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Effect of Irrigation Regime on Growth and Yield of Wheat (*Triticum aestivum* l.) Under Alhasa Conditions

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ABSTRACT

Three irrigation water regimes for wheat cv Bro bread, viz. 100%, 80% and 60% ETc were used over three successive seasons (2009/10, 2010/11 and 2011/12) at the Agricultural and Veterinary Research Station of King Faisal University using a randomized complete block design with three replicates. Data were collected on different parameters pertaining to crop agronomic and yield attributes viz. plant population and height, number of tillers, leaf area index (LAI), number of spikelets and grains/spike, 1000-grains weight, harvest index (HI) and total grain yield; as well as water use efficiency (WUE). Obtained results revealed that, watering regime of 60% ETc was statistically ($P \leq 0.05$) inferior in terms of almost all the prescribed parameters. 100% and 80% ETc watering regimes were statistically similar in comparison to their corresponding treatments in all seasons. In addition, the obtained results showed that averaged of watering regime viz. 100, 80 and 60% ETc were 2.90, 2.73 and 2.03 t/ha, respectively. WUE was recorded the highest values (0.42) at 80% ETc watering regime, whereas the lowest (0.36) at 100% ETc.

Keywords: irrigation regime, wheat, ETc, water use efficiency, growth, yield.

INTRODUCTION

Understanding the effects of water stress on yield formation is essential for planning irrigation and other mitigation strategies in arid and semiarid areas (Wakchaure *et al*., 2016). FAO (1995) mentioned that yield could be a product of three factors viz. usable water (available at the top 900 mm of soil), WUE and harvest index (HI). Saeed *et al*. (1990) stated that information on water requirement of crops is necessary for designing irrigation systems and proper management of water supply. However, it's difficult to match supplies exactly to reasonable demands of crop. Farah (1995) reported that saving of water without harming wheat yield and quality can be achieved, and that varietal response differences of wheat to irrigation regimes exist to fill the yield gaps. However, Farah et al. (1995) stated that reduction in grain yield of wheat was an inevitable outcome of the negative effect of excessive water deficiency on the major yield components. Water stress at any stage is detrimental but there are specific critical stages during which the negative effect is more pronounced. Jamal *et al*. (1996) stated that grain yield of wheat was significantly reduced by water stress at all stages of growth. Whilst, Elnadi (1969) concluded that flowering, grain filling and maturation stages are more sensitive to drought than the vegetative stage. Yield attributes were found to be influenced by moisture regime (Reddy and Bhardwaj 1983). Irrigation scheduling has a direct effect on wheat grain yield. Ahmed *et al*. (1989) stated that crop yield in Gezira, was reduced significantly when the crop was stressed at the booting stage. Satisfactory yields, not far below the optimum figures, could be obtained using about two-thirds or three-quarters of ETc. Conversely, water application for excess of evapotranspiration may result in poor yields. Clemmens (1987) found that in general, yield response to over – or under irrigation was not linear. Large deficits or over applications were found to have proportionally large impacts on yields. Water use efficiency (WUE) is the function of grain produced/unit of water utilized by the plant (Elnadi 1969; Singh 1979 and Rahman *et al*. 1981). WUE was found to decrease with increased amounts of irrigation water (Babu and Singh 1984). WUE can be increased either by increasing yield with a given amount of irrigation water, or by securing a given yield with less irrigation water (Prihar *et al*. 1978). Onyibe (2005) reported that the increase of irrigation regime from 60 to 90% Available Soil Moisture did not significantly affect most of the growth, yield and yield parameters evaluated in the study. Each increase in irrigation regime however increased days to maturity, water use and thermal time but decreased water use efficiency. The exposure of plants to drought stress leads to a noticeable decrease in transpiration rate, stomatal conductance, leaf relative water contents, nitrogen use efficiency and yield of wheat. Moreover, increasing drought stress water uptake capacity was increased and significant decrease was bringing about by nitrogen application (Akram *et al*., 2014). Shrief and Abd El-Mohsen (2015) found that highly significant differences in irrigation treatments of wheat plants effects on grain, biological and protein yields ha^{-1}, protein content (%), harvest index and water use efficiency. Grain, protein and biological yields were significantly increased due to the volume of irrigation water increased. Moreover, grain yield and its components significantly declined due to water deficit. Wakchaure *et al*. (2016) stated that maximum grain yield 6513.33 (kg ha^{-1}) could be produced with maximum water use efficiency of 0.73 kg m^{-3}. This amount of production was achieved with maximum water use efficiency with irrigation intervals set every 10 days.

