Effects of cotton spacing on insect infestation, natural enemies and yield, Gezira State, Sudan

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ABSTRACT

In the Gezira Scheme, Sudan, cotton (*Gossypium barbadense* L.) has been grown under irrigation without insecticidal use for more than 30 years (1911-1945). That was probably due to the traditional growing of cotton, in the same area, under rainfed before the establishment of the Gezira Scheme. Such practice witnessed a balanced agricultural ecological system in the cotton growing area. Since season 1945/46 till now, more than 300 insecticides and insecticide mixtures were recommended. The average yield was less than 7 kantar/feddan for upland cotton. The objective of this study was to test the effect of spacing on insect infestation, natural enemies and yield of Brazilian (LL) cotton cultivar enemies without insecticidal spraying. The crop was planted in June 20, 2012 at intra-row spacing of 10 cm, 20 cm, 30 cm and 40 cm and 50 cm with 4-6 seeds/hole and then thinned to three plants per hole, on 80 cm ridges. Insect pests and natural enemies were monitored. Results showed that the sucking insects, Jassid (*Jacobiassica lybica*) and the whitefly (*Bemisia tabaci*) appeared in July, increased in number to reach the peak in August and then decreased in October. The Brazilian (LL) cultivar was attacked by the bollworms, *Helicoverpa armigera* and *Earias insulana*. Shedding of reproductive structures due to bollworms was recorded. *H. armigera* resulted in higher damage of reproductive structures during August in the wider spacing (50 cm) while, the damage was lower during September. For *E. insulana*, damage of reproductive structures was lower in the wider spacing compared to narrow spacing during August and September. Natural shedding of reproductive structures was low during August and high during September in the widest spacing (50 m). The buildup of natural enemies started in July to reach the peak in September and decreased in October, in a density dependent pattern with sucking insect pest populations. The yield of cotton in kantar per hectare was 29.8 at 10 cm spacing (5 folds) and 14.8 at 20 cm (2.5 folds) as compared to 6 at 50 cm the recommended spacing. However, the quality, in term of stickiness, was satisfactory among all spacing under test. The study revealed that narrow spacing reflected higher yield with good quality of cotton. It is recommended to grow the Brazilian LL cotton cultivar at a spacing of 10 cm for higher yield and best quality.

INTRODUCTION

In the Sudan, cotton is an important crop it was the major cash and foreign currency earning crop and constitutes about 30-40 % of the total export. The Sudan was the world's second largest producer of extra long staple cotton after Egypt (Fadalla, 1990; El Amin, 1997).

The major cotton insect pests are the African bollworm, *Heliocoverpa armigera* which is a pest of worldwide distribution and is found in all cotton growing areas in the Sudan as well as jassid, *Jacobiasca lybica*, the whitefly, *Bemisia tabaci* and the cotton aphid, *Aphis gossypii* (Schmutterer, 1969).

Control of cotton insect pests depends mainly on insecticides. However, they are expensive and constitute 20 -40 % of the total cost of cotton production (Dabrowski, 1997). In the Sudan, also, the massive use of pesticides has led to substantial concerns about health and environmental impacts on humans and animals. (OTA 1990; Joffe, 1995).

Cotton is produced in many countries under integrated pest management (IPM). One of the major components of IPM is the cultural practices including plant population. Better design of plant population is a good tool for pest control, high yield and good quality of cotton production (Smith and Falcon, 1973). Cotton was produced under Gezira conditions before the establishment of the Gezira Scheme (Mudawi, 2007) and after that for more than thirty years (1911-1945) without insecticidal use. The first application of the insecticide DDT was started in season 1945/46 in 10% of the cotton area to control the indigenous pest, jassid, *Jacobiasica lybica*. Since then, insecticides were used and up to 300 insecticides and insecticide mixtures were recommended to control the insect pest complex on cotton. On the other hand, the numbers of insect pests were increased. The most serious pest was the African bollworm, *Heliocoverpa armigera* while the other pests are sucking insects which constitute food for predators and parasitoids. However, it was observed that the first pick of early sown cotton was not infested with bollworms.

