INSECT PEST CONTROL AND YIELD PATTERNS IN CENTRAL QUEENSLAND COTTON CROPS

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SUMMARY

During 1957-1960, six field trials were carried out mainly to investigate the status of *Heliothis armigera* (Hubn.) as a pest of cotton under a variety of agronomic conditions. Heavy fertilizer dressings and hormone applications were used to increase the potential yields of seed cotton per acre in both rain-grown and irrigated crops. Early-season control of *H. armigera* is shown to exert the same influence under all agronomic conditions encountered, i.e. higher early-pick yields with no increase in total yields.

In two trials in which severe infestations of *Pectinophora scutigera* Hold. were experienced, DDT applications resulted in considerably increased yields. Results of one trial indicated that relatively small populations of leaf-eating insects during the early and major square and boll production period can depress yields. Fertilizer is shown to have potential value in irrigated cotton, but the use of alpha naphthalene acetic acid sprays did not increase yields.

I. INTRODUCTION

Field trials during 1948-1957 demonstrated that *Heliothis armigera* (Hubn.) is not a pest of major economic importance during the early square and boll production period of cotton. The killing of Heliothis allowed the plants to hold a larger percentage of the early squares and bolls; thus sprayed cotton produced a greater early yield than unsprayed. Differences in later picks, however, were sufficient to give approximate equality in total yields (Passlow 1959).

The present work followed directly from these results. Six trials were carried out to test the validity of the above conclusions under a wide range of agronomic conditions. Plant reactions to pest kills were studied in five of the trials. Two (Trials 1 and 2, 1957-58) were established using standard agronomic practice, one with and one without supplementary irrigation; two (Trials 3 and 4, 1958-59), one with and one without supplementary irrigation, incorporated the use of heavy dressings of fertilizers and applications of alpha naphthalene acetic acid to prevent shedding of fruit forms; and two (Trials 5 and 6, 1959-60), both with supplementary irrigation, were carried out using heavy dressings of fertilizers.

The variety Miller 43-9-0 was used at Biloela, and Arkot 2-1 was planted in the rain-grown trials at Gracemere during the first two seasons and in the irrigated trial at Kabra in 1959-60. All trials were designed to give some insecticide cover during the major square and boll production period and to ascertain the value of this protection under the conditions operating in each trial.

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II. METHODS

Plot size varied among trials from 180 row-feet in Trials 5 and 6 to 396 row-feet in Trial 2. Plots of six yield rows were used in Trials 1, 2, 5 and 6 and of four yield rows in Trials 3 and 4. An inter-row spacing of 3 ft 6 in. was employed in all trials except Trial 6, where the spacing was 3 ft 9 in.

Heliothis egg counts were made weekly in each trial on 30 plant terminals per plot selected at random in six groups of five in Trials 1-4 and on 15 plant terminals per plot selected at random in five groups of three in Trials 5 and 6. A terminal was taken as that part of the plant from the growing point to the fifth leaf from the top.

Spray treatments were applied by power-driven twin-nozzle hand applicators and the materials used were:

DDT.—An emulsion concentrate containing 25 per cent. w/v active ingredient.

Endrin.—An emulsifiable preparation containing 20 per cent. w/v active ingredient.

Alpha naphthalene acetic acid.—A solution containing 2 per cent. w/v active ingredient.

Insecticides were applied during the eight weeks following the first burst of squaring to give protection from pest attack over this period of major square and boll production. The hormone was applied (in Trials 3 and 4) three weeks after the first burst of squaring, and in one treatment again three weeks later. Fertilizers were applied (in Trials 3-6) by hand as a basal preplant dressing, and as a side-dressing three weeks after the first burst of squaring. The basal dressing comprised 254 lb sulphate of ammonia, 400 lb superphosphate and 127 lb muriate of potash per acre, and the side-dressing 283 lb sulphate of ammonia per acre.

In all trials except Trial 6 some attention was given to plant behaviour in relation to pest control, and to fertilizer and hormone usage where applicable. Prior to the commencement of squaring, five plants (Trials 1 and 2) and four plants (Trials 3, 4 and 5) per plot were selected and weekly records of the numbers of squares, bolls and mature bolls were made. In addition, all fallen forms were collected weekly, counted and examined for insect damage, from two inter-row areas each 20 ft long per plot in Trials 1 and 2, from three inter-row areas each 14 ft long in Trials 3 and 4, and from four inter-row areas each 10 ft long in Trial 5. Numbers of larvae of the boll-feeding insects *Heliothis armigera* (Hubn.), *Earias huegeli* Rogen, *Pectinophora scutigera* (Hold.) and *Dichocrocis punctiferalis* (Guen.) were recorded.

