Sudan J. Des. Res. Vol. 12 (1) :48-61, 2020

Effect of Timing of Last Irrigation on Growth, Yield and Water Productivity in Cotton under Gezira Conditions

Bashir M. Ahmed[1-4] , M.A. Osama, H.A. Abdelrahman and A.E. Omer

Agricultural Research Corporation, Wad Medani, Sudan

Abstract: A Field experiment was conducted for two seasons (2015/16 and 2016/17) at Gezira Research Station Farm (GRSF) to determine the optimum timing of the last irrigation for the newly released BT. cotton (Seeni1) along with non BT. cotton (Hamid) on the basis of scheduling irrigation approach. The experiment was executed in a split plot design with the two cotton cultivars comprising the main-plots and eight timings of last irrigation as sub-plots. All treatments were replicated three times. Delay of final irrigation significantly increased number of sympodia per plant and plant height. Irrespective of cotton cultivar, 27 WAS recorded the highest number of bolls/plant in both seasons. Cotton yield, water productivity and fiber quality were highly affected by irrigation treatments. Delay of final irrigation up to 21 WAS resulted in higher crop and water productivities. Moreover, delaying the last irrigation after 21 weeks showed no improvement in cotton fiber quality. These results indicate that excessive irrigation might not produce more yield or improve cotton quality.

Key words: Irrigation interval, Last irrigation, Water productivity, Cotton fiber quality.

INTRODUCTION

Water availability is generally the most important natural factor limiting expansion and development of agriculture in arid and semi-arid regions.

[1-4]Agricultural Research Corporation, Wad Medani, Sudan

There is great need for judicious use of river water through a better understanding of the crop yield-water application interaction. This includes efforts to improve crop water use efficiency by changing irrigation methods, applied amounts (deficit irrigation), crops, tillage practices, and other management methods (Aujla *et al*. 2006; Buttar *et al*. 2006; Ibragimov *et al*. 2007).

Cotton (*Gossypium hirsutum* L.) is the major fiber crop in the Sudan. Due to crop intensification in Gezira Scheme after the adoption of the new Act of 2005, water became the major limiting factor for crop production. With increasing concern about water shortage with regard to summer season's crops in the Gezira there is a renewed interest in increasing the water use efficiency in cotton. Sowing of cotton, in the Gezira, is recommended from the beginning of July, which coincides with the onset of rainy season. During this period irrigation is supplementary to meet the crop water requirement. According to sowing date, harvesting of cotton starts in early December and continues until middle of March; irrigation water is available to farmers at two weeks intervals.

Many researchers proved that cotton yields can actually be reduced by application of excessive water (Jackson and Tilt, 1968; Grimes *et al*. 1969; Letey and Dinar, 1986; Grimes, 1994; Wanjura *et al*. 2002; Karam *et al*. 2006;). In the Sudan, previous work on Barac (67) B showed that terminating irrigation after 8 – 14 applications did not result in a significant yield reduction, however, for quality reasons irrigation water could be terminated after 10 irrigations without affecting adversely the yield or quality (Farah *et al*. 1986). On the other hand, water stress during the late stages of growth reduces cotton yield which can be attributed to reduction in net CO_2 assimilation and abscission of almost all young bolls (Grimes *et al*. 1970; Faver *et al*., 1996). Therefore, this study was conducted to determine the timing of last irrigation and its effects on growth, yield, fiber quality characteristics and water use efficiency of cotton grown on heavy clay soils of Gezira Scheme, Sudan.

MATERIALS AND METHODS

This study was conducted for two seasons (2015/2016 – 2016/2017) in the Gezira Research Station Farm (GRSF) at Wad Medani. The main objective was to evaluate the effect of different timings of the last irrigation on growth attributes, yield, yield components, fiber quality and water productivity of Bt. and non-Bt. cotton cultivars under Gezira State conditions. Treatments were combination of two cotton cultivars (Seeni1 and Hamid) and eight timings of last irrigation. The first irrigation treatment was started 13 weeks after sowing (WAS), then every two weeks. Split plot design was used with three replications. Cultivars were assigned to the main plot while irrigation treatments as sub plot. The sub plot size was 57.6m² (4.8 x 12m).

