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Effect of irrigation intervals during different growth stages on cotton (*Gossypium barbadence* L.) yield and fiber characteristics in semi- arid region of Sudan

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A field experiments were conducted for two consecutive seasons (2006/2007 and 2007/2008) in Demonstrated Farm, Sudan University of Science and Technology, to study the effect of irrigation intervals at different growth stages on growth, yield component and fiber characteristics of cotton (*Gossypium barbadence* L.). The experiment was lied out in a complete plots design with four replications. The treatments were standard irrigation every two weeks (W_1), extended irrigation intervals of one month during predetermined stages of cotton (W_2), the stages were early vegetative growth (W_3), early flowering (W_4), and early boll ripening (W_5). The results revealed that plant height, seed index and lint index were not affected by irrigation intervals. Plant height had significant difference in first season only. Seed yield had significant differences in second picking of both seasons, and first picking of second season. Lint yield showed significant differences in all three picking of first season and first picking of second season. In general irrigation interval every 15 days throughout growth (W_1) had the greatest values. On the other hand W_4 (30 days interval at early flowering) and W_5 (30 days interval at early boll ripening) showed the lowest values. Meanwhile, fiber characteristics had no clear evidence due to irrigation intervals.

Key word: Cotton, fiber, irrigation interval, yield.

INTRODUCTION

Environmental stress affects plant performance adversely and often results in significant reductions in crop yield and quality worldwide (Boyer, 1982). During square and boll formation different stresses (that is, drought, shading, fertility problems and insect pressure) can result in fruit abscission (Boyer, 1982). The use of irrigation strategies are fundamental to save more water without putting at risk crop yield (Jalota et al., 2006; Pereira et al., 2009).

Tang and Zhang (2005) obtained excellent results in cotton yield by managing water deficits during plant development and saving water during irrigation. Also Buttar et al. (2007) reported that saving water in irrigated areas is the definition of the suppression of irrigation correctly promoting the physiological seasoning of plants without compromising yield. The timing of the first irrigation is an important management consideration that depends primarily on soil water retention properties and the prevailing climate. Guinn and Mauney (1984) showed

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that too early irrigation does not results in lower final yield, timing of irrigation in midseason is important, too little water causes water deficit at the time of midseason and lead to abscission resulting in low yields, while too frequent irrigation may cause excessive vegetative growth. In late season, water stress can be tolerated by the crop because productivity at this development stage is not depended on retention of fruiting induced abscission (Grimes and Elzik, 1990).

Several studies have already demonstrated that skipping irrigation under different developmental stages of growth of cotton can alter growth and yield production but had no effect on fibre characteristics (Yagoub et al., 2007, 2009). Stickiness contamination also investigated, it was found to be caused by honey-dew excreted by the two insect's whitefly and aphids. The insects have a wide range of host plants, as well as many causes were reported under Sudan conditions (Khalifa, 1982; Abdelatif et al., 2009). The prolonged irrigation interval of 21 days resulted in a lower stickiness level (Abdelatif et al., 2009). Irrigation management had little influence on sugar concentration on lint (Slosser et al., 2002). The objectives of this investigation were to assess the effect of irrigation intervals at early stages of growth of cotton on the growth, yield component, yield and fiber characteristics.

MATERIALS AND METHODS

This study was conducted at the Demonstration Farm of College of Agricultural Studies, Sudan University of Science and Technology, Khartoum North, Sudan (latitude 15 40°N longitude 32 32°E and latitude 230 m asl), over two successive seasons (2006/2007 and 2007/2008). The soil of experimental site is clay (fine montomrilonitic, isohyperthermicentic chromustert), with alkaline pH. The climate of the locality is tropical semi- arid with mean annual rainfall of 100 to 200 mm and maximum temperature of about 42°C in summer and 21°C in winter. The cotton variety Barakat 90 was used in the study, it brought from Agriculture Research Corporation (ARC), Wad Madani, Sudan. The layout of the experiment was randomized complete block design with four replicates. Analysis of variance was carried out using the procedure of SAS (1989), and the L.S.D. was used for mean comparisons.

