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Use of Combined Economic Threshold Level to Control Insect Pests on Cotton

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Abstract
The economic threshold level (ETL) is a key factor to be studied for insect pests control. It is difficult to monitor cotton insect pests separately, and it is not reasonable to base decision-making for spraying on an ETL of individual insects and ignore sub-levels of other cotton insect pests. So, we want to use a combined ETL in a way of insect units, to put all major insect pests to consideration as an insect pests‘ complex. This means delaying the first spray to give a chance for natural enemies to develop and then lower the number of sprays and consequently reduce the cost of production.

Keywords: cotton, insect pest, economic threshold level

1 Introduction

Cotton in the Sudan is grown in the black cracking soil of the central clay plain, where rainfall ranges between 400 - 800 mm per annum (Schmutterer, 1969). However, cotton is the backbone of the Sudan economy. Its contribution is more than 40 % of Sudan export values (Morsal, 1992). One of the limitations of cotton production in Sudan is the insect pests. Their control contributes a great deal in the cost of production. The major cotton insect pests are the African bollworm, *Helicoverpa armigera* (Hubn); the cotton Jassid, *Jacobiasca lybica* (de Bergevin); the cotton white fly, *Bemisia tabaci* (Genni) and the cotton aphid, *Aphis gossypii* (Glov), (Matthews, 1989).

2 Materials and methods

2.1 The Insect Units

For protection of the cotton crop against insect pest complex damage, the group entomologist in the cotton producing schemes in Sudan used to intervene by chemical control when the insect pest level reached or passed the economic threshold level. However, in most cases they only considered spraying one pest and ignored the sub- levels of infestations of other insect pests. In this study we believe that the sub-levels could be even more serious in reducing cotton yield as in the case of jassid, for instance. To avoid persistence, for longer period of such sub-levels we suggest considering the insect units. The principle of the insect unit technique is as follows:
The major insect pests of cotton are the African bollworm (*H. armigera*), the jassid (*J. Lybica*), the white fly (*B. taboci*) and the aphid (*Aphis gossypii*). Hypothetically, if the

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count of jassid shows 30 nymphs per 100 leaves, the African bollworm shows 5 eggs plus one larvae per 100 plants, the white fly population 150 adults per 100 leaves and the aphid infestation is 5. None of the above reaches the sprayable level, and if we convert the numbers into units it will be as shown in Table l

Table 1: Insect units

Insect pests	*Conventional recommended ETL*	*Units*
African bollworm	10 larvae and / or eggs	0,8
Jassid	50 nymphs	0,6
White fly	200 adults	0,75
Aphid	20% %	0,25

When we combine the above mentioned infestation levels we believe that the impact on cotton could be damaging; specially if the Situation persists for a long time. Then, if we use the insect units, we could overcome the difficulties of the classical method of decision making in spraying of cotton by considering the sub-levels of the four insect pests infesting the crop.

2.2 Field studies

In this study two locations were selected: one in Gezira Research Farm (GRF) of Gezira Research Station (GRS), where the cotton variety Barakat 90 was planted, and the other location was in Rahad Research Farm (RRF) of the Rahad Research Station (RRS), where the cotton variety grown was Acala 67B. However, it was conducted in season 1997/98. In each location six levels of infestations were used and laid out in a randomised complete block design; (RCB), replicated four times.
The experimental plot size in both sites was (8x8m), the levels of infestation were 2R, 3R, 4R, 5R, current ETL(CRT.ETL) and untreated control (Untr.), where (R) was based on conventional ETL as shown in Table 2.

Table 2: Explanation of the (R) unit

Insect pest	*African bollworm*	*Jassid*	*Whitefly*	*Aphid*
Conventional ETL	10 larvae and/or eggs per 100 plants	50 nymphs per 100 leaves	200 adults per 100 leaves	20% infested plants
Current ETL	10 larvae or 30 eggs per 100 plants	70 nymphs per 100 leaves	600 adults per 100 leaves	40% infested plants
Hypothetical observation	5 larvae per 100 plants	30 nymphs per 100 leaves	150 adults per 100 leaves	5% infested plants
Insect unit (R)*	0.5	0.6	0.75	0.25

*R=0.5+0.6+0.7+0.25=2.1

The sowing date for Barakat 90 was 7^th August and for Acala 67B was 16^th July 1997. Seed rate and spacing were performed as standard procedures used in Gezira and Rahad schemes for cotton production: 80 cm between ridges and 50 cm between plant holes. Five seeds per hole were used and thinned to 3 plants per hole 3 weeks after germination. Nitrogen fertiliser was applied as urea (46%) at the rate of 80 kg / feddan. Each plot was hand-weeded 4 times. Depending on the insect pest infestation, different insecticides were used as shown in Table 3.