Further weekly records of insect species found on the aboveground parts of two plants (in an observation row) per plot were made in Trial 5.

Trial layouts, details of treatments with insecticide and hormone dosages, and other relevant information are given with the results.

III. RESULTS

(a) Trial 1. 1957-58, Biloela. 3 x 7 Randomized Block. Irrigated

The trial was planted on October 15 and insecticide applications were made on November 26, December 11 and 24 and January 8 at 33, 37, 105 and 125 gal per ac respectively. Heliothis egg counts did not indicate differences for oviposition among treatments, and numbers of eggs exceeded 5 per 100 terminals only on November 19 and 26 and December 2, 11, 16 and 23, when 5·6, 13·2, 53·3, 16·5, 9·0 and 10·0 respectively per 100 terminals were recorded. Small numbers of *Anomis flava* F. were recorded during December and March, and *E. huegeli* and *P. scutigera* respectively caused only minor damage during January and from April until the end of the season.

TABLE 1

TRIAL 1. TOTAL AND DAMAGED FALLEN FORMS PER PLOT SITE

Treatment	Fallen Forms (Mean)	Damaged Fallen Forms (Mean)	Damaged Fallen Forms (%)	
			Transformed Mean	Equivalent Mean (%)
DDT 0·1% spray	532	114	27·6	21·5
Endrin 0·05% spray ..	483	129	31·2	26·8
Check	589	142	29·6	24·4
Necessary differences for significance 5%	64	18	2·2	
Necessary differences for significance 1%	89	25	3·0	

Fruit form production conformed to the usual pattern of higher total production on unsprayed than on sprayed plants. Numbers of fallen forms and percentage of damaged fallen forms are given in Table 1. Harvest was on March 10-12 and May 6-8 and yields are given in Table 2.

TABLE 2

TRIAL 1. YIELDS AND PLANTS PER PLOT, AND YIELDS AND BOLLS PER SITE

Treatment	Yield (lb/ac)		Plants per Plot	Yield per Site (lb)	Bolls per Site
	1st Pick	Total Pick			
DDT 0·1% spray	1,156	1,455	338	4·29	390
Endrin 0·05% spray ..	1,069	1,428	337	4·28	366
Check	878	1,334	329	3·95	364
Necessary differences for significance 5%	106	132	24	0·33	34
Necessary differences for significance 1%	149	184	34	0·47	48

The results, in which differences are apparent on the first pick without significant differences in total yield, are similar to those in earlier work (Passlow 1959).

(b) Trial 2. 1957-58, Gracemere. 3 x 7 Randomized Block. Rain-grown

The trial was planted on November 7 and insecticide applications were made on January 9 and 23 and February 6 and 25 at 83, 109, 110 and 120 gal per ac respectively. Heliothis populations as recorded in egg counts per 100 terminals were low throughout, with no differences among treatments. Between December 20 and January 28 the maximum was 4·8 eggs on January 6, and during a second period of oviposition between March 10 and April 21 a maximum of 12·1 eggs was recorded. Counts other than during these periods were fewer than one. Small numbers of *E. huegeli* larvae were recorded throughout the trial in fallen forms. Relatively larger numbers of *P. scutigera* larvae were recorded in fallen forms from late April until the end of the trial (the maximum from all fallen forms was 126 on June 3).

Following low Heliothis populations early in the season, no differences in production occurred during this period; however, from late March the DDT-treated plants produced fewer forms than plants in the other treatments. Numbers of fallen forms and percentage damaged fallen forms are given in Table 3. The high percentage of damaged fallen forms was the result of late-season attack by *P. scutigera.*

TABLE 3

TRIAL 2. TOTAL AND DAMAGED FALLEN FORMS PER PLOT SITE

Treatment	Fallen Forms (Mean)	Damaged Fallen Forms (Mean)	Damaged Fallen Forms (%)	
			Transformed Mean	Equivalent Mean (%)
DDT 0·1% spray	635	195	33·5	30·5
Endrin 0·05% spray ..	634	205	34·7	32·4
Check	651	217	35·3	33·4
Necessary differences for significance 5%	98	42	2·2	
Necessary differences for significance 1%	131	60	3·1	

Harvest was on March 24-27, May 12-15 and June 23-30. Data collected do not explain the yield difference (Table 4) obtained. Probably control by endrin of the relatively light infestation of *A. flava* and other leaf-eating insects encountered was responsible for these differences.