Sowing was carried-out on the third week of July by hand on ridges 80cm apart and intra-row spacing of 30cm between holes within the ridges. Seedlings were thinned to 2 plants/hole four weeks after sowing. Nitrogen fertilizer in the form of urea at the rate of 186 kg/ha was applied 6 weeks after planting. Herbicides (Pendimethalin + Diuron) at the rate of 0.6 + 0.2 kg ai/fed were applied before sowing then the experimental plots were hand weeded four times during the growing season.

Plant height (cm) was measured for five plants randomly selected in each plot at harvest stage. Number of bolls and number of symbodial branches were recorded for five plants sample. Boll weight (g) and ginning out turn (%) were determined for ten bolls randomly taken from each plot prior to harvest. Seed cotton yields were taken from a net area of four central ridges (3.2m) at distance of 12.0m (38.4 m²) in each plot. The harvested cotton was weighed for seed cotton and lint yield (kg/ha) in each plot. Main fiber quality parameters, such as length, strength and micronaire (Mic.) were carried out by the cotton fiber testing laboratory of ARC according to international standards.

Total applied water (TAW) is the gross irrigation plus rainfall received during the growing season. Irrigation water applied was measured using water flow meter (BFM001 model). For computation of water

productivity (WP), seed cotton yields per hectare in different treatments were divided by the respective total applied water and expressed as kg/m^3. Data collected were subjected to the statistical split plot analysis of variance (Mstatc). Levels of significance at 0.05, 0.01 and 0.001 probabilities for the main factors (cultivar and irrigation treatments) and their interactions responses were calculated. Significantly different means were separated by the Duncan's Multiple Range Test (DMRT) for significance at the 0.05 level of probability.

RESULTS AND DISCUSSION

Plant height and number of sympodia/plant

Effect of timing of last irrigation on plant height (cm) and number of sympodia/plant of BT. and non-BT. cotton cultivars are presented in Table 1. Plant height (cm) was significantly affected by cultivar and time of last irrigation.

Cultivar Hamid significantly recorded taller plants when the last irrigation was delayed to 27 WAS compared to the other treatments, but this increase was significant only during the first season (2015/16). Time of last irrigation had significant effect on number of sympodia, while the cultivar and the interaction had no significant effect.Irrespective of cultivar, the first and second last irrigation treatments (13 and 15 WAS) showed lower number of sympodia/plant compared to the other treatments. Similar to plant height, there was an increase in number of sympodia/plant with the delay in last irrigation.

Yield components

Yield components (number of bolls/plant, boll weight and GOT%) as affected by cultivar and timing of last irrigation are presented in Table 2. No interaction effects were observed in means of irrigation treatments and cultivars. BT. cotton had significantly ($P < 0.01$) higher values of ginning out turn (GOT%) compared to non BT. cotton in both seasons (Table 2). Similarly timing of last irrigation had significantly affected number of bolls/plant in both seasons. No significant responses were observed

among irrigation treatments and cultivars for both GOT% and boll weight.

Table 1. Effect of timing of last irrigation on growth parameters of BT and non BT. cotton during 2015/16 and 2016/17 seasons.

Factor	Plant height (cm)	No of sympodia /plant	Plant height (cm)	No of sympodia /plant	Plant height (cm)	No of sympodia /plant
	2015/16		2016/17		Combined	
Timing of last irrigation (WAS)						
13	78	9.7	79	10.5	79	10.1
15	83	10.0	84	11.7	84	10.9
17	85	11.0	87	12.3	86	11.7
19	85	12.2	94	13.4	90	12.8
21	92	12.0	90	12.8	91	12.4
23	89	11.7	90	13.6	90	12.7
25	89	12.3	91	13.8	90	13.1
27	102	11.8	93	14.0	98	13.0
SE±	1.54	0.54	1.82	0.73	2.2	0.8
L.S.	***	**	***	***	***	**
Cultivar						
Hamid	94	11.2	91	13.2	93	12.2
Seeni1	81	11.5	86	12.4	84	12.0
SE±	1.01	0.43	2.91	0.63	2.8	3.0
L.S.	**	NS	NS	NS	NS	NS
CV%	4.3	11.7	5.0	12.2	6.5	12.5

L.S. = level of significance: **, *** = significant at p≤ 0.01 and 0.001 levels, respectively. NS= not significant.

