1270 Sustaining cotton productivity with minimum inputs use

Mr. Elfadil A. Babiker , Agricultural Research Corporation -ARC-, Wad Medani, Sudan
Mr. Ahmed M. Mustafa , Agricultural Research Corporation -ARC-, Wad Medani, Sudan
Mr. Hassan O. Kanan , Agricultural Research Corporation -ARC-, Wad medani, Sudan
Mr. Ahmed . H Mohamed , Agricultural Research Corporation -ARC-, Wad Medani, Sudan

Abstract

Cotton production in the Sudan is characterized by an all time stagnating low yields in the range of 450 to 550 kg lint/ha, since the establishment of the Gezira Scheme in 1925. This had been a normal course for the last 80 years, despite adoption of insecticides and fertilizers as a cotton based production technologies. However, the extensive use of the broad spectrum insecticides and fertilizers (86 -129 kg N/ha) with the bushy and late maturing commercial varieties, neither improved the yield nor the quality, instead it had largely contributed in escalating the cost of production, resurgence of secondary pests as major pests and aggravation of the stickiness problem. On the other hand, the recent advent of the short duration varieties had been a significant achievement and may resemble the road map for sustaining cotton productivity. Experimentation with these varieties revealed that four sprays of the conventional insecticides (pyrethroids at 2.5litre/ha) can be reduced to only one selective spray (Spinosad at 0.25 litre/ha) with concomitant improvement in fibre quality as had been indicated by the low stickiness levels. The optimum fertilizer rate that can meet the metabolic needs of the new varieties was found to be only 43 kg N/ha. Therefore, production cost can drastically be contained because insecticides represent 30-40% and fertilizers about 25-30% of the total cost. Moreover, the minimum use of selective as compared to the broad spectrum insecticides may pave the way for future cotton production without insecticides, hence, diverse natural enemies are still in place and can gradually be multiplied to over balance the insect pests. Thus, a non-pollutant environment for sustaining cotton productivity and improving life quality can easily be availed.

Introduction

The year 2004 marked the Hundred Anniversary (Massey Jubilee) of the Cotton Research Program (CRP) with more than 50 varieties and improved lines being released, in addition to varying recommendations on cultural practices, pest management and fibre quality improvement. Nonetheless, implementation at the farm level is disappointing with an all time average yield of 450 to 550 kg lint/ha as compared to 1200 to1500 kg lint/ha for research. The stagnating low yield had been a normal course for the last 80 years, despite the variation in the number of insecticides sprays (Table 1). Further more, many challenges are facing the cotton production such as: escalating cost of production, inefficient use of fertilizers, poor water management, insect unbalance due to irrational use of insecticides, crop diversification and intensification under dilapidated infrastructures coupled with unattended farming. Moreover, insects like bollworm (ABW) and jassid are threatening productivity whereas whitefly induced stickiness is the main bottleneck for marketability. Likewise, rank growth has emerged as a puzzling phenomenon for many farmers, indicating that cotton is a very inefficient crop in terms of input utilization due to its perennial and indeterminate growth habit with priorities of diverting assimilates partitioning to vegetative growth. Hence, under condition of poor input management like improper timing of fertilizers and insecticides application, excessive growth (rank growth) is eminent. Previous studies to optimize insecticides and fertilizers use were reported by Bindra, 1985; Abdelrahman *et al*. 2002 and Babiker *et al*. 2005. The outcome of these studies, though encouraging but not up to the expectations, because the commercial varieties used in these studies {Barakat and Barac (67) B} were of large leaf area, glabrous, late maturing and as such more vulnerable to insects damage. Barac (67) B was introduced from USA in the 60^{th} under the name Acala 4-42, in which bacterial blight resistant gene combination (B_2B_6) was introgressed and then released under the name Barac (67) B. Since then, it has been the major *hirsutum* commercial variety in the Sudan, but it is highly vulnerable to insect pest. On the other hand, the recent release of the new early maturing varieties (Hamid, Abdin, Buarhan, khalifa and knight) which are resistant to diseases and insects and of low leaf area (Mustafa and Babiker, 2007; Mustafa *et al*. 2007 and Mustafa and Babiker, 2006) may be the way out for both, reverting the course of stagnating low yields and lowering the cost of production. Therefore, early maturing cotton cultivars ensure proper insect pests management, reduce heavy insecticides use and secure profitable production, healthy environment and save irrigation water. Jenkins (1994) stated that the most universally valuable contribution of host plant resistance is avoidance or escape from damaging levels of pests by early maturing, rapid fruiting cultivars. The short-season cotton production system is a novel concept in cotton production, which may include certain cultural practices, narrow-row spacing, or both (El Zik and Frisbie 1985). Parker *et al*. (1980) demonstrated that short season cultivars have the ability to accumulate fruit in a much shorter period in comparison to longer season cotton cultivars, and hence a distinct advantage is present in escaping late-season insects and diseases. The present study has therefore, been focused on how to sustain cotton productivity through efficient use of insecticides and fertilizers via early maturing varieties with concomitant reduction in the production cost and improved environment for a better life quality.