TABLE 4

TRIAL 2. YIELDS AND PLANTS PER PLOT, AND YIELDS AND BOLLS PER SITE

Treatment	1st Pick	1st + 2nd Picks	Total Pick	Plants per Plot	Yield per Site (lb)	Bolls per Site
DDT 0·1% spray ..	572	892	1,188	342	4·16	414
Endrin 0·05% spray ..	629	938	1,317	351	4·55	444
Check	530	815	1,140	351	3·73	396
Necessary differences for significance 5%	72	74	161	12	0·77	60
Necessary differences for significance 1%	101	103	226	17	1·08	85

(c) Trial 3. 1958-59, Biloela. 3 x 3 x 3 Factorial Design. Irrigated

The trial was planted on October 14. Fertilizer treatments were: F0, no fertilizer; F1, basal preplant dressing applied on October 14; and F2, basal dressing as in F1 plus a side-dressing applied at maximum squaring on December 22. Insecticide treatments were: D0, no insecticide; D1, four fortnightly DDT 0·1% spray applications from the first burst of squaring on December 9 and 23 and January 8 and 21; and D2, eight weekly DDT 0·1% spray applications from the first burst of squaring on December 9, 16 and 23 and January 2, 8, 14, 21 and 28. DDT was used at an average rate of 161 gal per ac. Hormone treatments were: H0, no hormone; H1, one application of a solution of alpha naphthalene acetic acid at 10 p.p.m. to wet all fruit forms at major square production on December 22; and H2, two applications of alpha naphthalene acetic acid at 10 p.p.m. used as in H1 on December 22 and January 14. The hormone was used at 124 gal per ac.

Heliothis egg counts did not suggest differences in oviposition among treatments, and numbers of eggs exceeded 5 per 100 terminals on November 18 and 25, December 3, 9, 17, 23 and 30 and January 6, when 14·2, 9·6, 6·7, 15·3, 43·1, 28·5, 24·4 and 20·2 were recorded. Some eggs of *A. flava* were noted on terminals during November (maximum number 29 on November 18) and few larvae of *E. huegeli* and *P. scutigera* were recovered from fallen forms.

Total numbers of fallen forms per plot and percentages of damaged fallen forms per plot are given in Table 5. Calculated total production of fruiting forms per plant and numbers of plants per plot are given in Table 6. Harvest was on March 9-11, March 24-25, April 27 and July 31 and yields are given in Table 7.

Both DDT and fertilizer usage resulted in increased yields. Yields after DDT applications followed the usual pattern when applied for protection of early squares and small bolls, i.e. considerable increases over check plots in the early picks, with the check plots outyielding treated plots in the late picks. The early differences, however, were greater than the late, giving significant differences among treatments.

Despite the egg counts recorded, Heliothis larvae were seldom noted during the trial (10 only being recorded from all fallen forms), and although 16 per cent. of fallen forms were damaged in check plots, compared with 5 per cent. and 7 per cent. in DDT-treated areas, there were no differences among either total numbers of fallen forms or fruit form production per plant. Yield differences, therefore, were not related to Heliothis control. A pest factor not covered by the data collected was obviously present in this trial.

TABLE 5

TRIAL 3. TOTAL AND PERCENTAGE DAMAGED FALLEN FORMS PER PLOT

Treatment	Total Fallen Forms			Damaged Fallen Forms: Transformed Mean			Damaged Fallen Forms: Equivalent Mean (%)		
	F0	F1	F2	F0	F1	F2	F0	F1	F2
D0	1,344	1,876	2,301	24·5	23·1	22·5	17·2	15·3	14·6
D1	1,238	1,881	2,631	18·8	13·5	12·9	10·4	5·5	5·0
D2	1,243	1,932	2,565	15·0	11·6	11·7	6·7	4·1	4·1
	H0	H1	H2	H0	H1	H2	H0	H1	H2
D0	1,740	1,823	1,950	23·3	22·9	23·8	15·7	15·1	16·3
D1	1,986	1,828	1,936	14·7	15·2	15·3	6·4	6·9	6·9
D2	1,904	2,024	1,812	12·9	12·7	12·7	5·0	4·9	4·8
F0	1,253	1,212	1,359	19·0	19·7	19·5	10·6	11·4	11·1
F1	1,860	1,972	1,857	16·7	15·6	15·9	8·3	7·2	7·5
F2	2,516	2,491	2,489	15·2	15·5	16·3	6·8	7·1	7·9
	Marginal	Individual		Marginal	Individual				
Necessary differences for significance 5%	179	311		1·4	2·5				
Necessary differences for significance 1%	272	471		2·2	3·7				

Fertilizer applications increased yields proportionally to the amount of suphate of ammonia applied and irrespective of time of application. Yield patterns following DDT usage were not changed by applications of fertilizers.

Hormone applications did not significantly affect yields, although actual yields, particularly in the early picks, were lower where the hormone was applied than in the check treatment.

