U. of K. J. Agric. Sci. 15(3), 362-374, 2007

Effect of Extended Irrigation Intervals at Different Growth Stages on Growth and Yield of Cotton in the Sudan Gezira*

Samia Osman Yagoub[1], Hamid Osman Burhan[2], Saeed Mohamed Farah[3] and Abdelrahman Hassan Abdelatief[3]

Department of Agronomy, Faculty of Agriculture, University of Khartoum, Shambat, Sudan

Abstract: A field experiment was conducted for two consecutive seasons (1998/1999 and 1999/2000) at the Gezira Research Station, Gezira, Sudan, to study the effect of extended irrigation intervals at different growth stages on growth and yield of cotton (*Gossypium barbadense* L.) variety Barakat 90. The experiment was laid out in a complete block design with four replications. The treatments were irrigation every two weeks (standard) and extended irrigation intervals of one month during predetermined stages of cotton growth. These stages were early vegetative growth, late vegetative growth, early flowering, late flowering, early fruit opening and late fruit opening. The results indicated that growth and yield of cotton were adversely affected by extending the irrigation interval to one month throughout the growing season as well as when the irrigation interval was extended during the early flowering stage. The magnitude of this reduction was significant, and the levels of yield exhibited wide seasonal variation. The extended watering intervals had significant and substantial adverse effects on yield, associated with shorter plant height and reduced shoot dry weight and forced early 50% flowering and bolling compared with standard irrigation. The three components of cotton yield, i.e., lint index, seed index and ginning-out turn, were not affected significantly, because they are genetically controlled.

---

* Part of a these submitted by the first author to the University of Khartoum, in fulfillment of the requirements for the Ph.D. (Agric.) degree

[1] Department of Agronomy, Faculty of agricultural Studies, University of Sudan for Science and Technology, Shambat, Khartoum, North, Sudan

[2] Arab Authority for Agricultural Investment and Development (AAAID), Khartoum, Sudan

[3] Agricultural Research Corporation, Ministry of Science and Technology, Wad Medani, Sudan

INTRODUCTION

Cotton culture has been one of the oldest among commercial crops. Due to its importance in the Sudan, the agronomic problems involved in its production have always been the primary concern of agricultural research work. Research leaned heavily on the effect of watering intervals, water duty and early water stop on the seed cotton yield of the crop (Farah and Tambal 1988).

The main cotton producing area in Sudan is the Gezira, where irrigation has been the major limiting factor. To ensure that different crops receive adequate amounts of irrigation water, crop rotations were designed on the basis of the availability of a wide area of suitable land and a limited amount of irrigation water (Farbrother 1974).

In irrigation practice, the interval is normally defined as the number of days between successive waterings, calculated from the first day of the next (Frbrother 1974). 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 that too early irrigation does not result in low final yield. Timing of irrigation in mid-season is important as water deficit at the time of fruiting leads to abscission resulting in low yield, while too frequent irrigation may cause excessive vegetative growth and consequently low yield. Late in the season, water stress can be tolerated by the crop (Grimes and Elzik 1990).

Irrigation practice in the Gezira Scheme corresponds closely with the finding of 12-day intervals during establishment of the crop, and during hot weather it is increased to 14 days and finally to 16 days (Burhan 1969). Previous research in the Gezira indicated that terminating irrigation after 8-14 applications did not result in significant yield reduction (Farah and Abdel Rahman 1981). For quality reasons, irrigation water could be terminated after 10 irrigations without adversely affecting the yield (Farah *et al*. 1987). The objective of this study was, therefore, to investigate the effect of extended irrigation intervals on growth and yield of cotton in the Gezira.

MATERIALS AND METHOD

This study was conducted at the Gezira Research Station, Wad Madani, over two successive seasons (1998/1999 and 1999/2000). The locality is in the semi-arid zone, with a hot summer, mild winter and a short rainy season extending from July to September. Total rainfall ranges from about 250 mm in the northern Gezira to about 450 mm in the southern part. The Egyptian cotton (*Gossypium barbadense* L.) variety Barakat 90 was sown on the first of August 1998 in the first season and end of July 1999 in the second season. Land preparation consisted of ridging, harrowing, leveling, and ridging. The plots were 8x8 m2 in size, consisting of 8 ridges 80 cm apart. Between the main plots one metre was left as guard for water control. The seeds were sown on the top of the ridge at a rate of about seven seeds per hole and thinned to three plants per hole, six weeks after planting. Fertilizer nitrogen was applied at sowing at the rate of 80kg N per feddan (one feddan= 0.42 ha) in the form of urea. Phosphorus was applied immediately after thinning at the rate of 48 kg per feddan in the form of triple super-phosphate. Weeds were controlled manually, and the crop was sprayed against insects.