The objective of this study was to control early sown cotton pests by adopting different plant spacings and to check their role on natural enemies without insecticidal spraying.

MATERIALS AND METHODS

Experimental site

The experiment was conducted at the Experimental Farm, Faculty of Agricultural Sciences, University of Gezira, Sudan, latitude 14.22N, longitude 33.39 E and altitude 407m above sea level.

Execution of the experiment

The land was deep plowed, harrowed, leveled and then made into 80 cm between ridges. The experiment was composed of 20 plots, each of 7 ridges 10 m long. Cotton was grown at 5 spacing of 10 cm, 20 cm 30 cm, 40 cm and 50 cm, between holes and replicated 4 times in a randomized complete block design.

Cotton cultivar Brazilian (LL) was shown on June 2012. The seeds were treated with the seed dresser Gaucho 70 WP at a dose of 3.0 g per kilogram of seed to protect the germinating seeds against insect damage. Seeds were planted in holes on top of the ridge.

Four to six seeds were sown to three plants per hole and then thinned to one plant per hole, 3 weeks after germination.

All plots were supplied with nitrogen in the form of urea at the rate of 190 kg N/ha applied in a split dose .The first dose was applied one month after germination and the second dose was applied a month later. Irrigation was done every 10 days while weeding was done thrice before the crop reached full canopy.

Data collection

Flowers were counted every two weeks starting on the first week of August by selecting ten plants randomly per plot and the number of flowers per plant was recorded. Entomological data were collected weekly started on the second week of July and consisted of damage of flea beetle (*Podagrica puncticollis*), presence of Jassid, (*Empoasca, lybica*) and whitefly, (*Bemisia tabaci*), as well as damage and presence of bollworms (*Heliocoverpa armigera*), and (*Earias insulana*). Also, natural enemies were monitored and recorded. Mean while, monitoring of flea beetle damage was done through random selection of 10 plants per plot and then damaged plants were recorded. Also, for Jassid and whitefly, 10 plants were randomly selected per plot; from each plant, 5 leaves were checked for insect presence and recorded. The leaves selected were two from the top of the plant, one in the middle and two at the bottom of the plant. For bollworms, 10 plants were randomly selected and the eggs and larvae were recorded. Also, shedding reproductive structures were checked for bollworms damage if any. Cotton quality and quantity were recorded. Stickiness as for cotton quality was determined by using heat method.

Statistical analysis

Data were subjected to ANOVA. Count data were transformed to $\sqrt{x + 0.5}$ and percentage data were arcsine transformed before statistical analysis. Means were separated using Duncan's multiple range test (DMRT) at 5% level of significance.

RESULTS

Table 1 shows that Jassid population was low at all plant spacings. However, a slight increase was observed during August and then rapidly dropped during September and October .No significant differences were detected between spacing throughout the period, from July to October.

Table 1. Effects of cotton spacing on jassid population.

Spacing (cm)	Number of cotton Jassid per 100 leaves			
	July	August	September	October
10	(0.5)	(11.13)	(5.60)	(2.63)
	0.94	3.29	2.44	1.74
20	(0.00)	(13.00)	(3.30)	(3.25)
	0.70	3.49	1.89	1.77
30	(0.50)	(12.88)	(2.90)	(1.63)
	0.89	3.19	1.80	1.43
40	(0.76)	(11.38)	(3.30)	(5.88)
	1.00	2.89	1.89	1.13
50	(0.50)	(7.63)	(3.10)	(0.50)
	0.98	2.68	1.85	1.00
Sig. level	NS	NS	NS	NS
SE±	0.3	0.3	0.2	0.2
CV%	38.34	23.86	25.57	32.25

Means between parentheses are actual data.