TABLE 6

TRIAL 3. TOTAL FRUIT FORM PRODUCTION PER PLANT AND PLANTS PER PLOT

Treatment	Total Fruit Form Production per Plant			Plants per Plot		
	F0	F1	F2	F0	F1	F2
D0	26·4	38·0	48·0	399	406	407
D1	27·7	38·1	45·5	399	396	415
D2	27·0	37·9	48·7	400	404	402
	H0	H1	H2	H0	H1	H2
D0	40·0	37·1	35·2	401	400	411
D1	38·7	34·0	38·7	404	406	400
D2	38·9	39·4	35·3	401	413	392
F0	30·5	26·8	23·8	390	411	398
F1	36·9	39·8	37·3	406	403	396
F2	50·2	43·9	38·1	410	404	410
	Marginal	Individual				
Necessary differences for significance 5%	2·3	4·0		No significant differences		
Necessary differences for significance 1%	3·5	6·0				

(d) Trial 4. Gracemere, 1958-59. 3 x 3 x 3 Factorial Design. Rain-grown

The trial was planted on December 8-9. The treatments applied were the same as in Trial 3: F1, basal preplant dressing on December 8-9; F2, basal dressing on December 8-9 and side-dressing at maximum squaring on February 11; D1, four fortnightly DDT 0·1% sprays on January 29, February 12 and 26 and March 13; D2, eight weekly DDT 0·1% sprays on January 29, February 5, 12, 20 and 26 and March 5, 13 and 19; H1, alpha naphthalene acetic acid applied at major square production on February 12; H2, alpha naphthalene acetic acid applied as for H1 on February 12 and on March 5. DDT was used at an average rate of 128 gal per ac and the hormone at an average rate of 165 gal per ac.

Egg counts suggested that ovipositing Heliothis moths had a slight preference for oviposition sites on terminals within D2 and F2 treatments. Mean counts exceeded 5 eggs per 100 terminals on only January 20, February 5, February 25

TABLE 7

TRIAL 3. YIELDS PER PLOT (lb/ac)

Treatment	1st Pick			1st plus 2nd Pick			1st plus 2nd plus 3rd Pick			Total Pick		
	F0	F1	F2	F0	F1	F2	F0	F1	F2	F0	F1	F2
D0	753	839	731	1,167	1,681	1,553	1,428	2,268	2,673	1,640	2,448	2,830
D1	1,117	786	1,059	1,746	1,846	2,210	1,950	2,386	3,152	2,102	2,447	3,266
D2	757	1,157	1,357	1,547	2,210	2,691	1,851	2,559	3,311	1,995	2,677	3,487
	H0	H1	H2	H0	H1	H2	H0	H1	H2	H0	H1	H2
D0	926	690	708	1,667	1,362	1,372	2,275	2,085	2,008	2,448	2,275	2,195
D1	989	1,070	994	1,867	1,987	1,948	2,489	2,466	2,515	2,591	2,579	2,645
D2	1,164	1,154	953	2,227	2,179	2,042	2,662	2,587	2,472	2,795	2,745	2,620
F0	831	904	893	1,529	1,522	1,409	1,802	1,801	1,626	1,949	1,973	1,815
F1	1,124	852	805	2,112	1,781	1,845	2,529	2,265	2,401	2,656	2,408	2,508
F2	1,033	1,158	957	2,121	2,226	2,108	3,095	3,073	2,969	3,229	3,218	3,136

	1st Pick Marginal	1st Pick Individual	1st plus 2nd Pick Marginal	1st plus 2nd Pick Individual	1st plus 2nd plus 3rd Pick Marginal	1st plus 2nd plus 3rd Pick Individual	Total Pick Marginal	Total Pick Individual
Necessary differences for significance 5%	220	380	201	349	162	280	154	267
Necessary differences for significance 1%	333	576	305	528	245	425	233	404