The treatments comprised the following watering regimes standard irrigation at approximately fortnight intervals (W_1), intervals of thirty days throughout (W_2) and intervals of one month duration (Does it mean irrigation is carried out during this period only? But how many days are needed for early vegetative growth, early flowering or early boll ripening?) early vegative irrigated after the first month of seedling and then skipped irrigation for a month and then irrigated normally (every 15 days) to the end of experiment the following stages: Early vegetative growth (W_3), early flowering (W_4) beginning of flowering irrigation stopped for one month and then irrigated normal, and early boll ripening (W_5) beginning of boll ripening irrigation stopped for one month and then irrigated normal. The plots were 8×8 m^2 in size, and consisting of 4 ridges. Land preparation consisted of ridging, disking, harrowing, leveling and spacing of 80 cm between ridges. Sowing was on the first of August, 2006 in the first season and on 30 July, 2007 in the second season. The seeds were sown on the top of the ridge at a rate of seven seeds per hole and thinned to three plants per hole about 35 000 plants/ha (How many holes per ha? What is the planting density?), six weeks after planting. Fertilizer nitrogen was applied at sowing at the rate of 160 kg N per ha in the form of urea. Phosphorus was applied immediately after thinning at the rate of 96 kg per ha in the form of triple super-phosphate. (Do you use any potassium?) No. Weeds were controlled manually, and the crop was sprayed against insects. Ten plants were randomly selected from each plot for collecting data on the following parameters: plant height, seed cotton yield, lint yield, lint index, and seed index. As suggested by Hamby (1966), a sample of 50 bolls was taken from each entry by hand, picked from top, middle and bottom fruiting zones of the plants. Three picking times were taken, first, successive picks (optimum picking time) second, medium picking time and third, late picking.

Cotton seed was roller ginned. Main cotton lint characteristics were carried out at the Fibre Cotton Testing Laboratory of Cotton Research Program, Sudan, using high volume instrument (HVI) under standard testing conditions (temperature 20±2°C and relative humidity 65±1%). Stickiness level was measured by the sticky cotton tester (SCT) of CIRAD-CA, BP5035-34032 Montpellier Cdex 1, France. Additionally, some average of climatic factors for the growing seasons of the experimental years are summarized in Table 1.

RESULTS AND DISCUSSION

The effect of irrigation regime on plant height, seed index and lint index in the two seasons, are presented in Table 2. The results indicated that interval every 15 days (are not equal to two weeks about) throughout growth (W_1) had the tallest plant height, greater numbers of seed index and lint index but there were no significant difference among all treatments. This is line with Lazim (1987), who reported that plant height were not significantly affected by watering regimes, he attributed that to the wide adaptation of cotton to water regime.

The effects of watering regimes on seed yield kg/ha is presented in (Table 3). The results showed that first picking of the first season, and third picking of both season had no significant differences. Meanwhile, second picking of the first season had significant differences (P=0.05) at interval 30 days at early vegetative stage (W_3) and interval every 15 days throughout growth (W_1) which produced the highest yield production (1249.08 and 1248.9 kg/ha, respectively), and intervals 30 days at early ripening (W_5) had the lowest yield (447.53 kg/ha). The lack of irrigation during flowering stages resulted in boll with less weight. This was due to a decrease in photosynthesis because of the closing of stomata, limiting as a result CO_2 diffusion for the mesophyll in cotton plant (Tang and Zhang, 2005). In the second season pick one (W_2) and two gave the highest yield. In pick one was in intervals 30 days (W_2), (2439.5 kg/ha) and in pick two in intervals 30 days (W_2) (318.85 kg/ha) and interval every 15 days throughout growth (W_1) (286.25 kg/ha). The lowest values for two picking were in intervals 30 days at early flowering W_4 (926.7 kg/ha) and interval 30 days at early vegetative stage (W_3) (35.0), respectively.

Statistical analysis of lint yield of cotton affected by irrigation intervals in seasons 2006/2007 and 2007/2008 are shows in Table 4. The results found significant differences (P=0.05) at three picking of the first season

Table 1. The monthly metrological data (temperature, rainfall and relative humidity) of Shambat Demonstration Farm during the years (2006/2007-2007/2008).