Crop and water productivities

The crop and water productivities associated with the different timings of last irrigation are presented in Table 3. Timing of last irrigation had significantly ($p<0.001$) affected seed cotton yield and lint cotton yield ($p< 0.01$). However, with respect to cultivar, the first and second irrigation treatments (13 and 15 DAS) showed lower seed cotton yield (kg/ha) and

lint yield (kg/ha) than the other treatments, while delaying the last irrigation to 27 WAS significantly increased seed cotton yield, but this increase was significant only during the second season (2016/17). The results contradicted with those obtained by Farah *et al*. (1981). Who reported that no differences were observed when the irrigation was stopped after 8-14 irrigations on Barac 67 (B).

Table 2. Effect of timing of last irrigation on yield components of BT. and non BT. cotton during 2015/16 and 2016/17 seasons.

Factor	No. of bolls/ plant	Boll weight (g)	GOT (%)	No. of bolls/ plant	Boll weight (g)	GOT (%)	No. of bolls/ plant	Boll weight (g)	GOT (%)
	2015/16			2016/17			Combined		
Timing of last irrigation (WAS)									
13	8.1	4.8	38	9	4.6	36	8.6	4.6	37
15	8.4	4.2	38	10	4.6	37	7.2	4.4	38
17	11.3	4.3	37	10	4.8	38	10.7	4.6	38
19	10.1	4.6	36	11	4.9	38	10.6	4.7	37
21	11.0	4.3	38	10	4.6	38	10.5	4.5	38
23	11.2	4.6	38	11	4.7	37	11.1	4.7	38
25	10.5	4.5	38	10	4.7	37	10.3	4.6	38
27	14.4	4.7	37	11	4.6	38	12.7	4.7	38
SE±	0.39	0.21	0.85	0.53	0.42	0.64	0.65	0.5	0.9
L.S.	***	NS	NS	*	NS	NS	**	NS	NS
Cultivar									
Ham	10.0	4.6	34	10	4.6	34	10.0	4.6	34
Seen	11.3	4.3	41	10	4.7	41	10.7	4.5	41
SE±	0.29	0.07	0.38	0.89	0.19	0.34	0.90	0.2	0.4
L.S.	NS	NS	**	NS	NS	**	NS	NS	**
CV	8.9	11.5	5.6	12.9	10.9	4.2	11.5	11.8	6.5

L.S. = level of significance: *,**, *** = significant at p< 0.05, 0.01 and 0.001 levels, respectively. NS= not significant.

Table 3 showed that WP was significantly affected by irrigation treatment (p< 0.001) and no interactions effects were observed. Irrespective of timing of last irrigation, the two cultivars gave similar values of WP (0.59 kg/m^3 and 0.58 kg/m^3 for Hamid and Seeni1, respectively) during both seasons. This could be due to the similar amount of water that was

consumed by each cultivar (4305 and 4342 m^3/ha, respectively). It is also clear from Table 3 that timing of last irrigation offers beneficial effects to water productivity. During the first season, the three irrigation treatments (15, 17 and 19 WAS) significantly scored higher WP (0.63, 0.65 and 0.66 kg/m^3, respectively) compared to the last three irrigation treatments (23, 25 and 27 WAS) which gave 0.56, 0.52 and 0.52 kg/m^3, respectively.

Table 3. Effect of timing of last irrigation on yield and irrigation water productivity (WP_{i+r}) of BT. and non BT. cotton during 2015/16 and 2016/17 seasons.

Factor	Seed yield (kg/ha)	Lint yield (kg/ha)	WP_{i+r} (kg/m^3)	Seed yield (kg/ha)	Lint yield (kg/ha)	WP_{i+r} (kg/m^3)
	2015/16			2016/17		
Timing of last irrigation (WAS)						
13	1669	634	0.59	1748	629	0.57
15	1776	675	0.63	1793	663	0.56
17	2021	748	0.66	1857	706	0.55
19	2031	731	0.65	2453	932	0.71
21	2155	819	0.58	2267	861	0.64
23	2252	855	0.56	2308	854	0.59
25	2212	840	0.52	2320	858	0.57
27	2405	890	0.52	2071	787	0.49
SE±	77.2	30.0	0.021	127.2	54.0	0.035
L.S.	***	***	***	**	**	**
Cultivar						
Hamid	2105	716	0.60	2087	710	0.59
Seeni1	2026	831	0.58	2117	868	0.58
SE±	59.6	25.0	0.011	51.7	21.0	0.019
L.S.	NS	**	NS	NS	**	NS
CV%	9.2	10.4	9.4	14.8	12.5	9.4

L.S. = level of significance: **, *** = significant at p< 0.01 and 0.001 levels, respectively. NS= not significant.