TABLE 8

TRIAL 4. TOTAL AND PERCENTAGE DAMAGED FALLEN FORMS PER PLOT AND TOTAL FRUIT FORM PRODUCTION PER PLANT

Treatment	Total Fallen Forms			Damaged Fallen Forms (%) Transformed Mean			Damaged Fallen Forms (%) Equivalent Mean (%)			Total Fruit Form Production per Plant		
	F0	F1	F2	F0	F1	F2	F0	F1	F2	F0	F1	F2
D0	945	1,544	1,502	31·7	34·7	34·1	27·7	32·4	31·5	14·7	25·3	28·2
D1	973	1,241	1,359	27·2	26·2	27·7	20·9	19·4	21·6	17·3	21·8	23·8
D2	1,083	1,080	1,183	20·0	23·6	24·0	11·7	16·0	16·6	18·6	21·9	20·7
	H0	H1	H2	H0	H1	H2	H0	H1	H2	H0	H1	H2
D0	1,126	1,395	1,470	32·0	33·9	34·6	28·1	31·1	32·3	17·2	25·3	25·6
D1	1,283	1,199	1,091	25·1	25·8	30·2	18·0	18·9	25·3	25·5	17·8	19·6
D2	1,174	1,073	1,099	21·5	21·7	24·4	13·4	13·6	17·1	21·2	19·4	20·7
F0	1,031	1,002	967	25·1	26·0	27·9	18·0	19·2	21·9	18·3	15·1	17·1
F1	1,247	1,279	1,339	26·9	28·1	29·4	20·4	22·2	24·1	22·5	23·2	23·3
F2	1,305	1,387	1,353	26·6	27·3	32·0	20·1	21·0	28·0	23·1	24·1	25·4
	Marginal	Individual		Marginal	Individual					Marginal	Individual	
Necessary differences for significance % 5%	270	468		3·0	5·3					3·1	5·4	
Necessary differences for significance % 1%	409	709		4·6	8·0					4.7	8·2	

and March 4, when 17·3, 15·8, 19·5 and 9·0 eggs per 100 terminals were recorded. Few eggs and larvae of *A. flava* and *E. huegeli* were observed during the trial. Larvae noted in fallen forms were predominantly *P. scutigera*. Population differences among treatments were obvious (Figure 1).

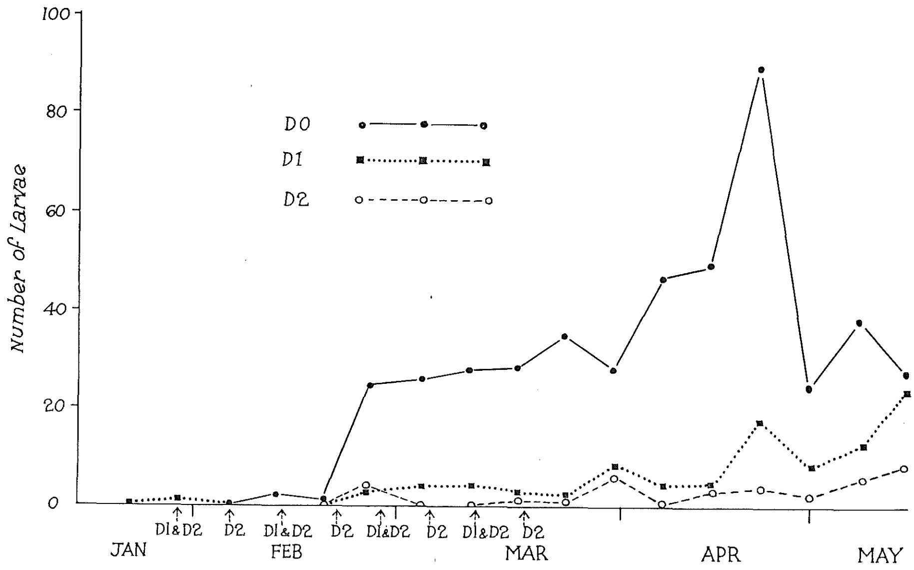

Fig. 1—*Pectinophora scutigera* larvae in fallen forms. Trial 4, 1958-59.

Total numbers of fallen forms per plot, percentages of damaged fallen forms per plot and calculated total production of fruiting forms per plant are given in Table 8.

Harvest was on April 21-24 and May 11-13 and yields together with numbers of plants per plot are given in Table 9.

As *P. scutigera* damage was severe in this trial, an assessment of damage on mature unpickable bolls (bolls mature without any pickable cotton) was carried out on April 28. All unpickable mature bolls were collected from sufficient plants to give 50 bolls and these bolls were examined for evidence of insect attack. Virtually all larvae recorded were *P. scutigera*. Numbers of unpickable bolls per plant and percentages of unpickable bolls damaged by insects are given in Table 10.

Relatively low Heliothis populations were experienced in this trial and any effect which these insects may have had was masked by severe attack by the pink bollworm, *P. scutigera*. The spectacular increases obtained from four fortnightly and eight weekly applications of DDT indicate the value of this insecticide in preventing damage from *P. scutigera*. Weekly applications gave better yields than DDT used at fortnightly intervals. As, however, detailed