The objective of this study was to identify the most suitable irrigation regime to attain maximum possible growth, yield and its attributes of wheat under Alhasa conditions.

MATERIALS AND METHODS

Local wheat seeds, obtained from market, were cultivated for three successive seasons (2009/10, 2010/11 and 2011/12) at the Agricultural and Veterinary Research Station of King Faisal University. A randomized complete block design with three replicates was used. Three irrigation regimes based on crop evapotranspiration (ETc%) assigned as 100%, 80% and 60% ETc were used. The experimental units (plots) were 4.5 × 6.0 m each.

A set of 90°V–notch weirs was used to measure the required watering regimes (ETc%) assigned for each plot. Excluding the first conventional irrigation, seven irrigations were needed each season. The volume (V) of water assigned for each plot, and the time (t) needed to apply that volume through the weir was calculated as follows:

$$Q = 0.0138\, H^{5/2} \quad \ldots\ldots\ldots\ldots\ldots (1)$$

$$V = \frac{Kc.\ ETo.\ I\ .\ A}{1000.\ e} \quad (Kc.\ ETo = ETc) \quad \ldots\ldots\ldots\ldots (2)$$

$$t = \frac{V\ .\ 1000}{Q.\ 60} \quad \ldots\ldots\ldots\ldots\ldots (3)$$

Where:

Q = discharge of weir (ℓ/Sec)

H = head of water over the notch (cm)

V=total volume of water applied/irrigation to a prescribed experimental unit (m^3)

Kc = crop coefficient.

ETo = daily reference crop evapotranspiration (mm/day)

ETc = daily total crop evapotranspiration (mm/day).

I = irrigation interval (14 days)

A = area of experimental unit (m^2)

e = irrigation efficiency (%)

t = time needed to apply the pre-mentioned total volume of water to a prescribed experimental unit (min).

All calculations pertaining to water measurement and application were carried out according to the methods described by Doorenbos and Pruitt (1977).

Plant population/m^2 and height, number of tillers, leaf area index (LAI), number of spikelets and grains/spike, 1000-grains weight, harvest index (HI), total grain yield and water use efficiency (WUE) were the major variables assessed and processed in this study.

The collected data were statistically analyzed according to the technique of Analysis of Variance (AOV) as methods described by Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Results:

Maximum values of plant population/m^2 at harvest, number of tillers/plant, and plant height at harvest were obtained with 100% ETc watering regime at 5% level of probability in all seasons (Table 1). Mean and maximum values pertaining to the pre-mentioned parameters were; 321.8 and 339.8 plant/m^2 at harvest; 1.34 and 1.72 tiller/plant; as well as 68.5 cm and 72.4 cm averaged over all seasons, respectively. However, in 2010/11 and 2011/12 seasons, plant heights at harvest obtained from both 100% and 80% ETc watering regimes were statistically ($P \leq 0.05$) similar. With respect to LAI, maximum values were obtained from both 100% and 80% ETc watering regimes which were statistically ($P \leq 0.05$) similar, and that mean and maximum values were 1.61 and 1.76 averaged over the two seasons, respectively. On the other hand, when number of tillers was assessed on per area basis (heads/m^2), the 100% and 80% ETc watering regimes were statistically ($P \leq 0.05$) similar and superior in 2009/10 and 2010/11 seasons, with a mean maximum value of 553.30 tillers/m^2.