The increased WP of 15 WAS treatment resulted from decreasing water amount rather than from increasing yield. However, for 17 and 19 WAS irrigation treatments, higher values of WP could be attributed to both

decreasing irrigation water amount and increasing seed cotton yield as shown in Table 3. On the other hand, no differences were observed among the treatments 13, 15, 19 and 21 WAS which gave 0.59, 0.63, 0.65 and 0.58 kg/m^3, respectively. The lowest WP values were obtained when the last irrigation was delayed beyond 23 WAS.

During the second season, treatment 19 WAS obtained significantly higher WP (0.71 kg/m^3) compared to other irrigation treatments. However, no differences were observed between 19 and 21 WAS which gave 0.64 kg/m^3. The higher WP achieved by 19 and 21 WAS was due to higher yield (2031 and 2155 kg/ha, respectively). Although the last three irrigation treatments (23, 25 and 27 WAS) produced similar yield compared to 19 WAS, the former treatments significantly gave lower WP which could be due to higher irrigation water consumed by these treatments.

Table 4. The combined analysis of timing of last irrigation on yield and irrigation water productivity (WP_{i+r}) of BT and non BT. cotton.

Factor	Seed yield (kg/ha)	Lint yield (kg/ha)	WP_{i+r} (kg/m^3)
Timing of last irrigation (WAS)			
13	1709	632	0.60
15	1785	669	0.62
17	1939	727	0.62
19	2242	832	0.58
21	2211	840	0.53
23	2280	855	0.50
25	2266	849	0.45
27	2238	839	0.45
SE±	135.0	57.0	0.02
L.S.	***	***	***
Cultivar			
Hamid	2096	713	0.56
Seeni1	2072	850	0.53
SE±	62.6	31.5	0.01
L.S.	NS	**	**
CV%	10.2	12.7	9.2

L.S. = level of significance: **, *** = significant at p≤ 0.01 and 0.001 levels, respectively. NS= not significant.

Cotton quality parameters

The main quality parameters such as length, strength and micronaire (Mic.) for BT cotton (Seeni1) and non BT. Cotton (Hamid) are presented in Table 5. The quality parameters (length and strength) showed almost the same result for both cotton varieties, because it is genetically controlled. Micronaire values were not clearly affected for the non BT. variety (Hamid). On the other hand, low micronaire values compared to standard were indicated for the BT. variety (seeni1). Therefore, irrigation of BT cotton after 21 weeks had no effect on quality improvement as indicated by the low micronaire value (second pick) as compared to the variety standard.

Table 5. Fiber characteristics of BT. and non BT. cotton varieties (First and Second pick) as affected by timing of last irrigation at Gezira Research Station Farm during 2015/16.

Irrigation	Pick 1			Pick 2		
	Length(mm)	Mic.	Strength g/tex	Length(mm)	Mic.	Strength g/tex
			Hamid			
13-15	29	5.0	31	27	5.0	28
17-19	30	5.1	32	28	5.0	28
21-23	31	5.0	29	29	5.1	29
25-27	31	5.1	31	29	5.0	29
			Seeni-1			
13-15	30	4.9	30	29	4.5	31
17-19	30	4.9	29	29	4.6	30
21-23	30	5.3	29	28	4.0	27
25-27	30	5.2	30	28	4.4	27

It can be summarized that cotton yield was significantly affected by the time of the final irrigation (Fig. 1). The yield from the treatments was significantly different at $P<0.01$ level. There were significant yield reductions in the first (13WAS) and second (15WAS) irrigation treatments, the third irrigation treatment (17WAS) was slightly higher than 13 and 15WAS by 12 and 8%, respectively. The other five irrigation

treatments (19, 21, 23, 25 and 27WAS) gave similar seed cotton yield that ranged between 2211 and 2280 kg/ha.