TABLE 9

Trial 4. Yields per Plot (lb/ac) and Plants per Plot

Treatment	Yields						No. of Plants per Plot		
	1st Pick			Total Pick					
	F0	F1	F2	F0	F1	F2	F0	F1	F2
D0	496	486	393	663	724	650	557	480	438
D1	869	1,064	1,043	1,116	1,431	1,326	537	514	533
D2	1,186	1,245	1,367	1,522	1,592	1,718	573	468	511
	H0	H1	H2	H0	H1	H2	H0	H1	H2
D0	571	372	432	825	583	628	520	473	482
D1	1,215	912	850	1,524	1,255	1,093	519	547	517
D2	1,274	1,287	1,237	1,630	1,597	1,605	502	497	553
F0	952	846	753	1,200	1,093	1,008	541	555	571
F1	1,088	823	884	1,395	1,110	1,242	470	463	529
F2	1,020	903	881	1,385	1,232	1,076	530	500	453
	Marginal	Individual		Marginal	Individual		Marginal	Individual	
Necessary differences for significance 5%	127	220		155	268		37	64	
Necessary differences for significance 1%	192	333		234	406		56	97	

TABLE 10

TRIAL 4. UNPICKABLE BOLLS PER PLANT AND PERCENTAGE DAMAGED

Treatment	No. of Unpickable Bolls per Plant			Unpickable Bolls Insect Damaged (%)					
				Transformed Mean			Equivalent Mean (%)		
	F0	F1	F2	F0	F1	F2	F0	F1	F2
D0	0·93	2·54	2·06	72·3	81·9	77·1	90·7	98·0	95·0
D1	0·61	0·77	1·31	66·0	70·5	73·5	83·5	88·8	91·9
D2	0·30	0·57	0·47	61·2	63·4	65·4	76·8	80·0	82·7
	H0	H1	H2	H0	H1	H2	H0	H1	H2
D0	1·17	2·31	2·05	75·7	79·1	76·4	93·9	96·9	94·5
D1	0·77	0·80	1·11	68·6	68·3	73·0	86·7	86·3	91·5
D2	0·52	0·38	0·44	66·2	60·3	63·5	83·7	75·5	80·1
F0	0·61	0·68	0·54	66·7	64·1	68·7	84·3	81·0	86·8
F1	0·97	1·61	1·30	75·7	67·7	72·3	93·9	85·6	90·8
F2	0·88	1·19	1·75	68·1	75·9	71·9	86·1	94·1	90·4

Necessary differences for significance		No. of Unpickable Bolls per Plant: Marginal	Individual	Transformed Mean: Marginal	Individual
	5%	0·47	0·81	4·6	7·9
	1%	0·71	1·22	6·9	12·0

observations on *P. scutigera* populations were not carried out, the results do not indicate the numbers of treatments required for economic control of the pest. Pest populations at harvest suggest that treatments later in the season may have further increased yields.

Response to fertilizer application was not obtained in this rain-grown trial although more fruit forms were produced. As overall seasonal conditions were somewhat drier than usual, this result was not unexpected. Apparently nitrogenous fertilizers are of value in rain-grown crops only when available moisture at critical periods approaches that of crops grown with supplementary irrigation.

The decrease in yields following hormone usage suggested in Trial 3 was obtained in this trial. As total yields in both treatments where hormone was applied were approximately equal, the loss of yield potential was associated chiefly with the application on February 12. Two explanations of this behaviour are possible: (1) production of squares may have been depressed (although a depression was not obtained in total cumulative production, production during the week ending February 18 was lower than in the check treatment) and (2) hormone application caused the fall of small squares which were not recovered in fallen form collections.

(e) Trial 5. 1959-60, Biloela. 9 x 3 Randomized Block. Irrigated

The trial was planted on October 7. Treatments were all combinations of three fertilizer rates—F0, F1 and F2 as in Trials 3 and 4 with dressings on October 7 and November 23—and three DDT treatments—D0, no insecticide, D1, four 0·1% applications during the second month after the first burst of squaring with treatments on January 6, 13 and 27 and February 3, and D2, four fortnightly 0·1% applications from the first burst of squaring with treatments on December 8 and 23 and January 6 and 27. DDT was used at an average rate of 176 gal per ac.

Egg counts indicated low Heliothis populations throughout the trial. Egg numbers exceeded 4 per 100 terminals only on November 30, December 7, 14 and 22 and January 5, when 4·7, 13·3, 6·4, 9·1 and 6·9 were recorded respectively. Few other insects were recorded on terminals: occasional Heliothis larvae were noted in fallen forms during January; larvae of *E. huegeli* were recorded during the January-April period but not in pest proportions; *P. scutigera* larvae, however, caused damage, considerable numbers being recovered during early January and March-April (Figure 2). In weekly observations of insect species on two plants in an observation row in each plot, small numbers of *Aulacosternum nigrorubrum* Dall., *A. flava, Bucculatrix gossypii* Turn., *Dysdercus sidae* Montr. and *Tectocoris diophthalmus* (Thunb.) were recorded. The only insects noted in high populations were *P. scutigera* and *Oxycarenus luctuosus* Montr., 10-20 of the latter being recorded per plant during late February and March.

