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Effect of Irrigation Regime on Wheat (*Triticum aestivum* L.) Yield under Shambat Conditions, Sudan

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Abstract: This study was conducted with the objective of determining the effect of application of different irrigation water amounts on the yield of wheat grown on different seedbeds. Three irrigation water regimes namely: 100%, 80% and 60% of crop evapotranspiration (Etc) were used under two types of seedbeds (sowing on the flat and sowing on ridges) over two successive seasons (2003/04–2004/05) at the Demonstration Farm of the Faculty of Agriculture, University of Khartoum, Shambat using a strip-split-plot design with three replications. The control was flat sown and with no-tillage. Data were collected to determine variables pertaining to plant population, plant height, number of tillers, leaf area index (LAI), number of spikelets/plant and grains/spike, 1000-grains weight, harvest index (HI), total grain yield and water use efficiency (WUE). Results obtained revealed that, the watering regime of 60% ETc was statistically inferior in almost all the mentioned parameters, and that the 100% and 80% ETc had similar results in both seasons.

Key words: Irrigation regime; ETc; seedbed; wheat yield; water use efficiency.

INTRODUCTION

Up to 60% of the cropped area in the world is used for cereals with wheat (*Tritcum aestisum* L.) ranking as top (FAO 1995). FAO (1995) concluded that yield could be a product of three factors; usable water (available at the top 900 mm of soil), water use efficiency (WUE) and harvest index

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(HI). Saeed *et al*. (1990) and Adam (2008) stated that information on water requirement of crops is necessary for designing irrigation systems and proper management of water supply. However, it is difficult to match supplies exactly to reasonable demands of crop. Farah (1995) reported that saving water without harming wheat yield and quality can be achieved, and that varietal response differences of wheat to irrigation regimes exist. However, Farah *et al.* (1995) stated that reduction in grain yield is 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 critical stages during which the negative effect is more pronounced. Jamal *et al*. (1996) stated that grain yield was significantly reduced by water stress at all stages of growth. However, 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). Thus, irrigation scheduling has a direct effect on wheat grain yield. Further, support to this was given by Ahmed *et al.* (1989) who 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 when about two-thirds to three-quarters of crop evapotranspiration (ETc) were used. WUE is the function of grain produced per unit of water utilized by the plant (Elnadi 1969; Singh 1979; Rahman *et al.* 1981). WUE decreased with increased amounts of irrigation water (Babu and Singh 1984), but it can be increased either by increasing yield with a given amount of irrigation water, or by less irrigation water (Prihar *et al.* 1978). The objective of this study was to identify the most suitable irrigation regime and seedbed type to attain maximum possible yield of wheat under the standard husbandry practices under Shambat area conditions near Khartoum.

MATERIALS AND METHODS

Wheat seeds "Elneelein cultivar" were obtained from Hudeiba Research Station and were sown for two successive seasons (2003/04 and 2004/05) at the Demonstration Farm of the Faculty of Agriculture, Shambat, University of Khartoum in mid November. A Massey Ferguson (MF165) tractor was used to perform the required tillage operations, just before seeding each season. The soil was disc harrowed and leveled. The experimental treatments were; three irrigation regimes based on crop evapotranspiration (ETc%) assigned as 100%, 80% and 60% ETc with two methods of sowing, flat and ridge. Seven ridges were established in each plot using a three bodied ridger. The plot area was 27 m^2 (4.5×6.0 m). A wooden peg was used to open two grooves along each ridge, one on each side at a 20 cm distance from the base of the ridge. Seeds were manually placed and covered in each groove. Seed rate used was 143 kg/ha. For the control treatment seeds were broadcast on the flat and covered with a rake. Nitrogen fertilizer was applied at sowing in the form of urea at the rate of 1 N (1443kg/ha).

Split-plot design with three replications was used. Crop evapotranspiration was determined using Penman modified equation described by Doorenbos and Pruitt (1977) as follows:

$$ETc = Kc.ETo = c[W.Rn + (1 - W).f(u).(ea - ed)] .Kc \quad (mm/day) \ldots (1)$$

Where:
ETc = crop evapotranspiration, mm/day.
ETo = reference crop evapotranspiration, mm/day.
Kc = crop coefficient.
W = temperature related factor
Rn = net radiation equivalent evapotransipration, mm/day
f(u) = wind related function
ea-ed = difference between the saturation vapour pressure at mean air temperature and the mean actual vapour pressure of the air.
c = adjustment factor to compensate for the effect of day and night weather conditions.

