat (*Triticum aestivum vulgare* L.) is the major cereal crop in the Kingdom of Saudi Arabia. Its annual production is estimated to be 2.082 million tons in 2001 (Statistical Year Book, 2002). Grain yield of wheat depends on many factors that influence plant growth and productivity. Water deficit was extensively reported to limit wheat productivity more than any other environmental factors. Causing marked reduction in yield (Gupta *et al*., 2001; Mahey *et al*., 2002; Kang *et al*., 2002; Wenlong *et al*., 2004; Zhang *et al*., 2006; Rafiq *et al*., 2005; Baghani and Ghodsi, 2004). In recent years most researchers are focusing on optimizing crop production with highest water use efficiency in irrigation particularly under arid and semiarid region (Kirnak *et al*., 2002; Zhang *et al*., 2006). The objective of the present study was to evaluate water use efficiency by regulating irrigation intervals to improve wheat production under irrigated condition.

MATERIALS AND METHODS

This study was conducted at the Agricultural and Veterinary Training and Research Station, King Faisal University during the winter seasons of 2002/2003 and 2003/2004. The experiment was carried out complete randomized block designed with four replicates. The four irrigation treatments are:

- Irrigation every 5 days with a 500 m^3/ha/irrigation, consuming 13950 m^3/ha/season.
- Irrigation every 10 days with a 650 m^3/ha/irrigation, consuming 9750 m^3/ha/season.
- Irrigation every 15 days with a 800 m^3/ha/irrigation, consuming 8350 m^3/ha/season.
- Irrigation every 20 days with a 950 m^3/ha/irrigation, consuming 7650 m^3/ha/season.

Irrigation treatments were started 35 days after sowing and stopped at 155 days after sowing. The volume of water received before treatment application was 1950 m^3 ha^{-1} (950 m^3 immediately after sowing+two irrigations applied at 15 and 25 days after sowing, each with 500 m^3 ha^{-1}). Rainfall was not included because it was rare during both the seasons of study.

Table 1: Main Properties of the used soil used for the experiments

Salinity (E.C) d Sm^{-1}	pH	$CaCO_3$ (%)	Org (%)	Particle size distribution (%) Sand	Silt	Clay	Textural class
4.4	7.80	7.00	0.5	85	10	4	Loamy sand

Soil analysis of the experimental field for samples taken randomly from the upper 30 cm of the soil surface is shown in a Table 1.

The experimental field area was well prepared through two perpendicular plows, good harrowing, leveling and divided into main and sub-plots. Seeds of wheat, "CV Yokoroga" at the rate of 200 kg ha^{-1} were hand drilled in rows, 20 cm apart. Thereafter, the field area was watered. Sowing date was the first week of November in both the seasons. Wheat plants were fertilized with nitrogen in the form of urea (46.6% N) at the rate of 180 kg N ha^{-1}, which was applied in three split doses of equal proportional, the first dose was broadcasted prior planting during land preparation. The second dose was applied at 35 days after sowing (tillering stage) and the third dose was added at panicle initiation stage. Other recommended agricultural practices for wheat production were followed.

At maturity, 170 days after sowing, i.e. when wheat plants turned a straw color and grains became solid, ten guarded plants were randomly collected from each replicate to estimate the following characters: Plant height (cm), number of grains/spike and 100-grain weight (g). Plants in the central square meter in each plot were harvested, tied, left for drying, and weighted to the nearest gram to estimate the yield (Straw+grains) and converted to record biological yield in ton ha^{-1}. Thereafter, wheat plants were threshed; grains and straw were separated and estimated in g m^{-2}, which was converted to record grain and straw yields in t ha^{-1}. The Water Use Efficiency (WUE) for grain, straw and biological yields were calculated by dividing the yield of each by the amount of water added (m^3) in each treatment (Stanhill, 1987).

Statistical analysis: Data obtained data in the two seasons were subjected to proper combined analysis of variance of the complete randomized block design, according to Gomez and Gomez (1984). To satisfy the assumptions of the ANOVA model, the homogeneity of the variances was verified using Bartlet's test. New Least significant difference (NLSD) at 0.05% level of significant was used to compare the treatment means (Waller and Duncan, 1969). Analysis of variance (ANOVA) and computations were done using SAS Version 8.0 (SAS, 2001).

RESULTS AND DISCUSSION

The chemical and physical properties of the soil experimental area were characterized by sandy loam texture, calcareous with low organic matter, low available moisture which is probably due to the texture of soil with nearly neutral to slightly alkaline pH. This type of soil was reported to need frequent irrigation (Al-Barrak, 1993; Al-Jabr, 2002). The data presented in Table 2 show that irrigation intervals (expressed in amount of irrigation water) significantly affected all estimated characters. Plant height was significantly decreased as amount of irrigation water was less than 9750 m^3 h^{-1} (10 days irrigation intervals). This trend was also noticed in number of grain/spike and 100 grain/wt. Similar results were reported by Rafiq *et al.* (2005), Abdorrahmani *et al.* (2005) and Bakhshandeh *et al.* (2004). Grain, straw and biological yields were significantly higher under the highest amount of irrigated water and thus there was a significant decrease with each decline in the amount of irrigated water (Table 2). The reduction in grain yield with the decrease of irrigation amount from 13950 and 9750 to 7650 was 1.43 (69%) and 1.82 (55%), respectively. It seems that the reduction of grain yield was much associated with reduction in both weight and number of grain indicating that irrigation water of 7650 m^3 ha^{-1} used in the present study did affect both pollination processes and accumulation of assimilate required for grain filling. Similar conclusion was reported in barley grown under the same condition (Al-Khateeb, 2006).