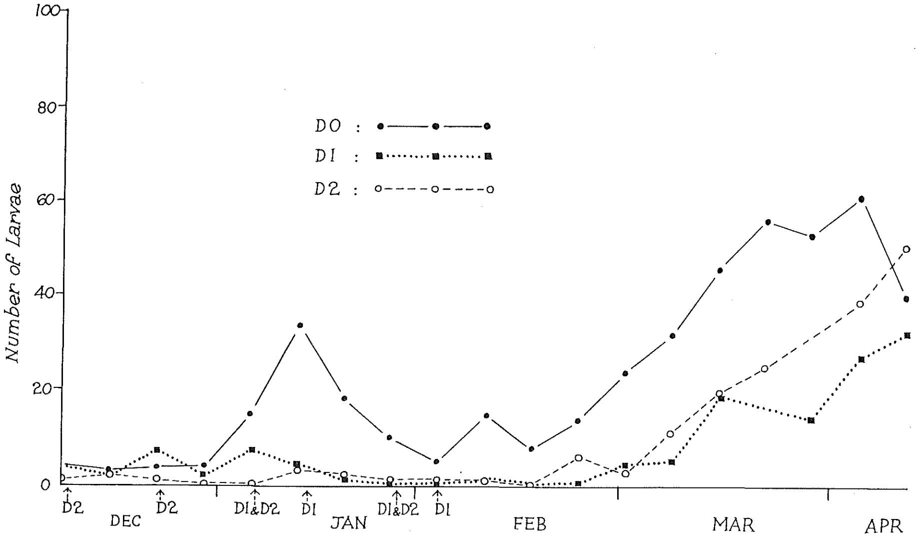

Fig. 2—*Pectinophora scutigera* larvae in fallen forms. Trial 5, 1959-60.

Total numbers of fallen forms per plot and percentages of damaged fallen forms are given in Table 11. Calculated total production of fruit forms per plant and the percentage of mature bolls damaged on plants in observation rows are given in Table 12.

Harvest was on March 9-10 and April 12-13 and yields together with number of plants per plot are given in Table 13.

Yields were low in this trial following a severe angular leaf spot (*Xanthomonas malvacearum* (E. F. Smith) Dowson) attack during December, and mid-season and late season damage from *P. scutigera*. Cumulative weekly records of mature damaged bolls (Table 12) indicate the severity of *P. scutigera* attack.

Heliothis populations were low throughout the season and had no influence on final yields.

TABLE 11

TRIAL 5. TOTAL AND PERCENTAGE DAMAGED FALLEN FORMS PER PLOT

Treatment	Total Fallen Forms			Damaged Fallen Forms (%)					
				Transformed Mean			Equivalent Mean (%)		
	F0	F1	F2	F0	F1	F2	F0	F1	F2
D0	1,799	2,326	3,215	23·57	22·50	22·40	16·0	14·6	14·5
D1	1,848	2,226	2,867	18·97	16·77	16·93	10·6	8·3	8·5
D2	1,778	2,316	3,163	16·00	12·93	16·17	7·6	5·0	7·8

	Marginal	Individual	Marginal	Individual
Necessary differences for significance 5%	290	502	1·41	2·45
1%	400	692	1·95	3·37

TABLE 12

TRIAL 5. TOTAL FRUIT FORM PRODUCTION PER PLANT AND PERCENTAGE MATURE BOLLS DAMAGED

Treatment	Fruit Form Production			Mature Bolls Damaged (%)		
	F0	F1	F2	F0	F1	F2
L0	20·3	27·3	36·3	50·0	41·9	23·1
D1	20·6	27·1	35·7	14·3	13·6	11·8
D2	19·2	29·1	37·8	13·8	18·5	8·3
	Marginal		Individual			
Necessary differences for significance 5%	3·2		5·6	No analysis		
Necessary differences for significance 1%	4·4		7·7			

Fertilizer applications significantly increased yields but the increases obtained were considerably lower than anticipated, much of the fertilizer advantage being lost in reduced potential fruit form production following the disease outbreak.

(f) Trial 6. 1959-60, Kabra. 9 x 3 Randomized Block. Irrigated

The trial was planted on October 21. Treatments were combinations of three fertilizer levels as in Trial 5, with dressings on October 21 and January 4, and three DDT treatments: D0, no insecticide; D1, two applications of DDT on January 25 and February 1, commencing one month after the first burst of squaring, and D2, three applications of DDT on December 21, January 4 and January 25, commencing at the first burst of squaring. DDT was used at an average rate of 188 gal per ac.

