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EFFECTS OF BURIAL ON OVERWINTERING POPULATIONS OF PINK-SPOTTED BOLLWORM (PECTINOPHORA SCUTIGERA (HOLDAWAY))

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SUMMARY

Moth emergence from infested boll material held on the soil surface was continuous through winter and proceeded well into the following cotton season, indicating a source of infestation from ratoon and standover crops.

Moth emergence was stimulated by rainfall, peaks of emergence appearing 3-4 weeks after a fall of 0·50 in. or more over a temperature range of 50–80°F. The application of irrigation also stimulated moth emergence.

Burial of infested boll material hastened moth emergence but significantly reduced total emergence. Time of crop residue disposal in relation to planting time is important in efficient control of the pest. Burial in midwinter was most effective. Burial as late as the end of August resulted in negligible moth emergence after mid October, the normal planting time of the new crop, while burial in late September was ineffective in suppressing carry-over populations.

I. INTRODUCTION

The pink-spotted bollworm (*Pectinophora scutigera* (Holdaway)) has been a major pest of cotton in Central Queensland for many years (Passlow and Sabine 1963). Virtually the whole period of the destructive larval stage is spent within the cotton boll, which is entered while the larva is small and inconspicuous. Frequently, therefore, growers are unaware of the insect's presence in a crop until an infestation is well established and consequently difficult to control.

These factors were partly responsible for the build-up of *P. scutigera* in Central Queensland cotton-growing areas each season during the period 1958-1963. The situation was aggravated by winter carry-over of the species in volunteer plants and standover and ratoon crops. However, no experimental data on the efficacy and importance of measures in suppressing carry-over of *P. scutigera* in Queensland were available.

Accordingly, a methods study, trial 1, was initiated in July 1961 at Rockhampton as a preliminary investigation into the determination of effects of burial on winter carry-over of the *P. scutigera* larvae.

Following the success of this preliminary work, a replicated field trial was carried out at the Biloela Research Station, beginning in June 1962.

II. METHODS

(a) Trial 1: 1961–1962

Treatments.—The trial consisted of eight treatment plots. Each plot comprised a single cage, having a basal frame surmounted by a bronze gauze pyramid (Figure 1). The sides of the frame were 8 in. wide and 1 in. thick and were embedded in the ground to a depth of 4 in. to anchor the cages and prevent the escape of insects.

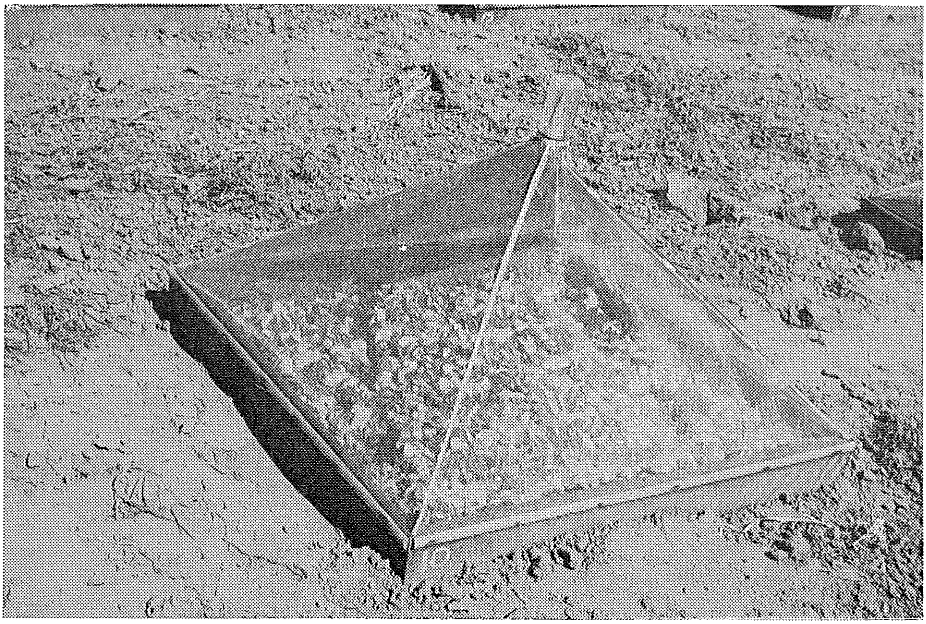

Fig. 1.—Emergence cage containing infested boll material on soil surface.

The apex of the pyramid was 18 in. above the wooden base and was fitted with an insect emergence trap consisting of a screw-top glass jar having an entry cone in the lid. Insects emerging from plant material in the cage normally made their way to the apex. Having entered the trap through the cone, they were unable to return. This enabled collection and recording of numbers and species of emerged insects.

Eleven pounds of dry cotton bolls from a heavily infested crop were introduced into each cage on July 7, 1961.

The treatments were as follows:

Cage 1: Boll material retained on the soil surface.

Cage 2: Boll material buried at a depth of 2 in.

Cage 3: Boll material buried at a depth of 4 in.

Cage 4: Boll material buried at a depth of 6 in.