Table 3: Insecticides used in combined ETL experiments

Gezira Research Farm (GRF)

Brand name	*Common name*	*Dose litre/feddan*	*g.a.i/feddan*
Endosulfan 50 EC	Endosulfan	0.75	375
Curacron 400 EC	Profenophos	0.50	200
Talstar 2.5 EC	Biphinthrin	0.6	15
Dursban 48 EC	Chlorpyrifos	0.75	365
Reldan 50 EC	Chlorpyrifos methyl	0.75	375

Rahad Research Farm (RRF)

Brand name	*Common name*	*Dose litre/feddan*	*g.a.i/feddan*
Larvin 80 DF	Thiodicarb	0.3*	240
Endosulfan 50 EC	Endosulfan	0.75	375
Curacron 400 EC	Profenophos	0.50	200

*kg/feddan

2.3 Insect counts

Regular periodical counts of the African bollworm *H. armigera* (eggs and Larvae) were taken from 100 plants in each subplot, where the top was examined for eggs and fruiting bodies were checked for larvae. Jassid nymphs (*J. lybica*) and white fly adults (*B. tabaci*) were counted on 20 plants at random in each subplot. In each plant 5 fully - grown leaves were inspected: 2 upper, 1 middle, and 2 lower on the main stem. The aphid counts were taken in terms of infested plants based on the absence or presence of the insect irrespective of the pest density on the plants. Scouting normally started early in the morning around 6. a.m.

2.4 Data collection

Insect pest population counts were carried out weekly. However, when the sprayable level was attained, the plots were sprayed one day later with the appropriate insecticides, according to the pest situation. Spraying was carried out using a knapsack sprayer with a delivering spray volume of 100 litre per feddan. The first post spray count was carried out two days after spraying.

2.5 Statistical analysis

The effect of each level of infestation (R) on cotton quantity and quality was recorded. The yield of cotton, (kantar / feddan) for the different treatments was analysed using ANOVA and Duncan's Multiple Range Test (DMRT) at 5% level of significance to separate between means. The statistical analysis for insect counts was made throughout the season to show the relative general performance of the insect pests.

The evaluation for fibre quality and degree of stickiness was done in co-operation with the Fibre Spinning and Stickiness Laboratory of the Agriculture Research Corporation (ARC). Fibre graphs 530 were used to determine the length parameters (2.5 %S.L mm). For uniformity ratio, (UR) Pat-Ar was used, for maturity and fineness, Micronair Value (MV) was done. The strengths were measured using the sterlometer. Thermodetector (SCT) was used to detect the number of sticky spots. All these procedures were carried out under laboratory conditions at 65% $\pm$ 2% RH at 20°C +2.

3 Results

The results of combined economic threshold level (ETL) were presented as cotton yield in kantar per feddan (K/F), quality of cotton and insect counts. These were shown as follows:

3.1 Cotton yield

Cotton yield per feddan due to different levels of infestation is shown on Table 4.
In the Barakat 90 variety at low level of infestations (R_2) the number of sprays was twice that of the high level of infestation (R_5).
In the Acala 67 B variety, the number of sprays at a low level of infestation (R_2) was 1.5 more than that at high level of infestations (R_5). However, in all treatments the number of Sprays were higher in the Barakat 90 variety compared to the Acala 67 B variety. In the Barakat 90 variety the yield in kantar per feddan was not significantly different at 5 between the low level of infestation (R_2) and the high level of infestation (R_5) perhaps due to the considerable experimental error (C.V 19.7%). Yet, the difference in yield was almost equivalent to one kantar /feddan.

The current ETL showed a significant difference at 5% in yield compared to the high level of infestation (R_5). However, the difference was more than one kantar per feddan, but the difference in yield was not significant at 5% from the rest of levels of infestation, R_2, R_3 and R_4. However, control of insect pests at all levels of infestation increased the cotton yield significantly at 5% from the untreated control. At most levels of infestations the yield of the untreated control was equivalent to less than 50% (Table 4). In the Acala 67B variety the yield in kantar per feddan was not significantly different at 5% level between all levels of infestation except the untreated control, where the difference in yield was more than 2 kantar per feddan. However, compared to all levels of infestations the yield of the untreated control was equivalent to more than 50% (Table 4).