Material and methods

Data shown in Table 1 was obtained from the Gezira Scheme which is the world's largest plantation (2.1 million acre) under one administration where the first cropping was commenced in 1925/26. The experimental work reported in tables 3, 4, 5 and 6 was carried out at the Gezira Research Station of the Agricultural Research Corporation (ARC), Wad Medani, Sudan (latitude 14^0 24' and longitude 33^0 29'E), during 2005 through 2007. Soil characteristics of the experimental site are shown in table 2. Four experiments were performed as hereunder:

Experiment 1

Growth and yield attributes for some of the newly released varieties as compared to the commercial variety Barac (67) B were studied in a randomized complete block design with five replications. Treatments were composed of four varieties {Hamid, Abdin, Knight and Barac (67) B}. The plot size consisted of 5 rows, 6-m long with 0.8-m row spacing. Other cultural practices were as recommended by ARC. Observations and data shown in Table 3 were recorded periodically as needed. The leaf area index (LAI) was calculated as the total leaf area over ground area.

Experiment 2

Effect of insecticides sprays on cotton yield and stickiness on Hamid cotton variety was studied in a randomized complete block design with four replications. The plot size consisted of 16 rows, 12-m long with 0.8-m row spacing for two seasons 2005/06 and 2006/07. Four insecticides treatments were used:

1. Control
2. One selective spraying of Spinosad (0.25 litre/ha).
3. Selective spraying of Spinosad (0.25 litre /ha) with the number of sprays decided according to the recommended threshold levels. In 2005/06 only one spray was applied whereas in 2006/07 three sprays were applied.
4. Conventional spraying as performed in the field with the broad spectrum insecticides (pryrethroids at 2.4 liter/ha). In 2005/06 only one spray was applied, but in 2006/07 four sprays were applied.

Nitrogen fertilizer used was applied at 43 kg N/ha. At harvest, sticky cotton due to honeydew secretions was thermodetectedly measured via counting the number of the sticky spots in sample size of ½ kg lint cotton from each plot at the Fibre Testing and Stickiness Laboratory of the Cotton Research Program, ARC, Sudan.

Count of cotton pests and their natural enemies were made as that of (Beije and Ahmed, 1997). Seed cotton per harvested area was hand picked, weighed, ginned and then adjusted to seed cotton or lint yield in (kg/ha).

Experiment 3

Effect of Nitrogen fertilizers (kg N/ha) on seed cotton yield (kg/ha) of three newly released varieties (Hamid, Abdin and Khieralla) and one selective insecticide (spionsad at 0.25 litre /ha) was studied in split plot design with four replications for two seasons 2005/2006 and 2006/2007.Treatments were comprised of factorial combinations of three varieties (Hamid, Abdin and Khieralla) and four levels of N (0, 43, 86 and 129 kg/ha). The sub-plot size consisted of 16 rows, 12-m long, with 0.8-m row spacing and assigned to the varieties whereas, the levels of N arranged in the main plots. Stickiness and yield data were determined as mentioned previously for the second experiment.