Cage 5: Material treated as 1 plus irrigation.

Cage 6: Material treated as 2 plus irrigation.

Cage 7: Material treated as 3 plus irrigation.

Cage 8: Material treated as 4 plus irrigation.

The irrigation for cages 5, 6, 7 and 8 was applied on July 7 and August 15, and was the equivalent of 3 in. of rainfall.

Assessment of results.—The initial larval population of the bulk boll material used in the cages was determined from an examination carried out within a few days prior to commencement of the trial. Five hundred bolls were examined by dissection in random samples of 10 and the numbers of *P. scutigera* larvae recovered were recorded.

The effects of the different treatments on pink-spotted bollworm survival and carry-over were assessed in terms of the numbers of *P. scutigera* moths emerging from the plant material. Records of moths trapped were made once, twice or three times weekly, depending on the intensity of the emergence rate. Regular inspections of the cages were carried out until the termination of the trial on June 26, 1962.

In addition, the numbers of a braconid parasite of *P. scutigera* (*Apanteles* sp.) which emerged were recorded.

Climatological data.—Records of the daily mean temperature and daily rainfall compiled by the Meteorological Bureau, Rockhampton, covering the trial period are presented as a graph and histograms respectively in Figure 3.

(b) Trial 2: 1962–63

Treatments.—A second trial involving 24 single cage plots in a 6 x 4 randomized block layout was conducted over a period of 12 months at the Biloela Research Station (Figure 2).

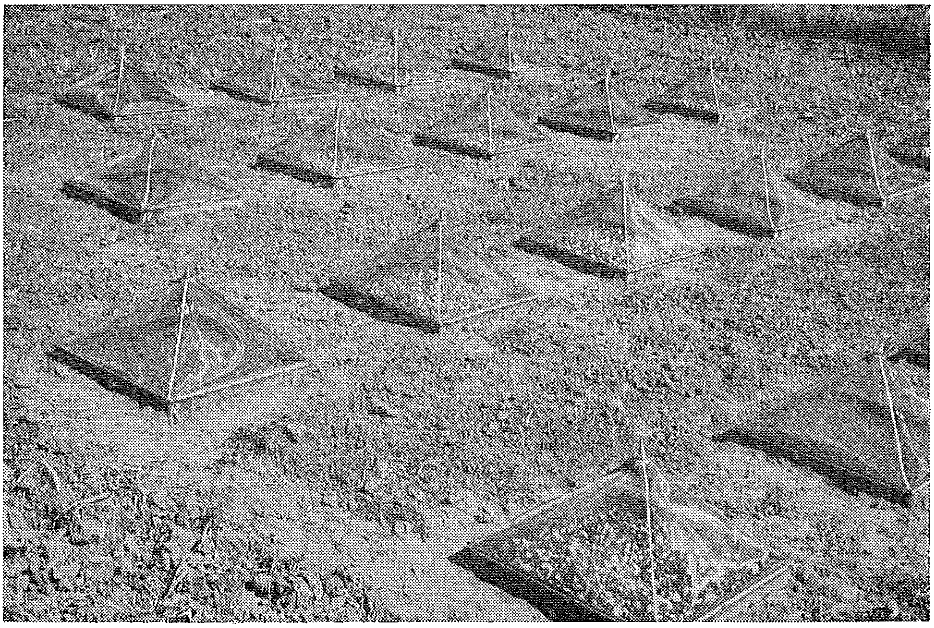

Fig. 2.—Emergence cages with some of the infested boll material buried.

A cage plot was similar to that used in trial 1. Drying cotton bolls were collected from a local heavily infested crop and bulked with thorough mixing. This bulk material was then divided into twenty-five 7 lb samples. Twenty-four of these were required for the cage material and the remaining sample was used for assessing the degree of infestation as representing untreated material.

The infested boll material was placed in the cages on June 4, 1962. A standard depth of 3 in. was used in all treatments where material was buried.

The treatments were as follows:—

1: Boll material retained on the soil surface for the duration of the trial.

2: Boll material buried on June 4, 1962.

3: Boll material on surface until burial on July 5, 1962.

4: Boll material on surface until burial on August 1, 1962.

5: Boll material on surface until burial on August 31, 1962.

6: Boll material on surface until burial on September 25, 1962.

Assessment of results.—The initial larval population representative of the bulk boll material was estimated from an examination of fourteen 8 oz samples.

As with trial 1, moth emergence was the criterion used in assessing the efficacy of the various burial treatments. The cage traps were inspected regularly at intervals not greater than 1 week. Living *P. scutigera* moths found amongst the boll material in each cage at the time of burial were also recorded. The trial was terminated on June 26, 1963.

Climatological data.—During the trial, daily mean temperature and rainfall were recorded at the Biloela Research Station weather recording site, which was situated adjacent to the trial area. Mean temperature is presented as a graph and rainfall as histograms in Figure 6.

III. RESULTS

(a) Trial 1: 1961-62

The pretreatment assessment data are presented in Table 1 as numbers of larvae recovered from sample units of 10 bolls with sub-totals per 100 bolls.