Table 4: The effects of combined ETL on cotton yield. Means of seed cotton yield for two varieties

	Barakat 90		*Acala 67 B*	
Treatments	*No. of Sprays*	*Yield (K/F)*	*No of Sprays*	*Yield (K/F)*
R_2 (2 units)	8	3.7 ab	3	6.8 a
R_3 (3 units)	6	4.2 a	3	7.4 a
R_4 (4 units)	5	3.8 ab	2	7.3 a
R_5 (5 units)	4	2.8 b	2	6.5 a
Current ETL	7	4.2 a	3	7.4 a
Untreated control	-	1.7 c	-	4.6 b
S.D. $\pm$		0.66		0.823
CV (%)		19.7		12.4

3.2 The cotton quality

Fibre quality characteristics of varieties under test were influenced by the different levels of pests' infestation (Table 5). However, in both cotton varieties used, the different levels of infestation showed no differences at all levels of infestation in the span length (Table 5).
Fibre fineness and maturity had shown no differences between all levels of infestation in both varieties (Table 5). Strength elongation showed a clear difference between the levels of infestation. However, in both varieties R_3 level and the current ETL treatments were better than other levels of infestation (Table 5). Nevertheless, the untreated control was lowest in both varieties Barakat 90 and Acala 67 B (26.7, 18.3 respectively).
The different levels of infestations showed differences in stickiness compared with the untreated control in both varieties. However, R_3 and the current ETL treatments were better than the other levels of infestations in both varieties (Table 5). The grade showed similar results concurrently with the stickiness values (Table 5).

3.3 Statistical analysis (general performance of the insect units)

For Barakat 90, the major insect pests were the jassid and the aphid (Table 6). The African bollworm presence was nil, while the white fly was scarce. For jassid, the general performance of the insect units CRT. ETL treatment was similar to that on R_2 and significantly different compared to other levels of infestations. However, for aphid control similar results were obtained with CRT. ETL, R_2 and R_3. These latter levels of infestations were significantly different compared to the other levels (Table 6). For Acala 67B all the insect pests complex were present with the dominant presence of the African bollworm and jassid (Table 7). However, the level of the African bollworm was nil at the time of the first post spray count of the treatment R_5. Jassid infestation was mediocre. Aphid and white fly control in R_2 and R_3 were significantly better than CRT. ETL. (Table 7).

4 General discussion

The combined economic threshold is one of the factors that greatly influences plant growth and development. The effects appeared to be essentially an expression of the response of the cotton plant to insect pests incidence. These insect pests are capable of having direct and indirect effects on cotton quantity and quality.

4.1 The cotton yield

In all tested treatments of the combined ETL, the number of sprays were greater in the Barakat 90 variety compared to the Acala 67 B variety; this is because Barakat 90 takes a longer time for maturation than Acala 67B (MATTHEWS, 1989). It also may be related to the influence of other agronomic factors. In the Barakat 90 variety, the R_2 level, which was the lowest level, gave a higher cotton yield than the untreated control (3.7, 1.7 K/F respectively,). However, the difference was almost two kantars per feddan (Table 4). A similar result was obtained from Acala 67B for R_2 and the untreated control, (6.8,4.6K/F respectively) (Table 4). The R_3 level and the current ETL treatments gave similar cotton yields which were (4.2 K/F) in Barakat 90 and (7.4 K/F) in Acala 67B (Table 4). They differ slightly however with respect to the number of sprays in the Barakat 90 variety. However, the difference was only one spray. This indicated that the combined ETL compares well with the current ETL. Nevertheless, the R_3 and the current ETL treatments produced higher cotton yields than the untreated control (Table 4). These studies were in accordance with the previous study, done on a large scale, which showed an increase of one kantar per feddan (ABDELRAHMAN *et al.*, 1991). However, the differences with the high levels of infestations, R_4 and R_5, were more than one kantar per feddan compared with the untreated control. A similar result was obtained when these were compared with the R_3 level. However, there was a decrease in cotton yield with the increase of insect units (R) (Table 4).
Nevertheless the difference in R_3 level was significant compared with untreated control and other levels of infestation in the Barakat 90 variety. In Acala 67B however there were no significant differences between cotton yield from the different levels (R) of infestations except for the untreated control (Table 4). The results indicated that the R_3 treatment is the best one with regard to cotton yield. However, to all levels of infestations the yield of untreated control was less than 50% (Table 4).