Table 2 shows that whitefly population was low during July. It reached the peak during August and then dropped during September to reach the bottom during October. During August and September, 10 cm and 20 cm spacing were harboring a large number of whitefly, compared to 50 cm spacing. However, during August 50 cm spacing was harboring significantly low number of whitefly compared to other spacings. During September, 30 cm, 40 cm and 50 cm spacing were harboring similar levels of whitefly that were significantly lower than those harbored at 10 cm and 20 cm spacings. Nevertheless, plants spacing had no significant effects on whitefly population during October.

Table 2. Effects of cotton spacing on whitefly population.

Spacing (cm)	Number of whiteflies per 100 leaves			
	July	August	September	October
10	(1.17)	(78.38)	(34.50)	(3.38)
	1.19	7.55	5.12	1.86
20	(0.50)	(60.25)	(35.80)	(2.88)
	0.94	6.58	5.16	1.76
30	(0.33)	(58.13)	(24.80)	(2.75)
	0.90	6.31	3.99	1.67
40	(1.00)	(60.88)	(34.90)	(1.25)
	1.15	6.47	4.73	1.25
50	(0.67)	(33.38)	(26.20)	(1.00)
	1.1	4.97	4.1	1.20
Sig. level	NS	*	*	NS
SE±	0.3	0.3	0.3	0.2
CV%	34.6	31.9	17.8	26.8

Means between parentheses are actual data.

Table 3. Effects of cotton spacing on number of eggs of African bollworm.

Spacing (cm)	Number of eggs of ABW per 100 plants		
	August	September	October
10	(13.8)	(5.0)	(6.3)
	3.7	2.2	2.5
20	(8.0)	(17.0)	(2.0)
	2.8	4.1	1.4
30	(8.0)	(5.0)	(3.8)
	2.8	2.2	1.9
40	(8.8)	(2.0)	(3.0)
	2.97	1.4	1.7
50	(5.0)	(3.0)	(3.0)
	2.2	1.7	1.7
Sig. level	NS	*	NS
SE±	0.4	0.2	0.3
CV %	32.7	28.3	31.4

Means between parentheses are actual data.

Table 3 shows significant effects of cotton spacing on the number of African bollworm during September only, but not during August and October. Generally, number of eggs was higher in the closer spacing than the wider spacing. No larvae for bollworms or eggs of spiny bollworm were detected.

Table 4 shows significant effects of cotton spacing on reproductive structures shedding during both August and September. It also showed that the cotton cultivar Brazillan LL was susceptible to both bollworms, *H. armigera* and *E. insulana*. However, shedding of reproductive structures due to African bollworm was significantly higher among cotton grown at wider spacing compared to cotton grown at narrower spacing in August while the result was opposite during September. Nevertheless, for spiny bollworm, the wide spacing reflected low infestation compared to narrow spacing in August and September. For natural shedding of reproductive structures, it was significantly lower under wide spacing in August and significantly high under wide spacing in September.

Table 4. Effects of cotton spacing on shedding of reproductive structures due to bollworms infestation.

Spacing (cm)	August			September		
	Natural shedding	African bollworm infestation	Egyptian bollworm infestation	Natural Shedding	African bollworm infestation	Egyptian bollworm infestation
10	(11.38) 19.79 a	(50.00) 45.24 c	(26.88) 31.7 a	(29.43) 32.54 b	(41.81) 40.04 a	(26.81) 30.42 a
20	(9.63) 18.08 a	(62.88) 52.74 b	(29.25) 32.87 a	(39.21) 38.59 a	(34.00) 35.16 b	(20.44) 26.71 bc
30	(7.63) 15.92 b	(72.13) 58.95 a	(20.75) 26.75 b	(30.94) 33.55 b	(73.38) 37.46 ab	(24.44) 29.38 ab
40	(12.25) 20.49 a	(30.13) 33.42 d	(10.05) 18.13 c	(34.73) 34.95 b	(27.44) 31.29 c	(16.08) 23.39 c
50	(5.63) 9.85 c	(78.00) 54.85 ab	(5.13) 12.69 d	(38.28) 38.19 a	(23.14) 27.49 d	(20.19) 25.18 c
SE±	1.5	1.5	0.9	1.0	1.2	1.0
CV %	38.97	12.2	9.5	24.8	32.6	32.7

Means in a column followed by the same letter(s) are not significantly different according to Duncan's Multiple Range Test at P = 0.05.