In this study, watering regimes were found to have significant ($P \leq 0.05$) effect on yield and its components (Table 2) such that, the 100% and 80% ETc watering regimes were superior to the 60 % ETc regime in terms of number of spikelets/spike, number of grains/spike, 1000-grains weight (g), HI, and total grain yield (t/ha) in all seasons. However, 100 % and 80% watering regimes were found statistically ($P \leq 0.05$) similar with respect to number of spikelets/spike, 1000-grains weight (g), HI, and total grain yield (t/ha) in all seasons, with mean and maximum values of; 13.02 and 13.69; 33.37 g and 34.97g; 38.80 and 40.64; as well as 2.55 t/ha and 2.81 t/ha, averaged over all seasons, respectively. On the other hand, mean and maximum values of number of grains/spike were 26.42 and 28.67 averaged over all seasons, respectively. Regarding WUE, data in Table 2 revealed that there is no significant differences between the examined watering regime. The 80% ETc watering regime recorded the best values in WUE whereas 60% ETc came in the second rank.

Table (1): Effect of watering regimes on growth components of wheat.

Watering regime (ETc %)	Plant population at harvest/m^2	Plant height at harvest (cm)	Leaf area index (LAI)	No. of tillers/ plant	No .of tillers/m^2
		2009/10 Season			
100%	347.90^a	75.18^a	1.87^a	1.66^a	545.10^a
80%	331.10^b	72.04^b	1.77^a	1.49^{ab}	541.10^a
60%	295.60^c	64.27^c	1.39^b	1.34^b	462.60^b
		2010/11 Season			
100%	330.00^a	70.99^a	1.67^a	1.70^a	554.80^a
80%	320.00^a	68.84^a	1.57^a	1.43^{ab}	572.20^a
60%	285.70^b	62.82^a	1.21^b	1.10^c	447.20^b
		2011/12 Season			
100%	341.40^a	71.02^a	1.85^a	1.80^a	352.60^a
80%	331.10^{ab}	70.64^a	1.84^a	0.85^b	359.40^a
60%	313.90^b	60.93^b	1.49^b	0.65^b	333.50^a

***Values having the same litter(s) in the same column is (are) statistically similar at 5% level of probability.**

Table (2): Effect of watering regime on yield components and water use efficiency (WUE, kg/m^3) of wheat.

Watering regime (ETc%)	No. of spikelets /spike	No. of grains/ spike	1000-grains weight (g)	Harvest index (HI)	Grain yield (t/ha)	WUE (kg/m^3)
		2009/10 Season				
100%	13.55[a]	28.75[a]	37.01[a]	43.10[a]	2.97[a]	0.37 [a]
80%	13.24[a]	27.30[b]	36.69[a]	43.77[a]	2.75[a]	0.43 [a]
60%	11.04[b]	24.57[c]	33.13[b]	39.10[b]	1.86[b]	0.38 [a]
		2010/11 Season				
100%	13.88[a]	29.23[a]	36.51[a]	42.70[a]	3.04[a]	0.37 [a]
80%	13.02[b]	26.35[b]	37.21[a]	43.70[a]	2.90[a]	0.45 [a]
60%	11.04[c]	23.14[c]	32.97[b]	38.06[b]	2.15[b]	0.44 [a]
		2011/12 Season				
100%	14.19[a]	28.03[a]	31.19[a]	35.08[a]	2.70[a]	0.33 [a]
80%	14.23[a]	28.33[a]	31.18[a]	35.46[a]	2.54[a]	0.39 [a]
60%	13.06 [b]	22.15 [b]	24.42[b]	27.88[b]	2.08[b]	0.42 [a]

***Values having the same litter(s) in the same column is (are) statistically similar at 5% level of probability.**

From our findings, it can be concluded that the watering regime of 60% ETc was found inferior with respect to all parameters assessed and processed at 5% level of probability, in all seasons. Whereas, 80% ETc gave the similar results when compared with 100% without significantly differences in the most parameters under the study.