4.2 The cotton quality

Fibre quality was influenced by the different levels of infestation. However, the cotton fibre span length did not show any differences between levels of infestation in both varieties (Table 5); this may be attributed to inheritance characters. A similar result was obtained for the micronaire value because the levels of infestation showed no differences in the micronaire value in both varieties (Table 5). But the R_3 and the current ETL treatments showed significant differences in the strength elongation in both varieties compared with the untreated control (Table 5). These indicate that R_3 and current ETL were better than other levels of infestation (R_2, R_4, R_5 and untreated control).
The different levels of infestation had shown differences in stickiness as evident by the number of sugar spots. However, the untreated control had the highest number of spots

for both cotton varieties (Table 5). The R_3 level and the current ETL had the lowest stickiness spots. However, the two levels were found to have a higher number of spots in Acala 67B compared to Barakat 90 variety. This may be due to a non sprayable level recorded for the white fly throughout the season, in the Barakat 90 variety, while they reached sprayable level of aphid earlier in Acala 67B.
These results of stickiness were supported by the grade reported in Table (6). Inspite of the higher number of sprayings in R_2 level, in both varieties (8, and 3 sprays), the stickiness was greater compared with the other levels of infestation (Table 5). This indicates that the number of sprays was not a factor in protecting cotton from stickiness.

4.3 Statistical analysis

The insect counts were analysed as general performance throughout the season. The statistical analysis shows significant differences between the levels of infestation (R) in both varieties (Tables 6 and 7).
In Barakat 90, the African bollworm gave a similar result in the statistical analysis, because the African bollworm was not a problem and/or not reached sprayable level at any levels of spraying (Table 6). In Acala 67B the African bollworm was a problem when the first and second sprays were directed towards its control. Also, significant differences between the levels of infestations were found (Table 7). Nevertheless, the R_2 and R_3 levels were statistically better than other levels of infestation and they did not differ in cotton yield (Table 4). This indicated that the African bollworm needs a good management according to the stages of the crop growth (BALLA, 1978; ABDELRAHMAN *et al.*, 1991).

In Barakat 90 the cotton jassid was dominant throughout the season. However, the statistical analysis showed significant differences between the levels of infestation in the different treatments (Table 6). Nevertheless R_2 was the best one (Table 6), while in Acala 67B R_2 and R_3 were the best ones (Table 7). These results indicate that the ETL of infestation differs according to the type of variety. But when we related the statistical analysis with the production and the number of sprays, we found that R_3 is the best level compared with other levels of infestation (Tables 4, 6 and 7).
In Barakat 90 the white fly was not the dominant insect pest. However, the statistical analysis showed significant differences between the levels of infestation in the different treatments (Table 6). The R_3 and the current ETL treatments mostly had similar results and were not statistically different in cotton yield (Tables 4 and 6), though they differ in the number of sprays (Table 4). These indicate that R_3 level was similar to the current ETL. While in Acala 67 B the R_3 level was statistically better than current ETL (Table 7).
In Barakat 90 the aphid was the dominant pest throughout the season. However, the statistical analysis showed significant differences between the levels of infestation (R). Nevertheless, no significant differences were found between R_2, R_3 and the current ETL treatment (Table 6). They differ however in cotton yield and the number of sprays (Table 4). These indicate that R_3 level was the best ones (6 sprays) and 4.2 K/F cotton yield (Table 4). But in Acala 67 B the R_2 and R_3 levels mostly showed similar statistical results in general performance throughout the season and they differ from the current

Table 5: The effects of spraying on the number of insect pests complex of two cultivars on cotton quality during 1997/98

Cultivars	*Treatment*	*2.5% Span length*	*Micronaire value (mv) (fineness+maturity)*	*Strenght elongation (m) (stelometer 1/8 g/tax)*	*Stickiness*	*Grade*	*No. of sprays*
Acala 67B	R_2	26.7	3,8	18.9	28	2	3
	R_3	27.0	3,7	20.5	16	2	3
	R_4	26.8	3,9	19.3	27	3	2
	R_5	26.8	3,7	20.0	31	3	2
	CRT. ETL	27.1	3,8	20.3	14	2	3
	Control	26.4	3,9	18.3	39	3	-
Barakat 90	R_2	31.7	3.6	27.1	11	4	8
	R_3	32.3	3.5	27.4	5	3	6
	R_4	31.7	3.4	27.2	13	4	5
	R_5	31.9	3.7	27.1	15	4	4
	CRT. ETL	32.2	3.7	27.7	5	2	7
	Control	31.9	3.9	26.7	16	4	-
Key		25.5-29.9	3.5 fine	18-19 low	0-2 not detachable		
			4.5 average	20-21 average	2-16 light		
			5.5 coarse	22-23 high	17-23 medium		
					23-50 strong		