Experiment 4

Effect of Nitrogen fertilizers and three conventional insecticides (pryrethroids at 2.4 liter/ha) sprays on seed cotton yield and stickiness on variety Barac (67) B was studied for two seasons 2005/06 and 2006/07. Treatments composed of four levels of N-fertilizers (0, 43, 86 and 129 kg N/ha) arranged in a randomized complete block design of four replications. Plot size consisted of 16 rows, 12-m long with 0.8-m row spacing. Stickiness and yield data was determined as mentioned above.

The data were statistically analyzed using the standard analysis of variance procedure. Duncan's multiple range test was used to test differences among treatment means.

Results

Agronomic attributes of the newly released varieties in experiment one (Table 3) as compared to the aging variety Barac (67) B showed that, the new varieties (Hamid, Abdin and Knight) were early maturing as reflected by the significant differences in the numbers of the first fruiting nodes and days to the last pick. Varieties (Hamid, Abdin and Knight) were hairy and as such are resistant to Jassid, were also of low leaf area index (LAI) and of wide genetic base for blight resistance as compared to Barac (67) B.

Different insecticides spraying regimes of experiment two (Table 4) in 2005/06 had no significant effect on lint yield whereas in 2006/07 only the non-sprayed treatment (control) had significantly lower yield as compared to other treatments. Even though, in season 2006/07, differences between treatments other than control (one selective spray, three selective sprays and four conventional sprays) were not significant. The stickiness increased with the increase in the level of sprays but the stickiness values of 2006/07 (Table 4) were higher than that of 2005/06, particularly that of the conventional for 2006/07 which was in the high range (35-50) sticky spots where that of 2005/06 for one conventional spray was in the light range (8-15) sticky spots. Season 2005/06 was characterized by low infestation of the bollworm where all treatments (except control) received one application to suppress the pest, whereas heavy bollworm infestation was exhibited in 2006/07. Results on the main number of predators revealed that the overall number of predators was higher in the untreated control (0 insecticides) as compared to the different spraying treatments (Table 5). However, the conventional treatment had lower predators as compared to that of the selective insecticides treatments. *Encarsia Lutea and Eretmocerus mundus* are the two parasitoids of whitefly recorded in cotton in the Gezira area. The two species resulted in a relatively higher rate of parasitism in the untreated control (11.3%) than in the other chemically treated cotton (7.8-10%). Three sprays of Spinosad reduced the rate of parasitism to 7.8% (Table 6).

Table 7 shows the overall mean insect pest infestation in cotton under different spraying regimes. The whitefly (*Bemisia tabaci*) was lowest in number in the untreated cotton (62 whitefly adults/100 leaves) and increased as the number of spraying increased (76-120) whitefly adult/ 100 leaves). The highest record of jassid (*Jacobiasca lybica*) was when three sprays of pryrethroids were applied (104 jassid/100 leaves). The aphids (*Aphis gossypii*) infestation ranged from 8 to 10%. The treatment with three Spinosad resulted in zero level of infestation of the African bollworm (*Helicoverpa armigera*). However, in cotton sprayed twice with the same product 16.7 eggs or larvae of ABW/100 leaves were recorded. Higher ABW infestation 20 eggs or larvae /100 plants was recorded in cotton received three sprays of pryrethroids. While in untreated cotton the mean level of infestation was 6-7 eggs or larvae /100 plants. The jassid infestation level under different treatments were higher than the recommended economic threshold levels (30 nymphs/100leaves), but yet the cotton yields were not affected. This shows the role of jassid tolerance in the cotton variety Hamid used in this study.