Temp. max	Temp. min	RF (mm)	RH %	Temp. max	Temp. min	RF (mm)	RH %
January 27.5	12.9	-	31	29.2	14.9	-	32
February 32.2	14.3	-	23	31.3	15.9	-	31
March 36.6	18.1	-	18	38.6	20.5	-	23
April 39.5	20.8	0.1	15	40.4	25.2	0.2	23
May 43.6	25.6	-	15	41.4	25.7	-	18
June 40.8	27.2	0.1	27	41.6	27.8	0.5	29
July 35.3	25.6	1.5	51	39.4	26.7	1.5	38
August 35.0	25.3	2.5	51	37.0	24.9	1.9	45
September 38.0	25.7	0.1	55	38.2	26.1	0.2	44
October 39.7	24.7	0.1	40	37.7	23.6	0.2	28
November 36.1	21.5	-	29	35.3	20.5	-	32
December 32.7	18.4	-	33	32.1	18.3	-	32

Table 2. Means of plant height, seed index and lint index of cotton as affected by irrigation intervals, during 2006/2007 and 2007/2008 seasons.

Treatments	Plant height (cm)		Seed index (g) check the data (correct data)		Lint index (g) check the data (correct data)	
	2006/2007	2007/2008	2006/2007	2007/2008	2006/2007	2007/2008
W_1	113.90[a]	116.00[a]	10.10[a]	11.8[a]	3.20[a]	3.23[a]
W_2	79.55[a]	131.70[a]	5.40[a]	8.3[a]	3.90[a]	3.80[a]
W_3	82.25[a]	124.70[a]	10.50[a]	9.1[a]	2.80[a]	2.50[a]
W_4	84.39[a]	132.00[a]	5.10[a]	7.5[a]	2.90[a]	3.03[a]
W_5	86.90[a]	132.50[a]	7.00[a]	9.8[a]	2.90[a]	3.38[a]
CV%	24.56	9.54	56.83	49.86	50.18	49.30
$Lsd_{0.05}$	33.82	18.66	6.69	7.125	3.42	2.42
SE±	10.98	6.05	2.17	3.31	0.78	0.78

W_1; interval every 15 days throughout growth, W_2; intervals 30 days throughout growth, W_3; intervals 30 days at early vegetative stage, W_4; intervals 30 days at early flowering, W_5; intervals30 days at early ripening. Means with the same letter in each column are not significant at 0.05 level of (LSD) lest significant difference test. CV%: coeffient of variation percentage, SE = stander error.

and the first picking of the second season. Interval every 15 days throughout growth (W_1) had the greatest lint yield kg/ha for pick one and two of the first season 583.58 kg/ha and 346.8 kg/ha, respectively. But in the third picking (W_3) was the highest lint yield (423.28 kg/ha). W_5 in the first picking was 117.38 kg/ha, and at second picking was 104.4 kg/ha had the lowest lint yield for the first season. These results indicated that irrigation every 15 days was better under Shambat conditions. The first picking of the second season W_2 was ranked first in lint yield of 753.45 kg/ha with highly significant differences among other treatments. On the other hand, second and third picking had no response to all irrigation intervals. This result revealed that lint yield was not affected by stress irrigation intervals and cotton had well adaptation to water stress (Yagoub et al., 2008, 2009).

In contrast Gwathmey et al. (2011), found that full irrigation in cotton had positive yield response 2.5 span length of cotton (mm) obtained from different pick in both seasons is presented in (Table 5). Mean staple length ranged from 32.68 to 34.88 mm. This is in harmony with data of the Sudanese Cotton Company which recommended the length of extra fine count cotton (Brakat, 90) as 29 to 36 mm (Fadlallah et al., 1999). It is evident that the extended irrigation interval had no effect on staple length on the first season and third picking of second season, as was confirmed by USDA (1995) and Yagoub et al. (2009), who reported that cotton quality is less responsive to environmental changes. The micronaire values of cotton lint obtained from the five picks of the two seasons are given in Table 6. The analysis of variance of the data showed no significant differences among the effects of the different irrigation treatments on micronaire values, this was in line with Yagoub et al. (2009). Who found that watering intervals during different growth stages of cotton had no affect on micronaire value of cotton lint. The stickness of cotton fiber was presented in Table 7. The result showed

Table 3. Seed yield (kg/ha) of cotton as affected by irrigation intervals, during 2006/2007 and 2007/2008 seasons.