Egg counts indicated low Heliothis populations throughout the trial period, numbers exceeding 4 per 100 terminals on only December 16 and February 8, when 6·2 and 4·4 were recorded respectively. The only insects noted in more than small numbers during the trial were *Aphis gossypii* Glov. and *Austroasca terrae-reginae* (Paoli). Both were active during early December, the former causing little damage, the latter causing severe foliage injury in some areas of the trial. This injury, however, was not permanent, affected areas being indistinguishable from the remainder of the trial by early January.

Detailed records of fruit form production and loss were not taken from this trial.

Harvest was carried out in four picks—February 22-March 3, March 3-8, March 19 and April 4-6. Yields are given in Table 14. Mean stand of plants per plot and total yields adjusted to an equal number of plants per plot are given in Table 15.

TABLE 13

TRIAL 5. YIELD (LB/AC) AND PLANTS PER PLOT

Treatment	Yield						No. of Plants per Plot		
	1st Pick			Total Pick					
	F0	F1	F2	F0	F1	F2	F0	F1	F2
D0	901	1,155	1,028	1,088	1,399	1,383	535	527	524
D1	1,157	1,143	1,286	1,341	1,788	1,802	523	529	519
D2	1,062	1,528	1,417	1,180	1,770	1,756	533	522	541
	Marginal	Individual		Marginal	Individual				
Necessary differences for significance 5%	200	347		224	388		No significance difference		
Necessary differences for significance 1%	276	478		309	535				

TABLE 14

TRIAL 6. YIELD (LB/AC)

Treatment	1st plus 2nd Pick			1st plus 2nd plus 3rd Pick			Total Yield (Four Picks)		
	F0	F1	F2	F0	F1	F2	F0	F1	F2
D0	1,880	2,059	1,813	2,405	2,758	2,652	2,603	3,035	2,981
D1	2,257	1,932	1,706	2,583	2,674	2,474	2,704	3,012	2,953
D2	1,624	2,108	1,329	2,235	2,870	2,398	2,543	3,179	3,126
	Marginal	Individual		Marginal	Individual		Marginal	Individual	
Necessary differences for significance 5%	337	584		365	632		385	667	
Necessary differences for significance 1%	465	805		503	871		531	919	

TABLE 15

TRIAL 6. MEAN STAND PER PLOT AND ADJUSTED YIELDS (LB/AC)

Treatment	Mean Stand			Adjusted Yield		
	F0	F1	F2	F0	F1	F2
D0	524	424	450	2,330	3,151	2,997
D1	562	398	416	2,283	3,229	3,101
D2	456	482	373	2,534	3,070	3,440

	Mean Stand: Marginal	Mean Stand: Individual	Adjusted Yield: Marginal	Adjusted Yield: Individual
Necessary differences for significance 5%	83	144	218	377
Necessary differences for significance 1%	115	199	301	522
			(approx.)	

IV. DISCUSSION AND CONCLUSIONS

Results of Trials 1 and 2 confirm the conclusions drawn from earlier work that Heliothis populations during the early square and boll formation period do not warrant insecticide control. The significant increase which followed the use of endrin in Trial 2 suggests that control of relatively small populations of leaf-eating insects, such as *Anomis flava,* is of value during the early and major square and boll production period.

Yield patterns were according to the usual pattern in Trial 3, while in Trial 4 any results from Heliothis control were masked by the severe attack of *P. scutigera.* In Trial 5, the black arm phase of angular leaf spot and *P. scutigera* exerted a much greater influence on yields than *H. armigera.* Pest incidence was so low in Trial 6 that yield differences due to insecticides could not be expected.

Trial 4 (rain-grown) indicates that fertilizer application in the absence of sufficient moisture is not worthwhile. On the other hand, the use of fertilizer with adequate irrigation, at the heavy applications made, gives economic returns (Trial 3) in the absence of complicating factors. Fertilizer response was minimized by black arm and *P. scutigera* damage in Trial 5, and in Trial 6 boll rots resulting from a severe storm causing lodging reduced yields by an estimated 500 lb per ac in the more heavily fertilized plots.

Applications of alpha naphthalene acetic acid to arrest the shedding of squares and small bolls in Trials 3 and 4 were not successful. Yields tended to be reduced where the hormone was applied, particularly in the rain-grown trial. This result indicates that if hormone applications are of value in cotton, timing is critically important. In India, on the other hand, Negi and Singh (1956) and Anon. (1958) obtained considerable yield increases following applications of alpha naphthalene acetic acid with similar timing and dosage.

The results of these trials indicate that Heliothis as an early-season pest is not of major importance in either rain-grown or irrigated cotton irrespective of the potential yield pattern. *P. scutigera* attacks, however, can reduce yields severely, and leaf-eating insects in relatively small populations are of economic concern in irrigated crops with high potential yields.

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