Different levels of N- fertilizers in experiment three (Table 8) affected the three varieties in the same trend, with the differences between (0N) and the other three levels (43, 86 and 129 kg N/ha) being significant but differences between rates other than control were not significant. The stickiness levels tend to increase with the increase in the levels of N-fertilizers but the over all effect (4-7 sticky spots) was very small and within the light level.

Response of the commercial variety Barac (67) B to the different rates of N- fertilizers in experiment four (Table 9) was high and the increases were significant up to (86 kg N/ha). The stickiness was on rise with the increase in levels of nitrogen; hence, three conventional sprays were applied. This was in particular, with the high rates of N-fertilizers (86 and 129 kg N/ha) where the stickiness spots recorded were in the heavy range of 35-55.

Discussion

For the first 25 years of the Gezira Scheme (1925-1950) cotton was neither N-fertilized nor insecticide sprayed. Despite of this, the lint yield (468 kg/ha) during this period, was within the range of the long time average but fibre quality as indicated by zero stickiness had been the best throughout the history of the Gezira Scheme (Table 1). The discovery of the DDT in the late 1940th aspired the chemical control of Jassid (*Jacobiasca lybica*) being the only major insect prevailing at that period (1950-1960). The chemical control of the jassid via the DDT had also reduced the natural enemies (beneficial insects) and therefore led to insect unbalance. Accordingly, secondary insects like whiteflies (*Bemisia tabaci*) and bollworm (*Helicoverpa armigera)* emerged as major pests. In response to this, the number of sprays was increased gradually reaching the peaks in the 70th and 80th, with concomitant rise in the levels of stickiness. The high cost of spraying, coupled with discount prices for the sticky cotton and stagnating low yield had empowered the economic based decision to reduce the number of sprays in the 90th .The reduction in the number of sprays was accompanied by the improvement in the level of stickiness, however, lint yields were still stagnating within the long time average. The effect of N-fertilizers (0-120 kg N/ha) on yields exhibited the same trend as that of the number of insecticide sprays, without a definite correlation between the rate of N applied and lint yields (Table 1).

Efforts to revert the long time course of stagnating low yields and to reduce the cost of production had been underway as shown in experiment one (Table 3). Varieties (Hamid, Abdin and knight) were found to be early maturing, of open canopy, low leaf area, hairy and resistant to bacterial blight as compared to the commercial variety, Barac (67) B (Table .3). Adoption of these varieties will reduce the cost of production; hence, low input management was appropriate for such varieties (Mustafa and Babiker, 2006 and 2007). This was also in agreement with (Bindra,1985) and (Babiker, 2004) who reported that switching to cultivars less vulnerable to the pests would ease the cotton protection problem, hence , traits which make a cotton variety more prone to insect infestation are bushiness, large leaf area and late maturity. Further more, variety Hamid proved to be very efficient under limited inputs (Table 4) where 1265 and 1270 kg lint/ha were obtained in 2005/06 and 2006/07, respectively under zero insecticides and lower rate of fertilizer (43 kg N/ha).This was in agreement with (Abdelrahman *et al.* 2002).Therefore, adoption of variety Hamid would be a rewarding achievement, hence, the cost of insect control was in the range of 30-40% and that of N fertilizers was 25-30% of the total production cost. Season 2005/06 was characterized by a low incidence of bollworm and therefore no differences between spraying treatments were observed (Table 4). On the other hand, heavy bollworm infestation was the main feature of season 2006/07; however, significant differences were only obtained between the control and the sprayed treatments. But, differences between one selective spray of Spinosad, three selective sprays of Spinosad and four conventional sprays (pryrethroids) were not significant (Table 4). It was therefore, suggested that for variety Hamid under heavy bollworm infestation, timely application of one spray of selective insecticide i.e. Spinosad at 0.25 liter /ha is quite enough for the bollworm control and preservation of the natural bio-control agents to avoid high stickiness levels (Table 5).