Treatment	2006/2007 (pick)			2007/2008 (pick)		
	1st	2nd	3rd	1st	2nd	3rd
W_1	1249.08[a]	1248.95[a]	531.38[a]	1456.95[a]	286.25[b]	139.08[a]
W_2	671.68[a]	679.98a[b]	506.88[a]	249.53[b]	318.85[a]	273.88[a]
W_3	1294.10[a]	1293.9[a]	368.80[a]	1128.13[ab]	35.00[b]	172.58[a]
W_4	631.85[a]	631.83[ab]	482.13[a]	926.70[b]	96.15[ab]	256.75[a]
W_5	859.28[a]	447.53[b]	534.38[a]	1171.85[ab]	162.03[ab]	333.88[a]
CV%	57.68	55.84	53.36	59.54	83.67	70.33
$Lsd_{0.05}$	836.50	740.20	398.50	1307.00	231.6	254.90
SE±	271.50	240.20	129.30	424.10	75.15	82.72

$W_{1;}$ interval every 15 days throughout growth, $W_{2;}$ intervals 30 days throughout growth, $W_{3;}$ intervals 30 days at early vegetative stage, $W_{4;}$ intervals 30 days at early flowering, $W_{5;}$ intervals30 days at early ripening. Means with the same letter in each column are not significant at 0.05 level of (LSD) lest significant difference test. CV%: coeffient of variation percentage, SE= standard error.

Table 4. Lint yield (kg/ha) of cotton affected by irrigation intervals during 2006/2007 and 2007/2008 seasons.

Treatment	2006/2007(pick)			2007/2008 (pick)		
	1st	2nd	3rd	1st	2nd	3rd
W_1	583.58[a]	346.80[a]	292.68[ab]	260.05[b]	39.63[a]	45.48[a]
W_2	157.55[c]	191.95[ab]	249.73[ab]	753.45[a]	109.03[a]	94.06[a]
W_3	325.60[b]	239.60[ab]	423.28[a]	242.60[b]	16.85[a]	50.73[a]
W_4	130.80[c]	147.65[b]	148.35[b]	256.50[b]	33.18[a]	89.63[a]
W_5	117.38[c]	104.40[b]	176.03[b]	328.65[b]	48.00[a]	119.45[a]
CV%	33.43	46.72	52.53	63.71	11.60	69.21
$LSD_{0.05}$	135.40	148.30	208.80	361.50	88.20	85.16
SE±	43.96	48.14	67.76	117.3	28.63	27.64

$W_{1;}$ interval every 15 days throughout growth, $W_{2;}$ intervals 30 days throughout growth, $W_{3;}$ intervals 30 days at early vegetative stage, $W_{4;}$ intervals 30 days at early flowering, $W_{5;}$ intervals30 days at early ripening. Means with the same letter in each column are not significant at 0.05 level of (LSD) lest significant difference test. CV%: coeffient of variation percentage, SE = standard error.

Table 5. Fiber length (mm) of cotton affected by irrigation regimes, during 2006/2007 and 2007/2008 seasons.

Treatment	2006/2007 (pick)			2007/2008 (pick)		
	1st pick	2nd pick	3rd pick	1st pick	2nd pick	3rd pick
W_1	35.08[a]	34.75[a]	33.28[a]	33.70[ab]	32.68[b]	34.70[a]
W_2	34.10[a]	34.90[a]	32.98[a]	33.84[ab]	34.88[a]	32.78[a]
W_3	35.23[a]	35.23[a]	33.50[a]	33.62[ab]	33.65[ab]	33.60[a]
W_4	35.05[a]	34.38[a]	34.03[a]	34.48[a]	33.63[ab]	34.15[a]
W_5	34.15[a]	35. 8[a]	33.50[a]	33.24[a]	34.33[ab]	33.98[a]
CV%	2.10	2.80	3.41	1.96	3.66	3.77
$Lsd_{0.05}$	1.12	1.50	1.75	0.88	1.90	1.96
SE±	0.36	0.48	0.57	0.29	0.61	0.63

$W_{1;}$ interval every 15 days throughout growth, $W_{2;}$ intervals 30 days throughout growth, $W_{3;}$ intervals 30 days at early vegetative stage, $W_{4;}$ intervals 30 days at early flowering, $W_{5;}$ intervals30 days at early ripening. Means with the same letter in each column are not significant at 0.05 level of (LSD) lest significant difference test. CV%: coeffient of variation percentage, SE = standard error.

significant differences at the first picking of two seasons, but the effect was fluctuated and not reflected the response of cotton fiber to watering intervals, this could be due to late picking. Open cotton bolls of late picking are subjected to more contamination with honeydew. Table 8 showed the effect of uniformity ratio of cotton as

Table 6. Micronaire value of cotton fiber affected by irrigation regimes, during 2006/2007 and 2007/2008 seasons.