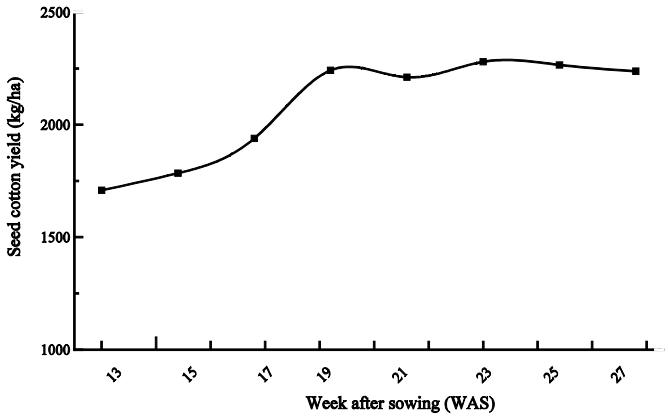
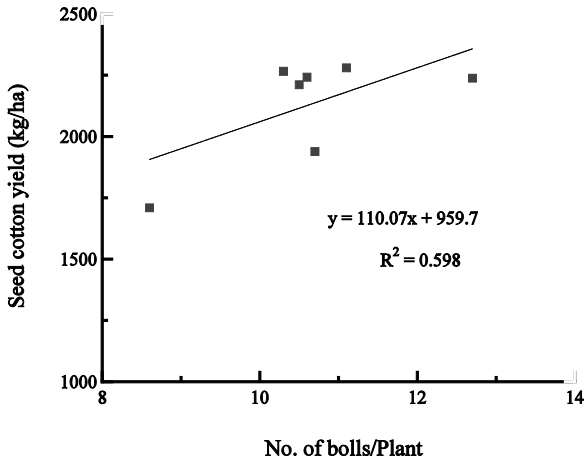


Fig. 1. Evolution of seed cotton yield during the two growing seasons (combined)

The plotting of seed cotton yield against plant height, number of bolls per plant and number of symbodia per plant (Fig. 2) showed strong positive and linear correlation between cotton yield and plant height (R^2= 0.72) and between cotton yield and number of symbodia per plant (R^2= 0.95) which in turn depends on optimum plant height.



(a)

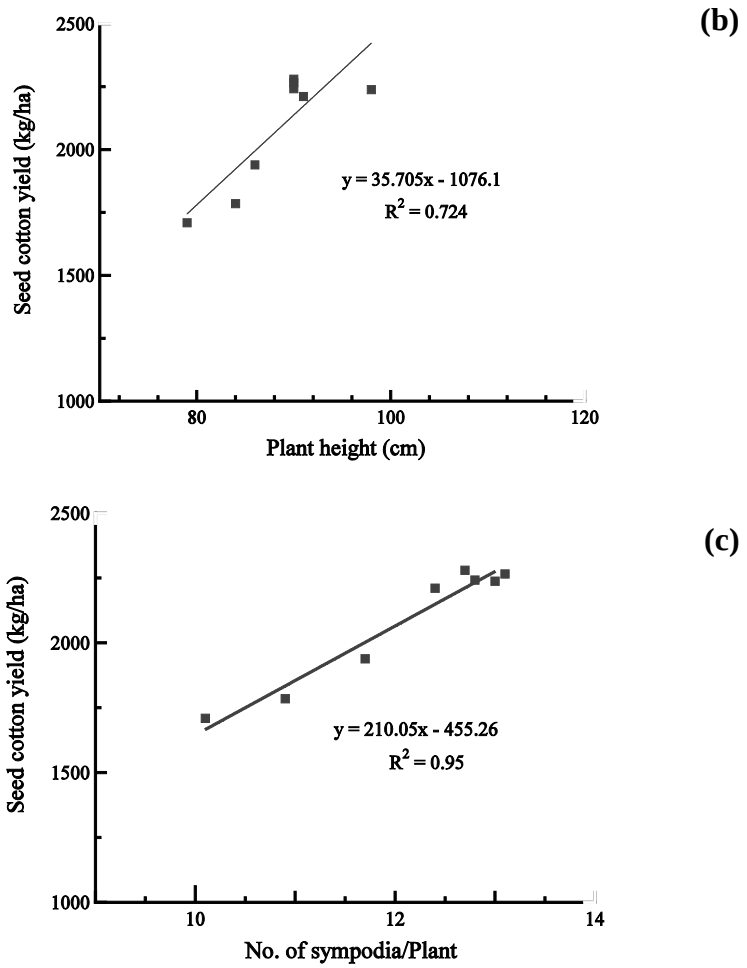


Fig. 2. Relationship of seed cotton yield with (a) number of bolls per plant, (b) plant height and (c) number of symbodia per plant.

SUMMARY AND CONCLUSION

Based on the results achieved during the two consecutive seasons (2015/16 and 2016/17) under GRSF, the maximum seed cotton yield associated with higher water productivity can be achieved when the irrigation is terminated at 21 weeks, as no improvements were observed in quality beyond this period (21WAS).