Table 6: The general performance of the insecticides used on the different treatments during the period 21/9 - 27/12/1997 Variety Barakat 90, Gezira Research Farm - Season 1997 - 1998 (actual figures in brackets)

Treatments	*Jassid nymphs per 100 leaves* [1]	*White fly per 100 leaves* [2]	*%age of Aphid infested plants* [3]
R_2	7.7 a (60)	7.1 ab (50.3)	18.7 a(10.3)
R_3	8.2 b (67.5)	7.3 ab (53.0)	20.5 a (12.3)
R_4	9.7 c (87.8)	7.6 b (57.8)	22.9 b (15.3)
R_5	10.9 d (119.3)	7.4 ab (54.3)	23.9 b (16.5)
CRT. ETL	7.7 a (59.6)	6.9 a (48.8)	20.5 a (12.3)
Untr. Control	15.4 e (236.0)	8.7 c (76.5)	37.8 c (37.5)
S.E. ($\pm$)	0.64	0.17	0.34
C.V. (%)	9.6%	4.6%	4.6%

[1] Data transformed to $\sqrt{x}$, (mean of 19 counts)
[2] Data transformed to $\sqrt{x}$, (mean of 17 counts)
[3] Data transformed to $\arcsin x$, (mean of 19 counts)
Means followed by the same letter were not significantly different at 5% level using Duncan's Multiple Range Test

Table 7: The general performance of the insecticides used on the different treatments during the period 21/9 - 27/12/1997 Variety Acala 67 B, Rahad Research Farm - Season 1997 - 1998 (actual figures in brackets)

Treatments	*A.B.W.(eggs + larvae) per 100 plants* [1]	*Jassid nymphs per 100 leaves* [2]	*White fly per 100 leaves* [3]	*% age Aphid infested plants* [4]
R_2	1.4 a (1.0)	4.9 ab (24.8)	10.1 a (102.8)	19.6 a (11.3)
R_3	1.4 a (1.0)	4.7 a (22.5)	10.3 a (107.0)	22.2 b (14.3)
R_4	1.7 b (2.0)	5.1 ab (26.3)	11.0 b (121.3)	23.6 bc (16.0)
R_5	–	7.1 c (50.8)	16.1 d (258.3)	27.9 c (22.0)
CRT.ETL	1.9 b (2.5)	5.5 b (30.0)	12.8 c (162.8)	28.8 d (23.3)
Untr. Control	4.4 c (18.8)	8.8 d (76,8)	18.2 e (332.3)	54.0 e (65.0)
S.E ($\pm$)	0.14	0.20	0.36	4.09
C.V. (%)	7.1%	6.8%	2.8%	13.9%

[1] Data transformed to $\sqrt{x+1}$, (mean of 7 counts)
[2] Data transformed to $\sqrt{x}$, (mean of 7 counts)
[3] Data transformed to $\sqrt{x}$, (mean of 7 counts)
[4] Data transformed to $\arcsin x$, (mean of 7 counts)
Means followed by the same letter were not significantly different at 5% level using Duncan‘s Multiple Range Test

ETL (Table 7). These agree with Abdelrahman *et al.* (1991) results in which ETL of aphid was increased from 20% aphid infestation to 40%.

5 Summary and conclusions

The findings of the present study can be summarised as follows:

1) The economic threshold is dynamic(action threshold) according to the variables such as cotton yield, number of sprays and their impact on the natural enemies as well as the cotton variety and growth stages.
2) The dominant insect pests in the cotton crop were the cotton jassid, the cotton aphid and to a lesser degree the cotton white fly as well as the African bollworm.
3) The number of sprays was not a factor in improving the cotton quality as well as reducing the stickiness.
4) The use of R_3 level was the most effective method compared to the classical method. However, this level does not differ significantly from the current ETL and hence needs more investigations on small and large scale levels.
5) The R_3 level (3 units), was the best level to be used as a combined threshold for the cotton insect pests complex.

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