TABLE 1

TRIAL 1: PRETREATMENT ASSESSMENT

Number of *P. scutigera* Larvae per 10 bolls (50 samples)										Number of Larvae per 100 bolls
5	5	8	11	3	5	4	4	8	5	58
9	8	3	7	6	3	4	5	2	7	54
3	2	3	3	14	2	4	1	2	4	38
0	6	5	6	3	2	3	5	3	2	35
7	8	1	1	6	8	2	0	3	1	37

Total per 500 bolls	222
Weight of 500 bolls	4 lb 4 oz
Approximate number of bolls in 11 lb material per cage	1,295
Estimated number of larvae in boll material per cage on July 7	575

Post-treatment emergences of *P. scutigera* moths are presented in Table 2 as weekly recordings with totals for the trial duration. Additional data presented in Table 3 consist of emergence prior to mid October (field planting time) and following late November (appearance of squares), and estimated percentage survival.

Percentage effective survival of *P. scutigera* refers to the percentage of total moth emergence that took place after November 26 (estimated time of squaring) when the insect has a greater potential for infesting the crop. In the absence of suitable host plants, moths emerging prior to squaring of the cotton crop would be unlikely to establish a new generation. Such early emergence could be regarded as ineffective in a biologically adaptive sense.

TABLE 2

TRIAL 1: POST–TREATMENT ASSESSMENT
Numbers of moths emerging weekly per treatment

Week Ending	Treatment No.							
	1	2	3	4	5	6	7	8
July 9 ..	..	..	..	..	1	..	..	..
16 ..	45	..	..	..	4	1	..	..
23 ..	15	..	..	..	2	..	..	..
30 ..	8	..	..	..	..	..	..	..
August 6 ..	1	..	..	..	..	..	..	..
13 ..	10	3	..	1	..	..	..	..
20 ..	10	4	..	5	11	1	..	4
27 ..	5	5	..	..	39	1	..	..
September 3 ..	21	5	1	1	27	11	1	3
10 ..	..	8	..	4	42	20	..	5
17 ..	1	14	1	4	94	12	1	16
24 ..	9	17	8	8	83	7	1	5
October 1 ..	11	..	5	2	27	1	..	..
8 ..	6	..	1	..	24	..	..	..
15 ..	5	..	..	..	23	..	..	..
22 ..	6	..	..	..	18	..	..	..
29 ..	11	..	..	..	17	..	..	..
November 5 ..	56	..	..	..	41	..	..	..
12 ..	38	..	..	..	20	..	..	..
19 ..	18	..	..	..	7	..	..	..
26 ..	6	..	..	..	1	..	..	..
December 3 ..	37	..	..	..	37	..	..	..
10 ..	31	..	..	..	13	..	..	..
17 ..	21	..	..	..	7	..	..	..
24 ..	11	..	..	..	1	..	..	..
31 ..	4	..	..	..	..	..	..	..
January 7 ..	2	..	..	..	..	..	..	..
21 ..	15	..	..	..	..	..	..	..
28 ..	17	..	..	..	1	..	..	..
February 4 ..	3	..	..	..	..	..	..	..
Total emergence	423	56	16	25	540	54	3	33

TABLE 3

TRIAL 1: POST–TREATMENT ASSESSMENT
Moth emergence, percentage survival and effective survival

Observation	Treatment							
	1	2	3	4	5	6	7	8
Total emergence	423	56	16	25	540	54	3	33
Emergence to Oct. 15 ..	147	56	16	25	377	54	3	33
Emergence after Nov. 26 ..	141	—	—	—	59	—	—	—
Estimated percentage survival	73·5	9·7	2·7	4·3	93·9	9·3	0·5	5·9
Percentage effective survival (after Nov. 26)	33·3	—	—	—	10·9	—	—	—