The treatments comprised the following watering regimes: Control, i.e., standard irrigation at approximately fortnight intervals, intervals of thirty days throughout the whole season and intervals of one month during the following stages: Early vegetative growth, late vegetative growth, early flowering, late flowering, early boll opening and late boll opening.

Ten plants were randomly chosen from each plot for collecting data on the following parameters : Plant height, shoot dry weight, the number of days to 50% flowering and 50% bolling, seed cotton yield, lint index, seed index and ginning out-turn. The layout of the experiment was randomized complete block design with four replicates. The data were subjected the analysis of variance, using the procedure of SAS (1989), and the L.S.D. was used for mean comparisons.

RESUTS AND DISCUSSION

The effect of irrigation treatments on plant height was not significant in the two seasons. However, they resulted in shorter plants than with standard irrigation (Table 1). This is in line with the finding of Lazim (1987) that plant height under the Gezira conditions is not significantly affected by the irrigation regime due to the wide adaptation of cotton to watering regimes.

The effects of extended irrigation interval at different stages of growth on the dry weight of the shoot are presented in Table 2. The results indicated that there were no significant differences among the different irrigation treatments at the first sample, in both seasons. The effect of irrigation did not exhibit an influence on growth at such an early stage. The shoot weight of samples taken in mid-season showed a regular trend of treatment effects. However, in the second season, the extended irrigation interval throughout the season continued to show the lowest shoot weight compared to all other treatments. The most important of the two seasons was the last sample, which represented the final shoot growth after extended irrigation. In this sample, irrigation treatments applied at different stages of growth showed highly significant differences. In both seasons, the treatment in which extended irrigation was practiced throughout the season resulted in the lowest shoot dry weight. Furthermore, the treatment which received extended irrigation interval during early fruiting showed low shoot dry weight. Silva *et al*. (1998) found that plant height, fresh and dry biomass and leaf area index were greater in irrigated than in water-stressed plants. The primary cause of reduced yield potential depends on the length of the growing season following recovery.

The extended irrigation interval throughout the growing season started to flower earlier than the control in both seasons (Table 3). This is expected since water stress forces the plants to flower early, and vegetative growth period is consequently shortened. The photosynthetic capacity of cotton is harmed if water deficit occurs during the important growth stage, from the appearance of the square to flowering (Gerik *et al*. 1994). This is also in agreement with Farah *et al*. (1987) who reported that consumptive use of water reaches its maximum rate during flowering and early boll opening.

Table 1. Mean plant height (cm) of cotton under different irrigation regimes, determined at different growth stages, during the growing seasons of 1998/1999 and 1999/2000

Irrigation regime	Sample No. (1998/99)		Sample No. (1999/00)		
	1	2	1	2	3
Standard irrigation	94.8	112.2	64.3	66.4	68.65
Extended interval:					
Throughout	85.7	102.1	57.9	61.4	61.5
Early growth	85.9	112.0	63.1	60.0	68.7
Late growth	85.1	107.8	57.8	59.2	63.9
Early flowering	90.6	107.4	56.1	66.5	64.6
Late flowering	80.8	107.2	58.7	69.8	64.4
Early fruiting	84.3	108.9	61.9	61.2	63.9
Late fruiting	97.0	107.0	65.6	63.2	61.1
Mean	97.8	108.1	60.7	63.5	64.6
LSD(0.05)	ns	ns	ns	ns	ns
C.V.(%)	10.57	7.16	8.37	7.8	7.02

ns= non-significant

The effect of irrigation on 50% boll opening was significant and consistent in both seasons (Table 3). Extended irrigation interval led to earlier boll opening compared to the standard irrigation. This is expected as flower opening and boll opening are closely tied together. Under standard irrigation, all the physiological processes pertaining to growth continue normally without interruption resulting in a longer period of vegetative growth. Under stress conditions, the vegetative growth period is shorter and the flowering and boll opening start earlier (Marani *et al*. 1985).