Means between parentheses are actual data.

Table 5 shows significant effects of cotton spacing on leave damage due to flea beetle. Generally, the wider the spacing, the lower the flea beetle infestation. The control (50 cm), resulted in significantly lower infestation compared to 10 cm and 20 cm spacing. Also, the percentage of damage increased steadily from August to October in all spacing.

Table 5. Effects of cotton spacing on leaf damage due to flea beetle.

Spacing (cm)	leaf damage %		
	August	September	October
10	(26.25)	(64.50)	(53.13)
	30.84 b	54.25 a	47.05 b
20	(37.50)	(52.00)	(48.13)
	37.51 a	46.59 b	44.04 c
30	(26.88)	(24.00)	(59.38)
	31.29 b	28.12 d	50.76 a
40	(23.13)	(31.50)	(41.88)
	28.73 bc	33.16 c	40.29 d
50	(21.88)	(34.50)	(39.38)
	27.83 c	35.92 c	38.89 d
SE±	0.9	0.9	0.9
CV%	20.6	26.6	14.4

Means in a column followed by the same letter(s) are not significantly different according to Duncan's Multiple Range Test at P = 0.05.

Means between parentheses are actual data.

Fig. 1 shows the number of jassid, whitefly and natural enemies, *Coccinellids*, *Spiders*, *Chrysopid*, and *Orius sp*, during the period of July to November. All kinds of insects and spiders were very low during July. However, whitefly and jassid increased significantly during August and then gradually decreased during September to reach the minimum during October and November. Natural enemies increased during September and then decreased during October and November.

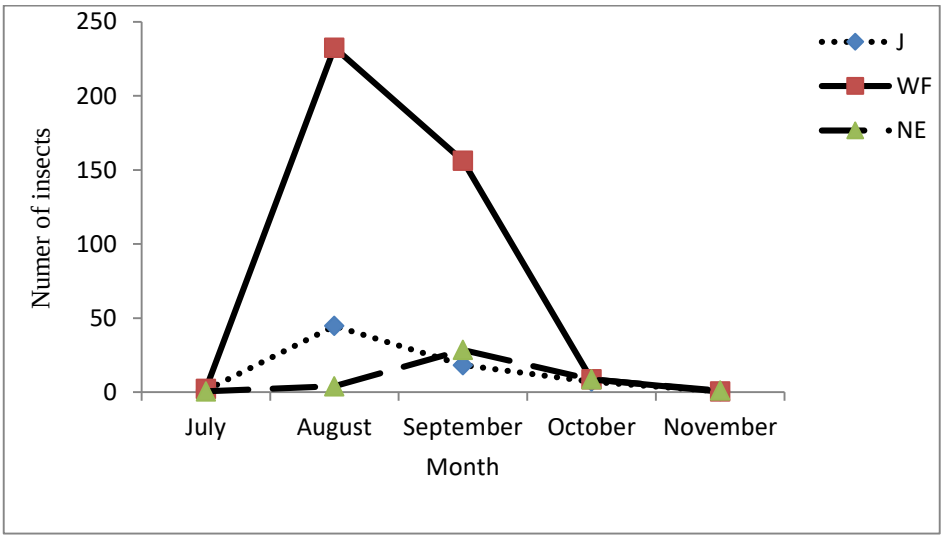

Fig. 1. Numbers of whitefly (WF), jassid (J), and natural enemies (NE) on cotton during July to November, 2012.

Table 6 shows that the number of flowers per plant increased with increased plant spacing. It was observed that at early flowering stage (45 days) the discrepancy in number of flowers between different spacing was small (15%-20%) compared to 50 cm spacing (100%) and getting large onwards to reach the peak at 90 days with a discrepancy of up to 73% compared to wider spacing (50 cm).

Table 6. Effects of cotton spacing on number of flowers per 10 plants.