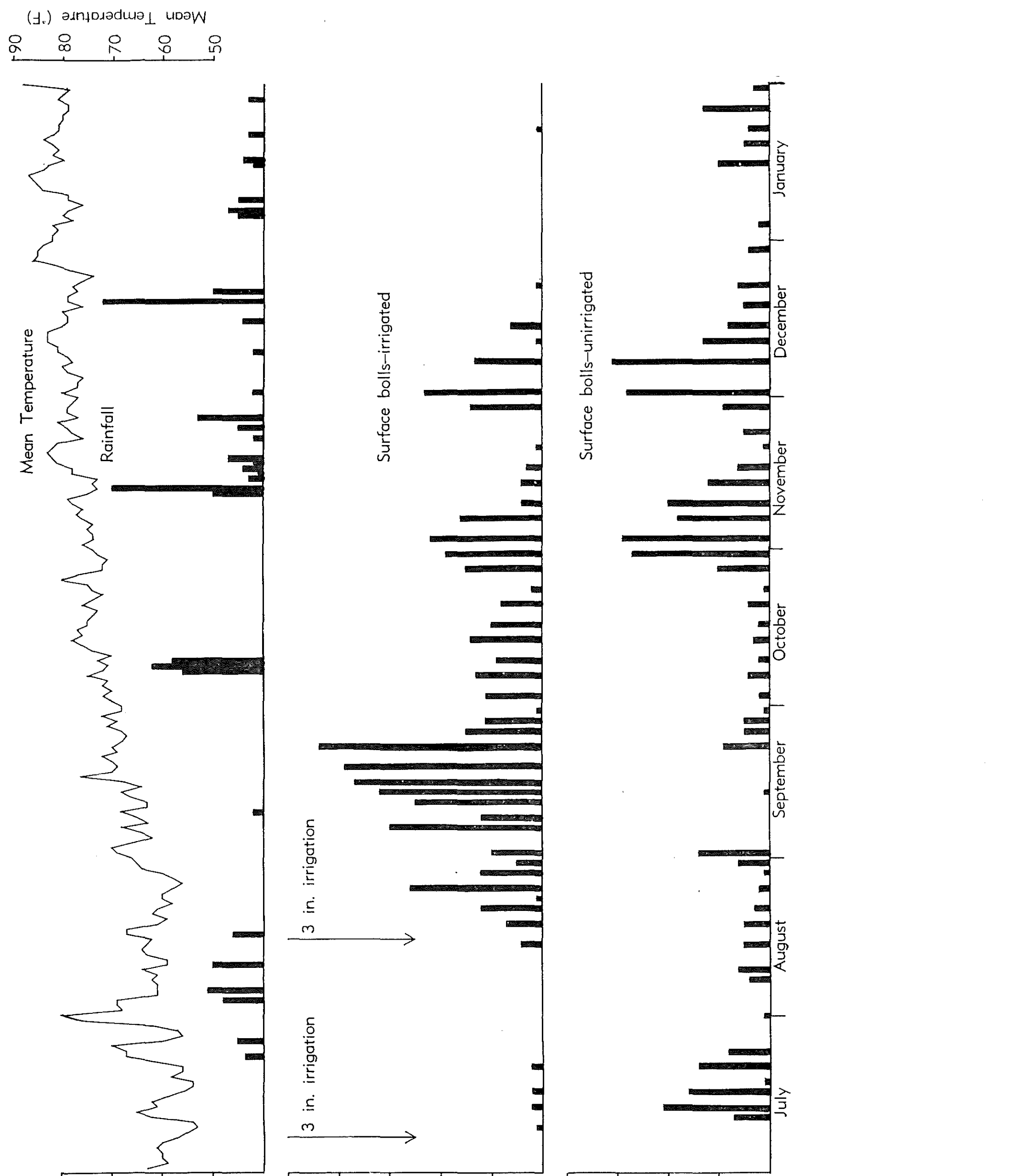

Fig. 3.—Trial 1, 1961-62. Moth emergence, rainfall and temperature data.

Emergence data for the braconid parasite *Apanteles* sp. in this trial are presented in Table 4 as weekly recordings with totals for the trial duration.

TABLE 4

TRIAL 1: WEEKLY EMERGENCE OF *Apanteles* SP. WASPS

Week Ending	Treatment							
	1	2	3	4	5	6	7	8
July 9 ..	1	..	..	..	1	..	..	..
16 ..	4	..	..	..	1	..	..	..
23 ..	2	..	..	..	2	..	..	..
30 ..	1	1	..	..	1	..	..	1
August 6 ..	..	..	..	..	1	..	..	..
13 ..	..	..	..	..	1	..	..	..
20 ..	..	4	..	..	1	..	..	..
27 ..	..	3	..	1	5	..	..	..
September 3 ..	..	2	..	..	3	..	..	..
10 ..	..	1	..	..	4	..	..	1
17 ..	..	2	..	..	2	..	..	..
24 ..	..	1	..	..	2	..	..	..
October 1 ..	..	..	..	..	2	..	..	..
8 ..	..	..	..	..	..	..	..	..
15 ..	..	..	..	..	1	..	..	..
Total emergence	8	14	..	1	27	..	..	2

The pattern of moth emergence throughout the trial period in relation to temperature and rainfall is shown in Figure 3.

(b) Trial 2: 1962-1963

The pretreatment assessment of larval numbers is presented in Table 5. Total moth emergence and post-burial emergence data are presented in Tables 6 and 7 respectively.

TABLE 5

TRIAL 2: PRETREATMENT ASSESSMENT

Number of *P. scutigera* Larvae per 8 oz sample (14 samples)							Total
12	18	27	14	18	16	16	224
18	14	15	13	13	14	16	

TABLE 6

TRIAL 2: POST-TREATMENT ASSESSMENT
Total emergence of *P. scutigera* moths

Treatments	Transformed Mean*	Equivalent Mean
1. All boll material retained on surface ..	9·7611	94·779
2. Burial of material on June 4	4·9004	23·514
3. Burial of material on July 5	3·8711	14·486
4. Burial of material on Aug. 1	4·6730	21·337
5. Burial of material on Aug. 31	6·5231	42·051
6. Burial of material on Sept. 25	10·2464	104·489
S.E.	0·62034	
Necessary differences for significance .. 5%	1·8699	
Necessary differences for significance .. 1%	2·5852	
	2,3,4,5 $\ll$ 6,1 3 $\ll$ 5	

* $\sqrt{x + \frac{1}{2}}$ transformation.