Table 2. Mean shoot dry weight (g) of cotton under different irrigation regimes, determined at different growth stages, during the growing seasons of 1998/1999 and 1999/2000

Irrigation regime	Sample No. (1998/99)					Sample No. (1999/00)				
	1	2	3	4	5	1	2	3	4	5
Standard irrigation	13.5	62.0	68.0	86.7	74.6	8.7	22.9	41.9	52.1	66.3
Extended interval:										
Throughout	13.6	81.5	78.5	80.7	63.6	13.2	21.5	35.5	41.9	43.6
Early growth	14.2	49.5	61.5	61.5	77.3	10.5	19.0	42.7	49.3	53.1
Late growth	13.0	68.2	73.0	70.5	86.0	12.7	24.7	47.5	44.5	51.8
Early flowering	13.4	53.0	78.0	80.7	77.6	11.3	24.0	37.5	48.9	48.4
Late flowering	10.2	48.5	70.2	72.7	81.2	10.0	22.6	62.4	55.1	60.4
Early fruiting	10.1	51.5	69.2	60.6	62.8	12.7	22.4	55.3	53.4	48.8
Late fruiting	10.5	56.8	68.8	79.2	91.2	11.6	23.4	54.8	49.9	51.8
Mean	10.3	58.8**	70.9	74.9**	76.8**	11.3	22.6	47.2**	49.8	52.8
LSD(0.05)	ns	15.23	ns	10.32	10.96	ns	ns	9.95	ns	8.44
C.V.(%)	17.26	17.62	15.09	9.38	9.7	24.62	11.1	14.3	15.48	10.87

** Significant at P = 0.01; ns = non-significant

Table 3. Mean 50% flowering and 50% boll opening of cotton under different irrigation regimes, determined at different growth stages, during the growing seasons of 1998/1999 and 1999/2000

Irrigation regime	50% flower opening		50% boll opening	
	(1998/99)		(1999/00)	
Standard irrigation	85	97	156	159
Extended interval:				
Throughout	82	95	150	144
Early growth	86	94	156	155
Late growth	86	94	155	149
Early flowering	86	93	158	147
Late flowering	85	93	154	148
Early fruiting	84	97	156	148
Late fruiting	85	98	156	153
Mean	85*	95	155**	150**
LSD (0.05)	1.88	ns	2.197	6.78
C.V.(%)	1.5	2.64	0.96	3.05

ns = non-significant
* Significant at P = 0.05
** Significant at P = 0.01

The effect of irrigation interval at different growth stages on the number of open bolls throughout the picking period in season 1999/2000 was significant in all the picks and in the total number of open bolls/plant (Table 4). With standard irrigation, the number of open bolls was the lowest in the first pick and increased in the next two picks. The treatments in which the interval was extended during early growth followed the same trend. With the extended irrigation interval throughout season, the number of open bolls was the highest in the first pick (2.25) and decreased drastically in the second pick (0.58). As far as the total number of open bolls is concerned, extended irrigation interval throughout the season resulted in the lowest value (5.16), whereas the standard irrigation recorded the highest value (9.3).

Marrow and Krieg (1990) reported similar observations and stated that in late growth stages water and nutrient deficits occur due to stoppage of vegetative growth, and this induces abortion of those fruits which have insufficient time to mature.

The results of the effect of irrigation regime on yield of seed cotton are presented in Table 5. In the first season, no significant differences were detected among the irrigation treatments in the first pick. In the second pick, the treatments resulted in significant differences. The standard and extended intervals during the late flowering stage gave significantly lower yields than all other treatments. In the second season, the irrigation treatments showed highly significant differences indicating that extended irrigation throughout the season and at early flowering have resulted in the lowest yield. The lack of significant effects in the first season is in accord with the findings of Lazim (1987). Farah *et al*. (1987) reported that there were no significant differences among number of irrigations ranging from 8 to 15 for several seasons. The results of the second season in which extended irrigation intervals had significant effect on cotton yield support the findings of Farah and Tambal (1988) who reported that lengthening the irrigation interval from 14 to 21 days decreased yield.

Wide variation was evident between the results of the two seasons, and a combined is analysis of variance is presented in Table 6. The fluctuation in cotton yield from season to season in the Gezira has for long been realized. Burhan (1969) reported that the complexity of the problem stems from the fact that a wide variety of factors are involved; these were classified into controllable and uncontrollable. Among the uncontrollable is monthly rainfall (mm), which varied from one year to another.