Discussion:

In this study, the association of higher values of plant population at harvest, HI , LAI, and number of tillers with 100% and 80% ETc watering regimes was expected since maximum tillering and vegetative cover were maintained at these levels. These findings were in line with Mahdi *et al.* (1998) and Onyibe (2005). Moustafa *et al.* (1996) also reported similar conclusions with 75% ETc watering regimes, while Farah (1995) generalized that maximum growth potentialities of wheat could be exhibited when its watering amounts approaches full evapotranspiration particularly from booting to anthesis and through grain filling. Moreover, the space and light availability incurred with flat sowing have induced profused vegetative growth, and in turn higher LAI values. Similar results were stated by Moustafa *et al.* (1996) and Singh *et al.* (1998).

It is evident that, both 100 % and 80% ETc watering regimes were needed to produce higher number of spikelets/spike, Number of grains/spike, 1000-grains weight, HI, and total grain yield. These results were justifiable as all these parameters were very sensitive to water deficiency owing to its significant effect on final yield. Similar findings were stated by Ishag (1995) who reported significant reduction in these parameters when conditions of moisture deficiency prevailed during heading until grain filling. Moursi *et al.* (1979) and Shrief and Abd El-Mohsen (2015) also generalized that, up to 70% ETc or more of moisture is a pre-requisite to attain maximum values of these parameters. The positive and linear relationship between grain yield of wheat and crop evapotranspiration (ETc), which was highlighted by Musik *et al.* (1994) under dryland farming was in agreement with these findings. Moreover, Hochman (1982) reported grain losses of up to 36 % and 28 % at harvest when 70% ETc moisture was maintained from anthesis to grain filling, and from tillering to anthesis, respectively.

The combined effect of economic grain yield maximization in wheat with WUE at intermediate watering regimes was reported by Ahmed (1992); Farah *et al.* (1994); Farah *et al.* (1995); Moustafa *et al.* (1996); Akram *et al*. (2014) and Wakchaure *et al*. (2016) who obtained maximum grain yields of wheat based on WUE maximization most likely due to enough moisture being available at the reproductive stages in particular.

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أثر مقررات الري على نمو ومحصول القمح تحت ظروف واحة الأحساء

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تم تقييم ثلاث مقررات مياه (100%، 80%، 60% تبخر- نتح) لمحصول القمح صنف Bro bread خلال ثلاث مواسم متتالية (2010/2009 ، 2011/2010 و 2012/2011) بمحطة التدريب والأبحاث الزراعية والبيطرية لجامعة الملك فيصل باستخدام تصميم قطاعات كاملة العشوائية ئو ثلاث مكررات. جمعت البيانات عن مجموعة من المعايير الخاصة بصفات النمو والانتاج - كالكثافة النباتية، عدد الخلف /للنبات، ولوحدة المساحة، عدد الحبوب في السنبلة، عدد السنيبلات في السنبلة، وزن الألف حبه، معامل الحصاد، معامل مساحة الورقة، وزن محصول الحبوب الكلي (طن/هكتار)، بالإضافة الى كفاءة استخدام المياه (كجم/متر مكعب) للمحصول، وتم تحليلها إحصائياً .أظهرت النتائج وجود آثار معنوية لمقررات المياه على كل الصفات النباتية والانتاجية للمحصول في كل المواسم تقريباً . فعند مستوى 5% من المعنوية تبين أن أقل مقرر مياه (60% تبخر-نتح) هو الأقل أداءاً في كل الصفات التي تمت دراستها تقريباً والمشار اليها سابقاً، مقارنة ببقية المقررات . كما تبين ان مقرري المياه 100%، 80% تبخر- نتح لم يصل حد معنوياً في تأثيرهما علي كل الصفات وفي كل المواسم . كما أشارت النتائج أن متوسط الانتاجية للمقررات المائية 100%، 80%، 60% تبخر-نتح بلغ 2.90، 2.73، 2.03 طن/هكتار علي التوالي. كما تم الحصول على أعلى متوسط كفاءة استخدام للمياه (0.42 كجم/متر مكعب) عند مقرر المياه 80 % تبخر- نتح ، بينما كان أقل معدل كفاءة استخدام للمياه (0.36 كجم/متر مكعب) مرتبطاً باستخدام المعدل الكلي (100% تبخر-نتح).