TABLE 7

TRIAL 2: POST-TREATMENT ASSESSMENT
Emergence of *P. scutigera* moths after burial

Treatment	Transformed Mean*	Equivalent Mean
2. Burial of material on June 4	4·9004	23·514
3. Burial of material on July 5	2·9178	8·014
4. Burial of material on Aug. 1	2·0307	3·624
5. Burial of material on Aug. 31	2·1280	4·028
6. Burial of material on Sept. 25	5·0065	24·565
S.E.	0·72888	
Necessary differences for significance .. 5%	2·2459	
Necessary differences for significance .. 1%	3·1487	
	4,5 < 2,6	

* $\sqrt{x + \frac{1}{2}}$ transformation.

Overwintering and time of emergence from overwintering of *P. scutigera* in relation to planting time of cotton are of fundamental importance with respect to infestation of the new crop. Under Central Queensland conditions, most cotton is planted in mid October and for the purposes of this investigation October 15 was selected as the average planting date. Moth emergences occurring after this date are presented in Table 8.

TABLE 8

TRIAL 2: POST–TREATMENT ASSESSMENT
Emergence of *P. scutigera* moths after October 15

Treatment	Transformed Mean*	Equivalent Mean
1. All boll material retained on surface ..	5·4271	28·953
2. Burial of material on June 4	0·7071	Nil
3. Burial of material on July 5	1·4489	1·599
4. Burial of material on Aug. 1	0·7071	Nil
5. Burial of material on Aug. 31	1·2792	1·136
6. Burial of material on Sept. 25	4·6376	21·007
S.E.	0·60632	
Necessary differences for significance .. 5%	1·8276	
Necessary differences for significance .. 1%	2·5268	
	2,3,4,5≪6,1	

* $\sqrt{x + \frac{1}{2}}$ transformation.

The pattern of moth emergence throughout the trial period in relation to time of burial, planting time, squaring time, temperature and rainfall is shown graphically in Figures 4 and 5 and as histograms in Figure 6.

IV. DISCUSSION

Trial 1 was initiated primarily to investigate the feasibility of using emergence cages in studies on overwintering of *P. scutigera.* Trial 2 arose out of this preliminary investigation owing to the need to obtain statistical confirmation of the results derived from the earlier work. In trial 2, the emphasis was placed on time of burial as it was considered that this could be an important factor in a pest control programme.

In both trials the continuous emergence of moths from surface material progressed well into summer—to early February in trial 1 and into March in trial 2. This clearly demonstrated that overwintering of *P. scutigera* in dried cotton bolls does occur. The uninterrupted emergence also proved that, unlike the related species *P. gossypiella* (Saunders) in America, *P. scutigera* does not enter a diapause or other form of quiescence. While development may proceed at a slow rate during winter, there is no definite break in the life cycle. These facts show that given suitable sites for development the insect would