Table 4. Mean number of open bolls per plant of cotton under different irrigation regimes, determined at different growth stages, during the growing season of 1999/2000

Irrigation regime	Pick 1	Pick 2	Pick 3	Total	Mean
Standard irrigation	1.44	2.49	5.42	9.35	3.1
Extended interval:					
Throughout	2.25	0.58	2.33	5.16	1.72
Early growth	0.91	2.08	5.16	8.17	2.72
Late growth	3.74	1.67	4.92	10.30	3.43
Early flowering	4.33	1.16	3.38	8.87	2.69
Late flowering	2.08	1.25	4.00	7.33	2.44
Early fruiting	4.00	0.83	2.99	7.83	2.61
Late fruiting	3.50	1.25	3.14	8.14	2.71
Mean	2.78**	1.42**	3.92**	8.15**	
LSD(0.05)	0.52	0.57	0.58	1.02	2.7
C. V. (%)	12.8	27.6	14.74	8.51	

** Significant at P = 0.01

Table 5. Mean seed cotton yield (kg/ha) under different irrigation regimes, determined at different growth stages, during the growth seasons of 1998/1999 and 1999/2000

Irrigation regime	Pick No. (1998/99)		Total	Pick No. (1999/00)			Total
	1	2		1	2	3	
Standard irrigation	152.6	56.3	208.9	66.9	95.6	73.2	199.7
Extended interval:							
Throughout	161.3	44.6	205.9	64.2	37.4	14.0	115.6
Early growth	147.9	55.8	203.7	51.3	66.4	37.4	155.1
Late growth	151.2	43.5	194.7	75.5	56.7	28.7	160.9
Early flowering	114.5	47.6	162.1	72.0	49.6	16.9	138.5
Late flowering	114.5	60.3	174.8	99.3	66.4	21.7	187.4
Early fruiting	120.6	52.8	173.4	75.8	76.8	27.6	179.7
Late fruiting	108.8	52.8	161.6	100.8	76.8	30.9	208.5
Mean	133.9	51.7*	185.6	75.7	65.7**	66.8**	165.2**
LSD(0.05)	ns	11.0	ns	Ns	63.6	10.77	42.8
C. V. (%)	20.5	14.5	16.5	29	24.4	27.3	17.6

* Significant at P=0.05; ** Significant at P = 0.01; ns= non-significant

Table 6. Combined analysis of variance of the effect of extended irrigation interval at different stages of growth on the yield of seed cotton (kg/ha) in 1998/99 and 1999/00 seasons

Source of variation	Degree of freedom	Sum of squares	Mean squares	f. value
Season(S)	1	4564.522	4564.5	1.9608^{ns}
Replication x season (RxS)	6	13967.013	2327.8	
Treatments(T)	7	14434.683	2062.1	2.3573
TxS	7	24156.049	3450.86	2.3573*
Error	24	36740.604	874.77	3.9449**
Total	36	93862.8		
C.V. (%)	16.7			

Table 7. Mean lint index, seed index and ginning out-turn (GOT) of cotton under different irrigation regimes, determined at different growth stages, during the growing seasons 1998-2000

Irrigation regime	(1998/99)			(1999/00)		
	Lint index	Seed index	GOT	Lint index	Seed index	GOT
Standard irrigation	3.87	7.3	29.5	4.9	8.97	32.0
Extended interval:						
Throughout	3.57	8.17	28.0	4.42	8.72	30.7
Early growth	3.47	7.67	29.7	4.57	10.07	31.2
Late growth	4.07	8.37	28.5	5.07	9.20	31.0
Early flowering	3.62	7.4	29.0	4.67	9.62	30.7
Late flowering	4.12	7.97	29.7	4.5	9.82	31.2
Early fruiting	4.0	7.77	29.0	4.57	9.72	31.5
Late fruiting	4.07	8.25	29.0	4.75	9.12	32.5
Mean	3.87	7.87	29.0	4.68	9.28	31.3
LSD(0.05)	ns	ns	ns	ns	ns	ns
C. V. (%)	11.12	11.6	2.7	10.28	14.09	1.9

* Significant at P= 0.05; ** Significant at P=0.1; ns=non-significant

Lint index, seed index and ginning out-turn (G.O.T.) are presented in Table 7. These parameters showed very slight response to water regime. Lower values of lint index were obtained under extended irrigation throughout the season. However, neither this nor any effect on seed index or G.O.T. had reached a statistically significant level. It seems that the genetic control of these characters and the limited influence of irrigation treatment had kept these characteristics unchanged (Munro 1987).

REFERENCES

Burhan, H.O. (1969). Factors involved in the fluctuation of cotton yields in the Gezira. *Sudan Agricultural Journal* 4(1), 37-50.

Farah, S.M. and Abdel Rahman, A.A. (1981). Effect of water stoppage on yield and quality of cotton variety Barac (69) B. Annual Report of the Gezira Research Station and Substations, 1980/1981 season. Agronomy and Crop Physiology Section. pp. 38-41. ARC, Wad Medani, Sudan.