Spacing (cm)	Age (days) of plants							
	45		60		75		90	
	actual	%	actual	%	actual	%	actual	%
10	8.8	80	18.6	50	17.4	45	9.2	27
20	9.8	89	22.00	60	25.8	67	22.6	67
30	9.4	85	29.2	80	27.9	73	26.4	78
40	9.2	83	33.7	92	33.00	86	30.3	90
50	11.0	100	36.4	100	38.2	100	33.6	100

Table 7 shows that cotton yield decreased with increased plant spacing. However, the effect on cotton quality was inconsistent. It is worth mentioning that plant spacing of 10 cm resulted in cotton free from stickiness.

Table 7. Effects of cotton spacing on yield and quality.

Spacing (cm)	Yield (kantar/fed)	Stickiness
10	29.8 a	0
20	14.8 b	7
30	7.8 c	4
40	7.0 cd	6
50	6.0 d	4
Sig. level	*	
SE±	0.47	
CV%	13.66	

Means followed by the same letter(s) are not significantly different according to Duncan's Multiple Range Test at P = 0.05.

DISCUSSION

When no insecticidal sprays were practiced on cotton, the peak of Jassid infestation was reported in August and then gradually dropped to reach the minimum in October and none was recorded during November. This was probably due to the action of the natural enemies that reach the maximum during September. Similar results wer reported by Ripper and George (1965) and Schultz and Elamin (1965). Predators may be the main causal agents (Klerks and Vanlenteren, 1991; Dabrowski, 1997).

Similar trend of Jassid infestation was reflected by whitefly population. However, spacing of 10 cm and 20 cm harbored large number of whitefly population. There was an agreement that dense plant population is very appealing for whitefly infestation (Sharaf Eldin, 1986; Dabrowski, 1997). Even though, whitefly population again came under control during September, October and November. This was again trailed with buildup of natural enemies of coccinellids, chrysopids, anthocorids and spiders. Parasitoids, (not monitored in this study) such as *Eretmocerous mondus* and *Encarsia lutea* may have had a role of whitefly population check since they were reported in Gezira before (Schumtterer, 1969; Gameel and Abdelrahman, 1978).

Managerial effect such as weeding (three times) that removed the alternative hosts of the polyphagous insects, Jassid and whitefly may have a negative impact upon their populations (Evans, 1965).

Similar presence of whitefly among dense plant population (narrow spacing) of cotton was also reflected by the flea beetle. However, the damage due to flea beetle on cotton was tolerated and did not affect the cotton plants as seen on yield. This may be due to nature of infestation of flea beetle that attack the cotton leaves. Cotton plant tolerate high damage on leaves before flowering and after boll maturity (Smith and Falcon, 1973) among the cotton crop planted early in the season (Schmutterer, 1969) or may be the natural enemies played their role undetectably (Hines and Hutchinson, 1997).

Although the percentage of the shedding of reproductive structures due to the damage of American bollworm (ABW) was in the range of 30-70% in August and 20-40% in September, among various spacing but yet no larvae were detected. It was known that the females of (ABW) were highly prolific and if left unchecked in cotton, severe crop damage will be done due to larvae feeding on reproductive structures, buds, flowers and bolls (Ibrahim *et al.*, 1993).

Nevertheless, the yield in term of quantity and quality in this work was highly acceptable among various spacing under study. This might be explained by the role of natural enemies that feed on Juvenile stages of bollworms (Smith and Falcon, 1973) which were more damaging to cotton crop (Schmutterer, 1969).

However, the shedding of reproductive structures due to infestation of spiny bollworm was in the range of 5-30% in August and 16-24% in September, but no larvae were detected and no apices subsequently wither or collapsed due to spiny bollworm damage as usually observed and stated in

the literature (Schmutterer, 1969). This might be due to the role of natural enemies that checked the larvae of spiny bollworm prematurely and preventing them from growing to the extent of killing the growing tips of cotton plants.