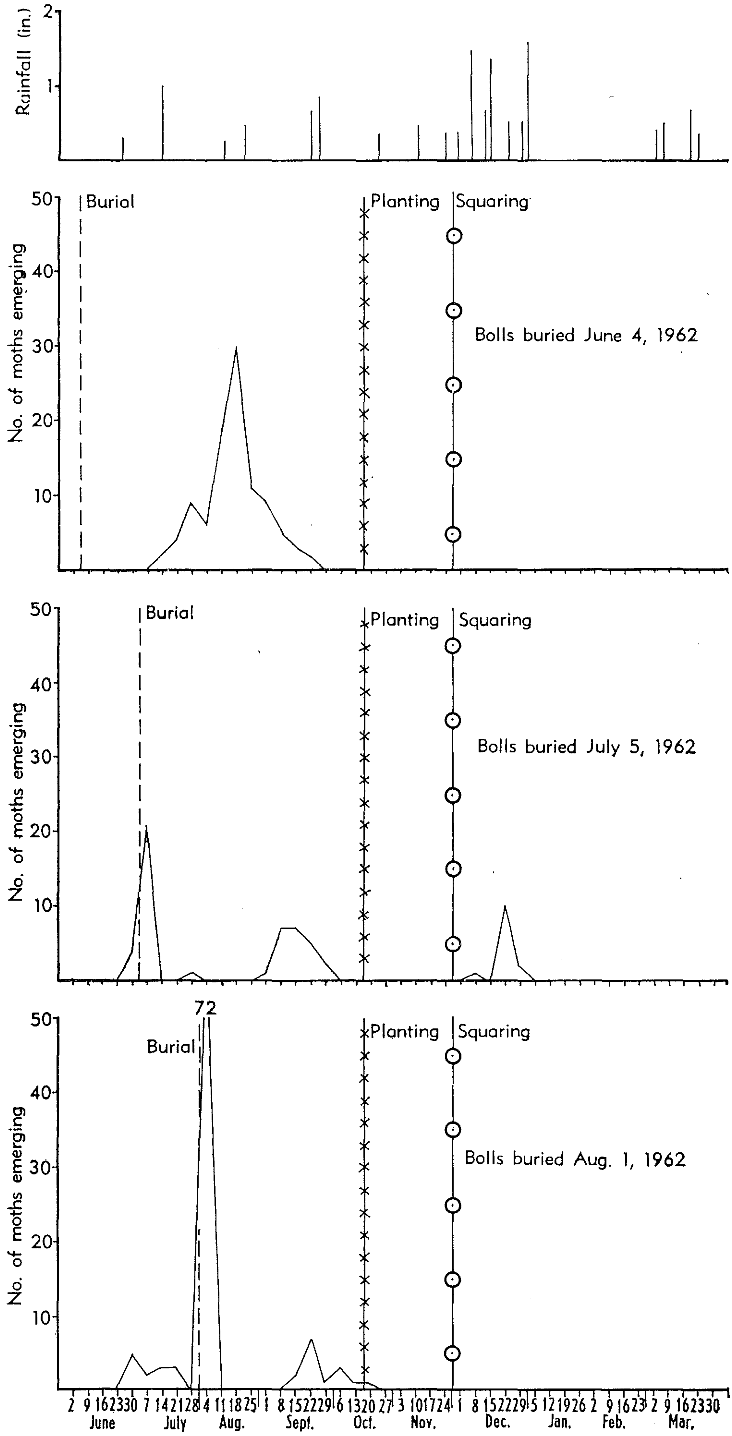

Fig. 4.—Trial 2, 1962-63. Weekly totals of emerging moths.

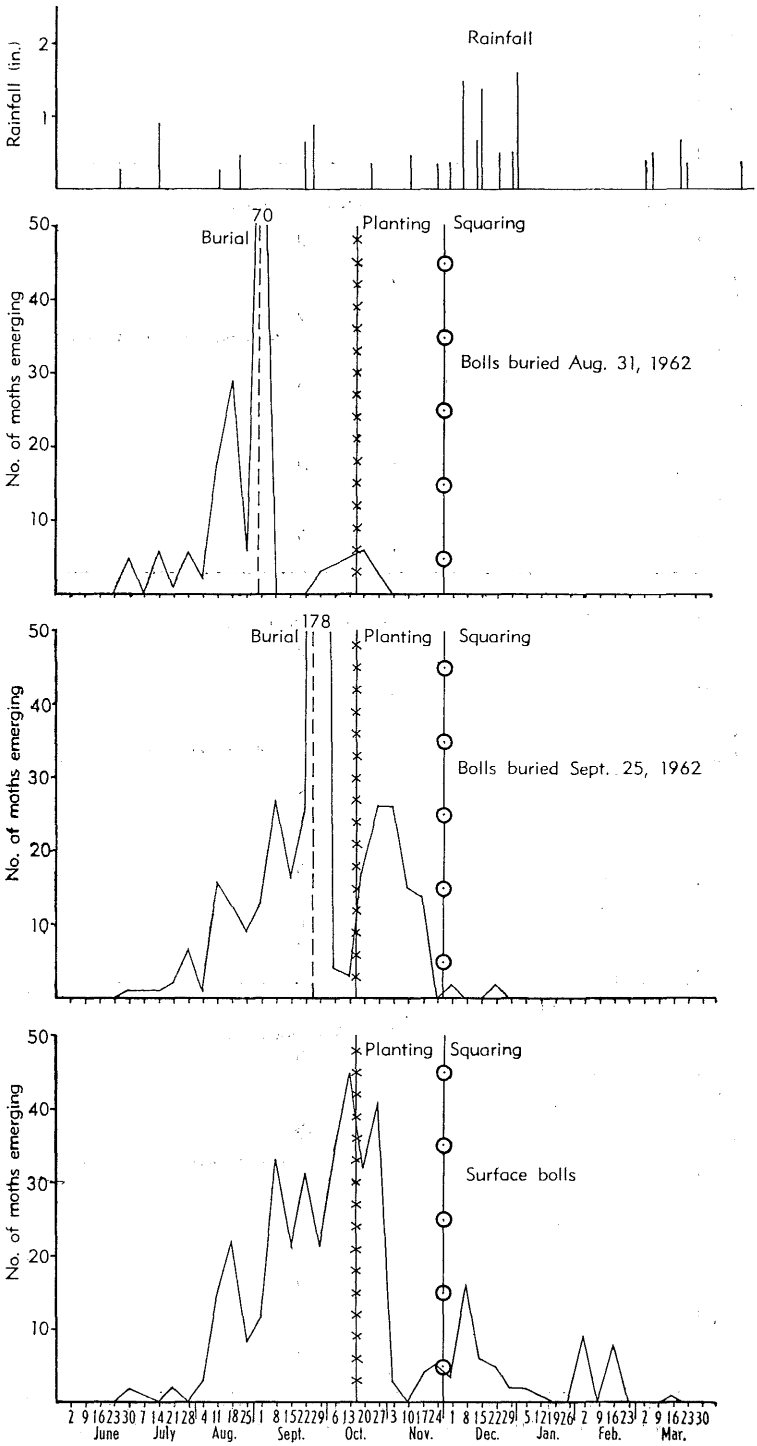

Fig. 5.—Trial 2, 1962-63. Weekly totals of emerging moths.