Treatment	2006/2007 (pick)		2007/2008 (pick)		
	2nd	3rd	1st	2nd	3rd
W_1	4.30[a]	3.63[a]	3.80[a]	4.25[a]	3.88[a]
W_2	4.35[a]	4.00[ab]	3.93[a]	3.83[a]	4.00[a]
W_3	4.15[a]	4.10[a]	3.83[a]	3.85[a]	4.15[a]
W_4	4.23[a]	4.38[a]	3.85[a]	4.15[a]	4.10[a]
W_5	4.65[a]	4.18[a]	3.93[a]	3.85[a]	3.78[a]
CV%	7.40	7.66	7.63	9.39	8.34
$LSD_{0.05}$	0.49	0.47	0.45	0.57	0.51
SE±	0.16	0.15	0.14	0.18	0.16

W_1; interval every 15 days throughout growth, W_2; intervals 30 days throughout growth, W_3; intervals 30 days at early vegetative stage, W_4; intervals 30 days at early flowering, W_5; intervals30 days at early ripening. Means with the same letter in each column are not significant at 0.05 level of (LSD) lest significant difference test. CV%: coeffient of variation percentage, SE= standard error.

Table 7. Stickness level (No. of sticky spots) as affected by irrigation intervals, during 2006/2007 and 2007/2008 seasons.

Treatment	2006/2007 (pick)			2007/2008 (pick)		
	1st	2nd	3rd	1st	2nd	3rd
W_1	14[b]	44[a]	52[a]	61[a]	29[a]	28[a]
W_2	63[a]	25[a]	28[a]	44[ab]	31[a]	37[a]
W_3	14.[ab]	40[a]	38[a]	26[b]	24[a]	39[a]
W_4	47[ab]	46[a]	29[a]	42[ab]	33[a]	24[a]
W_5	56[ab]	41.[a]	38[a]	42[ab]	37[a]	32[a]
CV%	56.03	56.98	62.84	45.81	40.91	54.53
$LSD_{0.05}$	44.18	34.46	35.77	30.35	19.25	26.97
SE±	14.34	11.18	11.61	9.849	6.284	8752

W_1; interval every 15 days throughout growth, W_2; intervals 30 days throughout growth, W_3; intervals 30 days at early vegetative stage, W_4; intervals 30 days at early flowering, W_5; intervals30 days at early ripening. Means with the same letter in each column are not significant at 0.05 level of (LSD) lest significant difference test. CV%: coeffient of variation percentage, SE= standard error.

Table 8. Mean uniformity ratio % of cotton fiber affected by irrigation intervals, during 2006/2007 and 2007/2008 seasons.

Treatment	2006/2007(pick)			2007/2008 (pick)		
	1st	2nd	3rd	1st	2nd	3rd
W_1	87.53[a]	87.80[a]	87.23[a]	86.05[a]	85.58[b]	86.30[a]
W_2	88.90[a]	78.63[a]	86.63[a]	85.95[a]	86.10[b]	86.83[a]
W_3	88.38[a]	87.73[a]	86.18[a]	86.03[a]	86.58[ab]	86.18[a]
W_4	87.60[a]	88.05[a]	85.25[a]	85.40[a]	85.28[b]	87.05[a]
W_5	87.48[a]	87.90[a]	85.58[a]	86.03[a]	88.40[a]	86.23[a]
CV%	1.80	1.49	2.30	1.64	1.48	1.95
$LSD_{0.05}$	2.43	2.01	3.05	2.17	1.97	2.60
SE±	0.79	0.65	0.99	0.70	0.64	0.84

W_1; interval every 15 days throughout growth, W_2; intervals 30 days throughout growth, W_3; intervals 30 days at early vegetative stage, W_4; intervals 30 days at early flowering, W_5; intervals30 days at early ripening. Means with the same letter in each column are not significant at 0.05 level of (LSD) lest significant difference test. CV%: coeffient of variation percentage, SE= standard error.

affected by irrigation intervals, during 2006/2007 and 2007/2008. The results showed no differences among all treatments except in second picking of second season. In general, Ünlü et al. (2011) and Yagoub et al. (2009), showed no statistical differences among all treatment for quality components of cotton lint due to irrigation intervals. The absence of variation in fiber characteristics responses to water stress in cotton, suggested that it is not vital because it is genetically control (Yagoub et al., 2009).

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