The reduction of growth and grain yield of wheat grown under drought condition was extensively reported (Behera *et al.*, 2002, Eitzinger *et al.*, 2002);

Water use efficiency expressed in grain, straw and biological yield was significantly higher under 9750 m^3 ha^{-1}. There was no significant differences in water use efficiency between 13950 and 8350 m^3 ha^{-1}. The lowest water use efficiency was significantly reported under 7650 m^3 ha^{-1} (Table 3).

Regressions between volume of irrigation water and grain yield gave positive nonlinear correlation with good coefficient of determination r^2 = 0.75 (Fig. 1), while regression between volume of irrigation water and water use efficiency had also non linear correlation but with intermediate coefficient r^2 = 0.57 (Fig. 2). Non linear relationship between volume of irrigated water and both grain yield and water use efficiency showed 12000 m^3 ha^{-1}

Table 2: Averages of plant height (cm), number of grain/spikes, 100-grain weight as well as grain, straw yields and biological yield (t ha^{-1}) as affected by irrigation treatments (Combined over both seasons)

Irrigation interval	Irrigation water (m^3/ha/season)	Plant height (cm)	grain /spike (No.)	100-grain wt.	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})
5 days	13950	81.1	64.4	4.7	6.924	7.555	14.479
10 days	9750	83.1	61.1	4.8	5.839	6.350	12.189
15 days	8350	75.4	45.8	4.1	3.983	5.256	9.239
20 days	7650	61.4	37.5	3.7	2.624	2.973	5.597
NSD 5%		5.2	6.0	0.4	0.481	0.658	0.852

Table 3: Averages of Water Use Efficiency (WUE) for grain, straw and biological (grain+straw) yield as affected by irrigation treatments (Combined over both seasons)

Irrigation interval	Irrigation water (m^3/ha/season)	Water use efficiency (kg m^{-3}) Grain	Straw	Grain+Straw
5 days	13950	0.50	0.54	1.04
10 days	9750	0.60	0.65	1.25
15 days	8350	0.48	0.63	1.11
20 days	7650	0.34	0.39	0.73
NLSD 5%		0.11	0.14	0.21

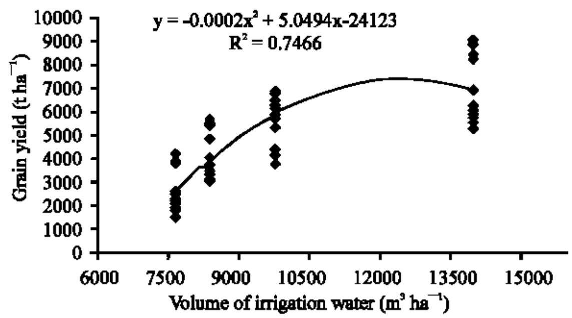

Fig 1: The relation between Grain yield (kg ha^{-1}) and volume of applied irrigation water (m^3 ha^{-1})

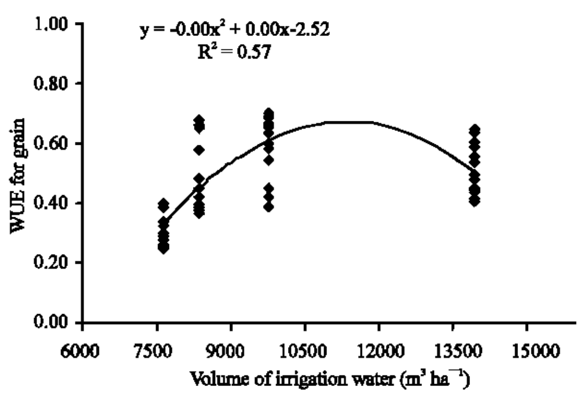

Fig. 2: The relation between water use efficiency (kg grain m^{-3} water) and the volume of irrigation (m^3 ha^{-1})

irrigation water as the critical value for maximum grain yield and water use efficiency of wheat under local condition. On the other hand maximum water use efficiency (0.65 kg m^{-3}) (Fig. 2) reached under 10500 m^3ha^{-1} of irrigation water (Fig. 2). This may indicate

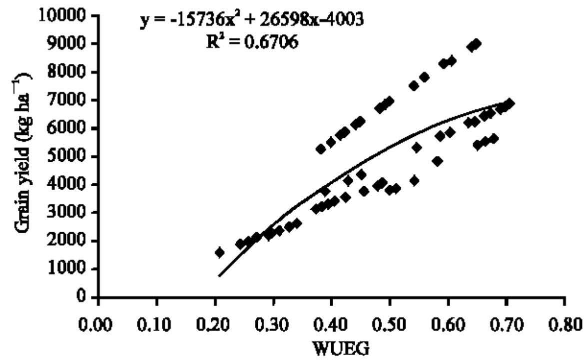

Fig 3: The relation between grain yield (kg ha^{-1}) and water use efficiency (kg grain m^{-3} water) (combined over both seasons)

that any increase of amount of irrigation water more than 12000 m^3 ha^{-1} would not give any positive results in term of grain yield. Relation between WUE and grain yield had non linear correlation with good coefficient of determination r^2 = 0.67 (Fig. 3). However, the intermediate correlation between volume of irrigation water and WUE a long with maximum WUE of 0.65 kg m^{-3} and grain yield about 7 ton ha^{-1} may indicate that alternative methods rather than irrigation intervals are needed for maximizing wheat production under local.

In conclusion the results of the present study showed that maximums grain yield (6.5 ton h^{-1}) could be produced with maximum WUE of 6.5 kg m^{-3}. This amount of production was achieved with maximum water use efficiency with irrigation intervals set every 6-7 days. Moreover, any increased in amount of irrigation water more than 12000 m^3 h^{-1} is expected to be accompanied with a lot of water loss and no increase in wheat production.

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