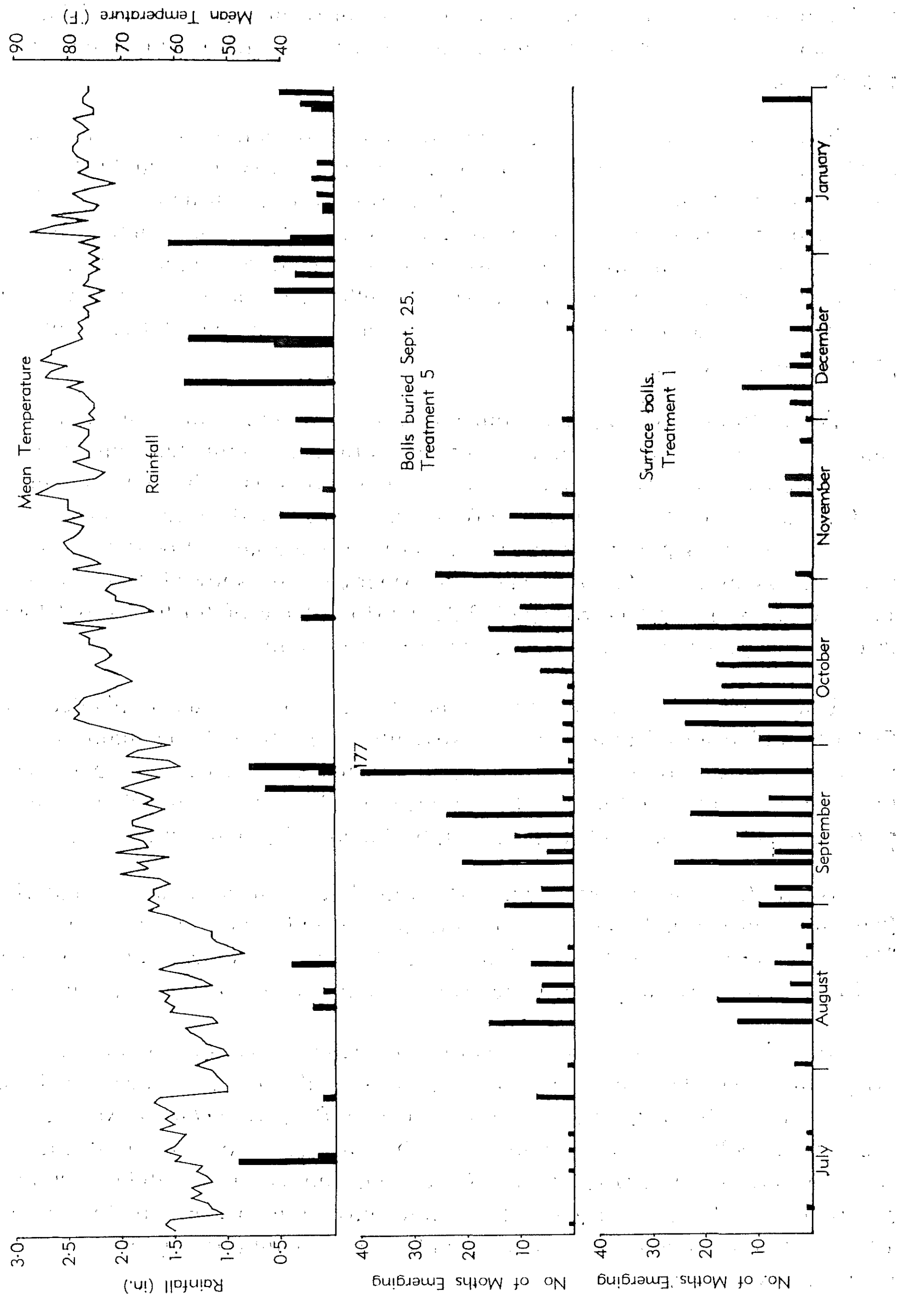

Fig. 6.—Trial 2, 1962-63. Moth emergence, rainfall and temperature data.

continue to breed throughout the year, thus providing a nucleus of infestation. The dangers to the new season's crop inherent in ratoon and standover crops are obvious.

The percentages of survival and the periods of emergence for the individual treatments in trial 1 (Table 3) indicated that carry-over could be checked by burial of infested crop residues. This was well confirmed in trial 2, where moth emergences from all burial treatments except the September burial were significantly less than those from surface bolls. In the preliminary trial, variations in burial depth to 6 in. did not appear to influence emergence greatly, although the percentage survival was slightly higher in the 2 in. burial treatment than at greater burial depths.