Farah, S.M. and Tambal, H.A. (1988). Crop physiology. Annual Report of the Gezira Research Station and Substations, 1987/1988 season. Agronomy and Crop Physiology Section, ARC, Wad Medani, Sudan

Farah, S.M.; Gandoul, G.L. and Tambal, H.A. (1987). Agronomy of cotton, sorghum and wheat. Annual Report of the Gezira Research Station pp. 7-8, ARC, W ad Medani, Sudan.

Farbrother, H.G. (1974). Irrigation practices in the Gezeira. Cotton Research Report, Republic of Sudan (1970/71), No. 89.

Gerik, T.J; Jackson, B.S.; Stockle, G.O. and Rosenthal, W.D. (1994). Plant nitrogen status and boll load of cotton. *Agronomy Journal* 86, 514-518.

Grimes, D.W. and Elzik, K.M. (1990). *Irrigation of Agricultural Crops*. Agronomy Monograph, No. 30.

Guinn, C. and Mauney, J.R. (1984). Effect of moisture status on flowering. *Agronomy Journal* 76, 90-94.

Lazim, M.E. (1987). Cotton agronomy. Annual Report of Gezira Research Station, 1986/1987 season. Agronomy and Crop Physiology Section, ARC, Wad Medani, Sudan, pp 1-6.

Marani, D.N.; Raddy, V.R; and Kinioni, M.C. (1985). Effect of water stress on canopy senescence and carbon exchange rates in cotton. *Crop Science* 25, 798-812.

Marrow, M.R. and Krieg, D.R. (1990). Cotton management strategies for a short growing season environment:water-nitrogen consideration. *Agronomy Journal* 82, 52-56.

Munro, J.M. (1987). *Cotton.* Second edition. Longman Group Limited, London.

SAS (1989). *Releases 6.11 of the SAS System for Windows*. SAS institute Inc., Cary, NC, U.S.A.

Silva, B.B. da; Souza, C.B. de; Rao, I.V.R.; Azevedo, P.V. de; Espirola, SJ.; Silva da de, Sanza, C.B. de Azevedo, P.V. (1998). Effects of water deficit on phenology and fibre characteristics of cotton *Revisit-Brasi-Leira-de-Engeriharia Agricola-e-Ambient* 2(1), 42-46.

تأثير إطالة الفترة بين الريات فى مراحل مختلفة من نمو نبات القطن على نمو وإنتاجيته فى الجزيرة*

سامية عثمان يعقوب[1] وحامد عثمان برهان[2] و سعيد محمد فرح
وعبد الرحمن حسن عبد اللطيف[3]

قسم المحاصيل الحقلية ، كلية الزراعة
جامعة الخرطوم – شمبات – السودان

موجز البحث : إجريت تجربة حقلية لموسمين متتالين 99/1998 و 00/1999 فى محطة بحوث الجزيرة ، ود مدنى – السودان ، لدراسة تأثير إطالة فترات الرى فى مراحل نمو مختلفة لمحصول القطن (الصنف بركات 90) على النمو والإنتاجية . اشتملت المعاملات على الرى التقليدى كل أسبوعين وإطالة فترة الرى إلى شهر طول فترة موسم النمو وإطالة فترة الرى لمدة شهر أثناء أطوار محددة من نمو المحصول هى طور النمو الخضرى المبكر ، والنمو الخضرى المتأخر ، والإزهار المبكر ، والإزهار المتأخر ، والإثمار المبكر والمتأخر . وقد دلت النتائج على أن النمو والإنتاجية يتأثران سلباً بإطالة فترة الرى إلى شهر طيلة موسم النمو أو أثناء طور الإزهار المبكر . كما أظهرت الإنتاجية تبايناً كبيراً بين الموسمين . وكان لإطالة فترة الرى تأثير سلبى ومعنوى على الإنتاجية مصحوباً بقصر النبات ونقص الوزن الجاف للنبات والتبكير فى الإزهار وتكوين اللوز مقارنة بالرى كل أسبوعين . ولم تتأثر مكونات الإنتاجية الثلاثة (وزن الشعرة ووزن البذرة ومعدل الحليج) معنوياً ويعزى ذلك إلى أن هذه الصفات تتحكم فيها الجينات .

---

* جزء من أطروحة الكاتب الأول التى قدمها للحصول على درجة الدكتوراه من جامعة الخرطوم

[1] كلية الدراسات الزراعية ، جامعة السودان للعلوم والتكنولوجيا ، الخرطوم بحرى - السودان
[2] الهيئة العربية للإستثمار والإنماء الزراعى ، الخرطوم - السودان
[3] هيئة البحوث الزراعية ، وزارة العلوم والتكنولوجيا ، الخرطوم – السودان