The recommended rate of N-fertilizers for cotton is 86 kg N/ha which represents 25-30% of the total production cost. It is worth noting that previous studies (Burhan, 1971) recommended that the rate of N- fertilizer should be increased from 86 to129 kg N-ha. This finding was adopted during the 80th in some parts of the Gezira Scheme where N was applied at 129 kg N/ha but it was later found to be not economically feasible. The response of the new varieties (Hamid, Abdin and Kheiralla) to N fertilizers was very small and no significant interactions were found between the different treatments. Different N- rates had significantly out yielded the control treatments whereas differences between 43, 86 and 129 kg N-/ha were not significant. Accordingly a sizeable reduction in the production cost will be achieved if the new varieties are to be adopted .Hence, the lower rate of 43 kg N/ha with one selective spray would be the optimum components in the production package for these new varieties. On the other hand, the commercial variety Barac (67) B was more responsive to N- application with the optimum rate of 86 kg N/ha, hence, its metabolic needs to nutrition were higher than that of the newly released varieties (Table 9). However, yields obtained with Barac (67) B at 86 kg N/ha were lower than that achieved with the newly released varieties with the lower rate of N (43kg N/ha). Moreover, three conventional sprays were administered (pryrethroids) according to the threshold levels for pest control in Barac (67) B. Spraying of the broad spectrum insecticides was necessitated by the variability of insects pests being harbourd by this variety i.e. bollworm, jassid, aphids, thrips and whiteflies. This had also resulted in the increase of stickiness levels, particularly under the higher rates of N (86 and 129kgN/ha).These findings resemble the exact status of the commercial production where whitefly indicated stickiness as flared by spraying of the broad spectrum insecticides is the major reason for the stickiness discount prices. Even though, comprehensive research work had been done to improve the marketability of the sticky cotton (Gourlot J-P and Frydrych, R. 2001). However, elimination of the stickiness source at the field level remains to be a challenging problem, if insect appealing varieties such as Barac (67) B are to be continued in the commercial production.

Table 1. Lint yield (kg/ha), number of sprays and rate of fertilizer (kg N/ha)

and sticky spot for seasons 1925-2005, Gezira, Sudan.

Seasons	lint yield (kg/ha)	Number of Sprays	Rate of Fertilizer (kg N/ha)	Stickiness Level **
1950-1925	468	0	0	0
50-51/ 60-61	518	1	43	light
71/70- 62/61	481	5.9-2.0	86	medium
81/80-72/71	468	9.3-5.0	86	high
91/90-82/81	543	8.5-3.1	86-120	high
91/92-01/02	506	5.1-2.7	86	medium
01/02-05/6	543	3.5-2.5	86	light

** 0 = No stickiness

0 - 15 = light stickiness

15 - 35 = medium stickiness

35 - 55 = high stickiness

Above 56 very high

Table 2. Soil characterization for the Gezira testing site

Character	Gezira
Series	El Remetiab
Parent material	Blue Nile Alluvium
Land suitability	Moderate
% Clay	54.0
Wetting front (cm)	25.0
Bulk density	1.71
% $CaCo_3$	3.7
ESP(0-30 cm)	6.0
PH	8.1
O.C. (%)	0.36
N%	0.039
CEC (cmol/kg soil)	54.0
Available P(ppm)	2.0
Soluble SO_4 meq/L	0.8-74.2
SolubleNO_3 meq/L	2.1-11.5

Table 3. Average number of growth and yield attributes for some of the newly released varieties as compared to the commercially old variety Barac (67) B

Variety	First fruiting node	Days to last pick	Hairiness (leaf and stem)	LAI	Gene combination for blight resistance
Hamid	5.0 a	1030-140	medium	2.3 a	$B_2B_3B_6B_7$
Abdin	5.3 a	150-160	medium	2.7 a	$B_2B_3B_6B_7$
Knight	5.0 a	140-150	medium	2.6 a	$B_2B_3B_6B_7B_9$
Barac (67) B	6.1 b	160-170	glabrous	3.6 b	B_2B_6
S.E(±)	0.12	-	-	0.2	-
C.V%	4.6	-	-	6.8	-