Crop coefficient values for wheat were taken as proposed by Doorenbos and Kassam (1986) and number of days for each stage were taken from Farah *et al.* (1994) as follows:

0.35	→	initial stage, 15 days
0.75	→	development stage, 30 days
1.15	→	vegetative stage, 30 days
0.70	→	late season, 25 days
0.25	→	maturity stage, 15 days

Meteorological data were obtained from Shambat Meteorological Station. A set of 90°V–notch weirs was used to measure the required amount of water to be applied to the plots. Eight irrigations were applied in each season.

Calculations for determining the required amount of irrigation were carried out according to the methods described by Doorenbos and Pruitt (1977).

The measured growth and yield parameters were: plant population and height, number of tillers, leaf area index (LAI); number of spikelets and grains/spike, 1000-grains weight and total grain yield. The calculated values were HI and WUE.

The collected data were statistically analyzed according to the methods of Gomez and Gomez (1984).

RESULTS AND DISCUSSION

The average plant population/m^2 at harvest, number of tillers/plant, and plant height at harvest obtained with the different watering regimes under the different seedbeds in both seasons are shown in Table 1. In the two seasons plant height at harvest under both 100% and 80% ETc watering regimes and LAI were statistically ($P \leq 0.05$) similar. However, when number of tillers was based on area basis (heads/m^2), the 100% and 80% ETc watering regimes were statistically ($P \leq 0.05$) similar and superior in the two seasons. The interaction effect between watering regimes and method of sowing showed the superiority of the 100% and 80% ETc flat or ridge sowing combination with respect to number of tillers/m^2 in the first seasons, at the same level of probability (Table 1). The effect of tillage was pronounced in plant height at harvest. No-tillage produced shorter plants under all watering regimes. This may be attributed to the fact that plants growing on the heavy montmorillonitic clay soil depend on relatively less moisture stored in the root zone, compared to ridged plots. Furthermore, the compact flat soil provides more mechanical resistance to root growth with depth and therefore less availability of soil and mineral nutrition. In addition, the downward and upward circulation of salts after every irrigation cycle of the flat surface create more salinity hazard on the salt-affected soils, such as that of Shambat. The association of higher values of plant population at harvest, HI, LAI and number of tillers with 100% and 80% ETc was expected since maximum tillering and vegetative cover were maintained at these levels. These findings are in line with those reported by Mahdi *et al.* (1998). Moustafa *et al.* (1996) also reported similar findings with 75% ETc. However, Farah (1995) generalized that maximum growth potentialities of wheat could be exhibited when its watering amount approaches full evapotranspiration particularly from booting to anthesis and through grain filling. Moreover, the space availability incurred with flat sowing has induced profuse vegetative growth, and in turn higher LAI values. Similar results were stated by Moustafa *et al.* (1996) and Singh *et al.* (1998).

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 were superior to the 60% ETc in terms of number of spikelets/spike, number of grains/spike, 1000-grains weight, HI, and total grain yield in both seasons. However, 100% and 80% ETc were found statistically ($P \leq 0.05$) similar with respect to number of spikelets/spike, 1000-grains weight, HI and total grain yield in both seasons. The general trend was that, WUE tended to increase sharply below 100% ETc and above 60% ETc (Table 3). The effect of tillage was reflected very clearly in the final yield and water use efficiency compared to the control treatments. The relationships of moisture deficiency with parameters of growth and yield were studied by several workers (e.g. Ishag 1995) who reported significant reduction in the mentioned variables when conditions of moisture deficiency prevailed during heading until grain filling. Moursi *et al.* (1979) also generalized that, up to 70% ETc or more is a pre-requisite to attain maximum values of these variables. The positive and linear relationship between grain yield of wheat and crop evapotranspiration (ETc) as 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 was maintained from anthesis to grain filling, and from tillering to anthesis, respectively.

The combined effect of economic grain yield maximization of wheat with WUE at intermediate watering regimes was reported by Ahmed (1992), Farah *et al.* (1994), Farah *et al.* (1995) and Moustafa *et al.* (1996) who obtained maximum grain yields of wheat based on WUE maximization and attributed this to presence of enough available moisture at the reproductive stage in particular.