The buildup of pests and natural enemies from July to October reflected a typical density dependent pattern as stated in the literature (Samways, 1981). In the Sudan, cotton was grown under a population of less than 70000 plants per hectare. However in USA this number of plants per hectare was increased 7-10 times (Smith and Falcon, 1973). In this study, when the number of plants per hectare was increased 5 times (spacing 10 cm) the yield was 5 fold more and when increased 2.5 times (spacing 20 cm) the yield was 2.5 fold more than the traditional spacings, (50 cm). Over and above the stickiness level in all spacings under study were satisfactory (less than 11).

In conclusion, it is recommended to grow Brazilian cotton cultivar (LL) at spacing of 10 cm for high yield and good cotton quality.

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تأثيرات مسافات زراعة القطن على الإصابة بالحشرات والأعداء الطبيعية والإنتاجية- ولاية الجزيرة ، السودان

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الخلاصة

استمرت زراعة القطن طويل التيلة بالري الصناعي بمشروع الجزيرة بالسودان لأكثر من ثلاثين عاماً دون رش المبيدات لحماية المحصول من الآفات (1911-1945). يُعزى ذلك لزراعة القطن قصير التيلة بالأمطار ولمدة طويلة سبقت قيام المشروع. تمخض عن هذه الممارسة توازن إيكولوجي في بيئة المشروع. ومنذ أن بدأ إدخال المبيدات لمكافحة الآفات في الموسم 1946/1945، حتى الآن تمت إجازة أكثر من 300 من المبيدات ومخاليط المبيدات. عليه الهدف من هذه الدراسة معرفة أثر الزراعة المبكرة في مسافات متباينة على كمية ونوعية القطن المنتج. تمت زراعة القطن في 20 يونيو 2012 وعلى مسافات 10 سم، 20 سم ، 30 سم و 40 سم بين النباتات وتمت مقارنتها مع المسافة المعيارية 50 سم و ذلك بزراعة 3 بذور في كل حفرة. تم رصد الآفات الحشرية والأعداء الطبيعية. أظهرت النتائج أن الحشرات الماصة، النطاط الأخضر (*Jacobiasca lybica*) والذبابة البيضاء (*Bemisia tabaci*) بدأتا في الظهور في شهر يوليو ووصلتا قمة التواجد في أغسطس وبدأتا في الانحسار في أكتوبر. اتضح أن الصنف تحت الاختبار (Brazillian LL) يصاب بديدان اللوز الأفريقية (*Helicoverpa armigera*) والمصرية (*Earias insulana*). تساقط الأزهار واللوز (reproductive structures) قد دون. التساقط نسبة للإصابة بدودة اللوز الأفريقية كان كبيراً في أغسطس في المسافات 40 سم و50 سم بينما انخفض خلال سبتمبر. بالنسبة لديدان اللوز المصرية الإصابة على الأزهار واللوز كانت قليلة على المسافات الواسعة مقارنة بالإصابة على المسافات الضيقة خلال شهري أغسطس وسبتمبر. أما التساقط الطبيعي لهذه المكونات فقد كان قليلاً في أغسطس وكثيراً في سبتمبر عند المسافة 50 سم. زيادة الأعداء الطبيعية بدأت في يوليو ووصلت قمتها في سبتمبر ثم انحسرت في أكتوبر بمنوال الكثافة غير المستقلة عن عشائر الآفات الماصة. إنتاجية القطن بالقنطار للفدان 29.8 (5 أضعاف) للمسافات البينية 10سم و 14.8 (2.5 ضعف) للمسافات البينية 20 سم مقارنة بالمسافة البينية 50سم. نوعية القطن المنتج من حيث اللزوجة (Stickiness) كان مرضياً لكل المسافات تحت الاختبار. أفضت الدراسة إلى أن المسافات البينية المتقاربة أدت إلى زيادة الإنتاج مع جودة نوعية المنتج للقطن. عليه نوصى بزراعة صنف القطن البرازيلى (LL) بمسافة 10 سم بين النباتات ليعطي أعلى إنتاجية ونوعية من القطن.