*Means within columns followed by the same letter are not significantly different at 0.05 level of probability

LAI = Leaf area index

Table 4. Effect of insecticide spraying on cotton lint yield (kg/ha) and stickiness of variety Hamid for seasons 2005/06 and 2006/07 with 43kgN/ha

Season 2005/2006			Season 2006/2007		
Number of sprays	Cotton lint(kg/ha)	Stickiness (sticky spots/ sample)	Number of sprays	Cotton lint(kg/ha)	Stickiness (sticky spots/ sample)
Control	1265 a	0-2	Control	1270 b	2-3
One selective	1279 a	3-7	One selective	1413 a	6-9
One selective	1283 a	4-8	Three selective	1465 a	17-22
One conventional	1315 a	8-15	Four conventional	1383 a	35-50
Mean	1285	4-8		1383	15-21

*C.V (%) = 5.5

* Means within columns followed by the same letter are not significantly different at 0.05 level of probability.

Table 5. Mean numbers of predators per 10 cotton plants (variety Hamid) under different number of spraying at ARC Farm Wad Medani, Season 2006/2007

No. of sprayings	Campylomma	Spiders	Chrysoperla	Coccinellids	Over all predators
Control	5.6	0.2	1.0	0.1	6.9
One selective	3.7	0.1	0.9	0.0	4.7
Three selective	3.1	0.2	1.1	0.0	4.4
Four conventional	2.8	0.1	1.1	0.1	3.0

Table 6. Overall mean infestation levels of insect pests in cotton (variety Hamid) under different spraying regimes at ARC Farm Wad Medani, Season 2006/2007

Spraying treatment	Whitefly/100 leaves	Jassid / 100 leaves	% aphid infestation / 100 plants	African bollworm/ 100 plants
Control	62	82	9	6.7
One selective	76	68	10	16.7
Three selective	120	40	10	0
Four conventional	106	104	8	20

Table 7. Mean % of parasitism in whitefly nymphs in cotton (variety Hamid) under different insecticides spraying regimes at ARC Farm Wad Medani, Season 2006/2007

Spraying treatment	Mean % parasitism	Mean number of whitefly nymphs /100 plants
Control	11.3	40.7
One selective	10	44.5
Three selective	7.8	42
Four conventional	9.1	42.7

Table 8. Effect of N fertilizers on seed cotton yield (kg/ha) and stickiness of the newly released cultivars with one selective spray averaged for seasons (2005/2006 and 2006/2007)

Rate of N-fertilizers (kgN/ha)	Varieties Increase (%) Stickiness (sticky spots/sample) Hamid Abdin Kheiralla Mean				
0	2849 b	2449 b	2283 b	2527 b	0	0-3
43	3033 a	2599 a	2433 a	2683 a	6	4-6
86	3082 a	2582 a	2518 a	2733 a	8	5-8
129	2982 a	2599 a	2549 a	2710 a	7	7-11
Mean	2987	2558	2466	-	-	4-7

* Mans within columns followed by the same letter are not significantly different at 0.05 level of probability

Table 9. Effect of N fertilizers(kgN/ha) on seed cotton yield and stickiness of variety Barac (67) B with three conventional sprays averaged for seasons 2005/06 and 2006/07

Rate of fertilizers (kgN/ha)	Seed cotton (kg/ha)	Increase (%)	Stickiness (sticky spots /sample)**
0	2008 c	0	-
43	2270 b	13	35-25
86	2448 a	22	35-45
129	2487 a	24	46-55
Mean	2303	20	39-51

* Means within columns followed by the same letter are not significantly different at 0.05 level of probability.

** 0 = No stickiness

0-15 = light stickiness

15-35 = medium stickiness

35-55 = high stickiness

Above 56 very high

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