Conclusions

1. Application of 80% or 100% ETc produced similar results giving maximum grain yield of wheat in this study
2. Seedbed type did not affect grain yield of wheat significantly, but tillage improved grain yield and WUE although not at the statistical level of significance.
3. Flat sowing coupled with 80% or 100% ETc produced high WUE in both seasons in this study.

Table 1. Effect of watering regimes on growth components of wheat
a) Average plant population (plants/m^2) and height (cm).

Season	Watering regime(ETc)	Plant population emergence/m^2			Plant population at harvest/m^2			Plant height harvest (cm)		
		S1	S2	Nt	S1	S2	Nt	S1	S2	Nt
2003/04	100%	337.5	332.0	330.1	330.0^a	328.1^a	327.8^a	78.0^a	79.1^a	65.5^b
	80%	337.2	331.7	335.2	320.0^a	317.0^a	325.8^a	77.7^a	78.2^a	63.3^b
	60%	336.8	332.0	337.5	285.7^b	280.0^b	261.3^b	70.6^b	69.1^b	60.5^c
2004/05	100%	331.9	325.0	330.3	341.4^a	335.7^a	320.7^a	72.1^a	78.0^a	65.2^a
	80%	331.5	324.1	319.7	331.1^{ab}	331.0^{ab}	325.3^a	70.7^a	73.3^a	62.2^c
	60%	331.8	321.0	335.4	313.9^b	310.5^b	300.6^b	65.6^b	66.5^b	58.3^c

Table 1. Cont.
b) Leaf area index (LAI) and number of tillers

Season	Watering regime(ETc)	Leaf area index			Average no. of tillers/plant			Average no. of tillers/m^2		
		S1	S2	Nt	S1	S2	Nt	S1	S2	Nt
2003/04	100%	2.00^{a}	1.90^{a}	1.30	1.80^{a}	1.90^{a}	1.53^{c}	570.0^{a}	520.0^{a}	320.0^{d}
	80%	1.90^{a}	1.75^{ab}	1.60	1.68^{ab}	1.61^{b}	1.52^{c}	549.0^{a}	533.2^{a}	327.1^{d}
	60%	1.61^{b}	1.40^{b}	1.25	1.63^{b}	1.53^{c}	1.11^{b}	460.9^{b}	464.9^{b}	287.6^{d}
2004/05	100%	2.01^{a}	1.90^{a}	1.51^{c}	1.64^{a}	1.60^{b}	1.50^{b}	373.7^{c}	331.0^{d}	314.3^{d}
	80%	1.80^{ab}	1.75^{a}	1.72^{cb}	1.73^{a}	1.59^{b}	1.22^{c}	377.8^{c}	335.0^{d}	325.2^{d}
	60%	1.60^{b}	1.40^{b}	1.30^{c}	1.32^{b}	1.31^{c}	1.01^{d}	338.8^{d}	328.1^{d}	270.3^{d}

S1 = Flat sowing; S2 = Ridge sowing; Nt = No-tillage

* Means followed by the same letter(s) in columns or rows were of the same variable are not statistically different at $P \geq 0.05$ according to Duncan's Multiple Range Test.

Table 2. Effect of watering regimes and seedbed on yield components of wheat
a) No. of spikelets/spike, No. of grains/spike and 1000-grains weight (g)

Season	Watering regime(ETc)	No. of spikelets/spike			No. of grains/spike			1000-grains weight (g)		
		S1	S2	Nt	S1	S2	Nt	S1	S2	Nt
2003/04	100%	13.87[a]	15.35[a]	13.72[a]	29.23[a]	28.13[a]	227.12[b]	36.51[a]	48.20[a]	48.11[a]
	80%	13.45[b]	14.57[a]	13.33[a]	26.35[b]	24.17[b]	222.33[c]	27.21[c]	49.00[a]	46.71[a]
	60%	11.05[c]	11.07[b]	12.22[b]	23.14[c]	21.50[c]	19.18[c]	32.97[b]	47.10[a]	44.20[a]
2004/05	100%	13.47[a]	14.09[a]	12.28[b]	28.03[a]	27.70[b]	26.50[b]	35.08[a]	46.20[b]	45.50[a]
	80%	14.40[a]	14.23[a]	11.51[b]	28.33[a]	29.20[a]	26.30[b]	35.46[a]	54.10[a]	46.90[a]
	60%	13.15[b]	13.06[b]	10.95[c]	22.15[b]	20.30[c]	19.50[c]	27.88[b]	44.30[bc]	40.30[a]