REFERENCES

Aujla, M.S., Thind, H.S., and Buttar, G.S. 2006. Fruit yield and water use efficiency of eggplant (*Solanum melongena* L.) as influenced by different quantities of nitrogen and water applied through drip and furrow irrigation, Scientia Horticulturae 112: 142-148.

Farah, S.M., Gandoul, G.I., and Hassan A.T. 1986. Effects of the date of final irrigation on the yield of cotton. Annual report, Gezira Research Station, 7-8.

Farah, S.M. and Asim, A.A. 1981. Effect of water stoppage on yield and quality of cotton variety Barac 67 (B). Annual report, Gezira Research Station, 7-9.

Faver, K.L., Gerick, T.J., Thaxton, P.M., and El-Zik, K.M. 1996. Later season water stress in cotton. II. Leaf gas exchange and assimilation capacity. Crop Science 36: 922-928.

Grimes, D.W. 1994. Efficient irrigation of pima cotton. In: Proceedings of 1994 Beltwide Cotton Conferences, vol. 1, National Cotton Council of America, Memphis, TN, 90-93.

Grimes, D.W., Miller, R.J., and Dickens, L. 1970. Water stress during flowering of cotton. California Agric. 24: 4-6.

Grimes, D.W., Yamada, H., and Dickens, W.L. 1969. Function for cotton (*Gossypium hirsutum* L.) production from irrigation and nitrogen fertilization variables. I. Yield and evapotranspiration. Agron. Journal 61: 769-773.

Jacksoon, E.B., and Tilt, P.A. 1968. Effects of irrigation intensity and nitrogen level on the performance of eight varieties of upland cotton, *Gossypium hirsutum* L. Agron. Journal 60: 113-17.

Karam, F., Rafic, L., Randa, M., Daccache, A., Mounzer, O., and Rouphael, Y. 2006. Water use and lint yield response of drip irrigated cotton to length of season. Agric. Water Management 85 (3): 287-295.

Letey, J., and Dinar, A. 1986. Simulated crop-water production functions for several crops when irrigated with saline waters. Hilgardia 54(1).

Wanjura, D.F., Upchurch, D.R., Mahan, J.R., and Burke, J.J. 2002. Cotton yield and applied water relationships under drip irrigation. Agric. Water Management 55(3): 217-237.

تأثير زمن الرية الأخيرة علي نمو وانتاجية و كفاءة الري لصنفين من القطن تحت ظروف الجزيرة

بشير محمد أحمد[4-1]، أسامة محمد أحمد، عبدالرحمن حسن عبداللطيف وعمر عبدالقادر النور

هيئة البحوث الزراعية، واد مدني، السودان

مستخلص البحث: أجريت تجربة حقلية خلال موسمي 2015/ 16 و 2016/ 17 بمزرعة محطة بحوث الجزيرة وذلك لتحديد أنسب ميقات للرية الأخيرة لأصناف القطن المحورة وراثياً (صيني1) و غير المحورة وراثياً (حامد) استناداً علي طريقة جدولة الري. تم استخدام تصميم القطع المنشقة، وضعت الأصناف في الأحواض الرئيسية بينما وضعت مواقيت الرية الأخيرة في الأحواض الفرعية. كررت كل المعاملات ثلاثة مرات. أوضحت النتائج أن تأخير الرية الأخيرة زاد عدد الأفرع المثمرة في النبات وكذلك زاد طول النبات بصورة معنوية. بغض النظر عن صنف القطن، ايقاف الري عند 27 أسبوع بعد الزراعة أعطي أعلي عدد من اللوز في النبات خلال الموسمين. كذلك أوضحت النتائج أن انتاجية القطن و انتاجية مياه الري ونوعية القطن تأثرت بصورة واضحة بمعاملات الري. تأخير الرية الأخيرة لـ21 اسبوع بعد الزراعة أعطي أعلي انتاجية للمحصول ومياه الري.اضافةً الي ذلك وجد أن تأخير الرية الأخيرة بعد 21 اسبوع بعد الزراعة لم يودي الي تحسين في نوعية القطن. أوضحت هذه النتائجأيضاً أن الري الزائد لا يزيد الانتاجية أو يحسن نوعية القطن.

[4-1] هيئة البحوث الزراعية، واد مدني، السودان