Apart from reducing the numbers of *P. scutigera* completing development, burial, except in the earliest treatment (June), stimulated emergence. A comparison of the graphs in Figures 4 and 5 shows that the bulk of emergence in the early burial treatments took place earlier and over a shorter period than that from September-buried and surface material. Investigations on the winter carry-over of *P. gossypiella* in America also showed this phenomenon (Fife, Cowan Jr., and Davis 1957; Fife 1961). Time of trash disposal therefore is of considerable importance in a control programme.

Under Central Queensland conditions, cotton is usually planted in mid October and begins fruiting in late November. In trial 2 the major portion of moth emergence from earlier burial treatments had ceased by planting date, October 15, and therefore in the absence of alternative host plants emergence prior to this date must fail to effect establishment of a new generation.

By contrast, moth emergences after this date from both surface material and September-buried bolls were significantly greater and persisted for a longer period. Therefore, crop disposal operations in cotton fields carried out later than the end of August obviously are ineffective in suppressing carry-over populations.

In trial 2, greatest total moth emergence was shown in treatment 6 (September burial), where boll material was held on the surface for 4 months before burial. This has also been shown with *P. gossypiella* in America, where the longer boll material remained on the surface prior to burial the greater was the percentage survival (Fife, Robertson, and Graham 1963). Other treatments in trial 2 indicated a trend in conformity with this, except for the earliest (June) burial treatment, where cloddy soil conditions might have been a contributory factor.

Furthermore, moth emergences after burial were greatest in the latest (September) burial treatment, and while the earliest (June) burial treatment gave comparable figures the intermediate treatments were far significantly lower. This shows that burial of crop residues in midwinter achieves greatest mortality of the insects.

Despite the post-burial emergence data favouring the early and late August treatments, for least moth emergence, early disposal of crop residues is still preferred. It is obvious from Figures 4 and 5 that as burial is delayed the safety margin between cessation of emergence and time of fruiting in a new cotton crop is correspondingly reduced.

In trial 1, specimens of a braconid wasp (*Apanteles* sp.), presumably a parasite of *P. scutigera,* were recovered from the emergence traps. Again, time of emergence is the important feature if the parasite is to act as a controlling influence against the pest. No parasites were recorded after October 9. Any *P. scutigera* emergences prior to this date would not survive in the absence of suitable host plant material and effective new populations of this insect would not develop until late November after cotton fruiting. If early parasite emergence occurs in the field, it could be inferred from the lack of co-ordination between parasite emergence and host activity that this species of braconid wasp would exert little influence on *P. scutigera* populations infesting cotton crops.

In trial 2, no parasites emerged although the boll material had been selected from a crop heavily infested with *P. scutigera* and grown in the absence of insecticide sprays. The apparent difference in parasite activity between seasons indicates a lack of reliance for effective control of *P. scutigera* by this parasite.

The sequence of *P. scutigera* emergence shown in Figures 3 and 6 reveals a relationship with rainfall. A similar pattern has been shown with *P. gossypiella* in America (Fife, Schiller, and Chapman 1947; Fife 1961).

In trial 1 (Figure 3), peaks of emergence in general occurred 3-4 weeks after a fall of approximately 0·50 in. or more of rain. In this respect temperature did not appear to influence the rate of emergence greatly. The interval between rainfall and emergence peak was approximately the same over a temperature range of 55-70°F as it was over a range of 70-85°F.

In trial 2, the interval between rainfall and emergence peaks at the lower temperatures (50-60°F, 55-70°F) was similar to that in trial 1. However, the response was more variable at a higher temperature range (70-80°F). This is in contrast to results with *P. gossypiella* in America (Fife 1961).

Of the two irrigations applied in trial 1, only the August irrigation appeared to exert any particular direct influence on moth emergence. In considering the irrigation applied on July 7, 49 days elapsed from this date to the appearance of the first emergence peaks, which correlate better with rainfall in the first two weeks of August.

A number of prominent emergence peaks occurred in treatment 5 during September (Figure 3). As no further rain had fallen since early August, and as there were no comparable peaks for the corresponding unirrigated treatment, these September emergences must constitute a response to the August 15 irrigation. These emergence peaks were some of the highest recorded in the trial and extended over 16 days, the first occurring 22 days after the irrigation.

Furthermore, this response to the August irrigation provides an explanation for approximately 70% of the total emergence in treatment 5 having taken place by October 15 whereas only 35% of the total emergence in treatment 1 had occurred by this date. This resulted in a percentage estimated effective survival (as defined earlier) of 10·9% in irrigated surface material and 33·3% in unirrigated surface bolls (Table 3).

These patterns of moth emergence, although at times slightly variable, suggest that adequate rain or irrigation in winter could result in a reduced complement of moths emerging during the critical period of the growing season.

These trials have demonstrated that *P. scutigera* can survive winter conditions in cotton crop residues with significant moth emergence at a time suitable to ensure damaging infestations in the new season's crops. For sound farm management in Central Queensland districts, cotton-growers must avoid ratoon and standover cotton crops. Crop residues must be destroyed by thorough ploughing under in midwinter and certainly not later than August.

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