Table 2. Cont.

b) Harvest index (HI) and grain yield (t/ha)

Season	Watering regime(ETc)	Harvest index (HI)			Grain yield (t/ha)		
		S1	S2	Nt	S1	S2	Nt
2003/04	100%	48.20[a]	49.10[a]	28.31[d]	3.40[a]	3.04[a]	2.47[cd]
	80%	49.00[a]	48.10[a]	33.41[c]	3.20[a]	2.59[b]	2.23[d]
	60%	47.10[b]	47.30[b]	27.51[d]	2.20[c]	2.15[c]	1.52[e]
2004/05	100%	46.20[b]	44.30[b]	26.12[c]	3.70[a]	3.70[a]	2.15[d]
	80%	54.10[a]	53.10[a]	30.34[c]	3.60[a]	3.30[a]	2.50[c]
	60%	54.30[a]	42.80[b]	23.05[d]	2.60[b]	2.08[d]	1.41[e]

S1 = Flat sowing; S2 = Ridge sowing; Nt = No-tillage

* Means followed by the same letter(s) in columns or rows were of the same variable are not statistically different at P $\geq$ 0.05 according to Duncan's Multiple Range Test.

Table 3. Effect of watering regimes (ETc %), amount of irrigation water (m^3/ha) and seedbed on grain yield (t/ha) on water use efficiency (WUE, kg/m^3)

Season	ETc%	Amount of water (m^3/ha)	Grain yield (t/ha)			WUE (kg/m^3)		
			S1	S2	Nt	S1	S2	Nt
2003/04	100%	8068	3.40^a	3.04^a	2.47^b	0.42^a	0.39^b	0.31^b
	80%	6454	3.20^a	2.95^a	2.23^c	0.50^a	0.46^a	0.35^b
	60%	4841	2.20^c	2.15^c	1.51^d	0.44^a	0.45^a	0.31^b
2004/05	100%	82.30	3.70^a	3.70^a	2.15^c	0.45^a	0.45^a	0.26^d
	80%	6589	3.60^a	3.30^a	2.50^d	0.50^a	0.39^b	0.38^b
	60%	4938	2.50^b	2.08^d	1.41^b	0.53^a	0.42^a	0.29^b

S1 = Flat sowing; S2 = Ridge sowing; Nt = No-tillage

* Means followed by the same letter(s) in columns or rows were of the same variable are not statistically different at $P \geq 0.05$ according to Duncan's Multiple Range Test.

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تأثير معدل الري ومهد البذرة على إنتاجية القمح تحت ظروف شمبات، السودان

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المستخلص: أجريت هذه الدراسة بهدف تحديد تأثير كميات مياه الري على إنتاجية القمح المزروع في خطوط بالمقارنة مع المزروع في أحواض منبسطة لم تتلق أي حراثة مع ثلاث معاملات ري هي: 100% و80% و60% من تبخر–نتح المحصول، وقد أجريت التجارب في موسمين متتاليين (04/2003 – 05/2004) في المزرعة الإيضاحية بكلية الزراعة – شمبات، جامعة الخرطوم باستخدام القطع المنشطرة وثلاث مكررات. جُمعت البيانات عن عدد وطول النباتات وعدد الخلف ودليل مساحة الورقة (LAI) وعدد السنابل وعدد الحبوب في السنبلة ووزن 1000 حبة . وقد تم حساب دليل الحصاد (HI) وإنتاجية الحبوب الكلية وكفاءة إستخدام الماء (WUE) . أوضحت النتائج أن الري بنسبة 60% من تبخر– نتح المحصول أعطى نتائج متدنية إحصائياً في كل العوامل المذكورة ، بينما أعطى الري بمعدل 80% و 100% من تبخر– نتح المحصول نتائج متشابهة في الموسمين ، وتمثلت في أفضل إنتاجيه للمحصول ومكوناته في الموسمين .

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