Investigations on *Phthorimaea operculella* management in tomatoes at Bundaberg

Final Report on projects funded by the Bundaberg and District Fruit and Vegetable Growers' Association and the Horticultural Research and Development Corporation, 1990/91 and 1991/92.

Projects V/0023/RO and V/0133/RO

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Summary

A range of experiments and activities were done during 1990-1992 to investigate improved management of *Phthorimaea operculella* on tomatoes at Bundaberg.

Two season-long insecticide screening trials showed that none of the following insecticides (g a.i. ha^{-1}) controlled heavy infestations of *P. operculella*: azinphos ethyl (440); *Bacillus thuringiensis* as "Dipel" (500); methamidophos (377, 1102); methomyl (450); monocrotophos (600, 1000); sulprofos (720); thiodicarb (375, 525). However sulprofos and thiodicarb were most effective in controlling *Helicoverpa* spp.. Methomyl had the greatest ovicidal effect against *Helicoverpa* spp. eggs, while monocrotophos, thiodicarb and sulprofos prevented over 80% of eggs from hatching.

Resistance tests on a population of *Tetranychus urticae* showed they were susceptible to propargite and to fenbutatin-oxide, resistant to dicofol, and highly resistant to monocrotophos.

A small exploratory trial indicated that tomato plant spacings from 0.25 - 1.0m had no effect on insecticidal control of *P. operculella*.

Comparisons of four pheromone trap designs showed that the order of efficacy of trapping *P. operculella* moths was: triangular sticky trap > horizontal water trap > water pan trap > commercial funnel trap. Horizontal water traps caught significantly more moths than did vertical water traps. The height of pheromone traps relative to crop height affected the efficacy of trap catches. In young, low crops trap height had no effect, but in mid-height and fully grown crops traps above the crop caught more moths than did lower placed traps.

The susceptibility of seven tomato varieties to *P. operculella* was compared in sprayed and unsprayed trials. Summertaste had a lower percentage of fruit damaged than the other varieties apart from Solarset in the sprayed trial, and apart from Solarset and Mountain Pride in the unsprayed trial. The other varieties were Tornado, Kestrel, Floradade and FDA3. Several plant characters were measured.

Background to the Project

Phthorimaea operculella (Zeller) (Lepidoptera: Gelechiidae), the potato moth or leafminer, has become an important pest of fresh market tomatoes in the Bundaberg district of Queensland. By 1990 the insect was causing large losses in tomato crops despite the use by growers of frequent applications of insecticides in an attempt to control it. Secondary pest problems, particularly with *Tetranychus urticae* Koch (Acarina: Tetranychidae), twospotted mite, have developed.

The fresh market tomato industry at Bundaberg is valuable. In 1989 tomatoes with an estimated gross value of $79 million were grown on approximately 1570 ha. (Figures compiled by J.L. Lovatt, QDPI). Tomatoes are produced all through the year, with peaks of production in autumn and early summer. The district supplies the Australian markets at times when other areas are unable to produce, and an export trade to New Zealand has been established. Growers are innovative, they have large investments in machinery, grading and packing equipment, and they employ a large labour force.

The fresh fruit tomato market demands high quality, blemish free fruit, and export markets have particularly high standards. Hence it is essential that growers can effectively manage and control the insect and mite pests that attack the fruit. New Zealand quarantine authorities consider *P. operculella* a quarantine pest so effective control of the insect is essential to allow export of the fruit.

Given the high value of the tomato industry, the high levels of damage and loss caused by *P. operculella*, and the difficulties in controlling the insect being experienced by growers it was obvious that research work aimed at understanding and managing the pest was required. Accordingly, the two 1 year projects reported here were undertaken. (The two projects are considered here as a single project).

Crop Tech Laboratories Pty Ltd in 1989 started a three year project aimed at introducing and developing integrated pest management control systems for fruit and vegetables in the Bundaberg district, a project wide ranging in its scope. The projects reported here were designed to complement the Crop Tech Laboratories work, and to provide specific answers to questions about *P. operculella* and related tomato problems.

Objectives of the Project

General

The principal aim of the project is to improve pest management practices for *Phthorimaea operculella* on tomatoes in the Bundaberg region.

Specific objectives

a) To assess the effectiveness of a range of insecticides in controlling *P. operculella*.

b) To assess the impact of insecticides used to control *P. operculella* on other pests of tomatoes, with particular reference to *T. urticae* and *Helicoverpa* spp. (Lepidoptera: Noctuidae), heliothis.

c) To assess the effectiveness of pheromone trapping as a means of monitoring population levels of *P. operculella*.

d) To assess the potential of host plant resistance, and some cultural methods, in reducing infestation levels.

e) To investigate aspects of the biology and ecology of *P. operculella* in the Bundaberg area.

f) To publicise and extend research results to individual growers and to grower groups as pertinent ones arise.

Introduction

P. operculella larvae damage tomatoes by mining the stems of young plants, by mining in the leaves, and most importantly by tunnelling into fruit. Rothschild (1986) reviewed the general biology, ecology and control of the insect. It is interesting to note his comment that "It is a minor pest of other crops such as tomato and eggplant although damage may be severe locally".

Insecticides are commonly used to control *P. operculella*. Smith (1978) reported that methomyl and methamidophos at seven day intervals were effective, while Hargreaves and Cooper (1979) showed that sulprofos was effective. J. Hargreaves (pers. comm.) conducted several insecticide trials at Bundaberg from 1988 to 1990, and found that sulprofos applied every four days was the most effective of the insecticides he tested, although considerable fruit loss still occurred. Hargreaves' trials did not include a few insecticides that often are used on tomatoes (e.g. thiodicarb) so the trials described in this report were done to test those insecticides and to re-test several others.

Tomatoes also are attacked by other insect and mite pests. Important among these are two species of *Helicoverpa, H. armigera* (Hübner) and *H. punctigera* (Wallengren), commonly called heliothis, and *T. urticae*, twospotted mite. *Helicoverpa* spp. control was also assessed in the insecticide trials, as it is useful to know if the one insecticide will control both pests. *T. urticae* often is a secondary pest, and it can be difficult to control because populations can develop resistance to miticides. The resistance statues of *T. urticae* populations from Bundaberg was not known, so this was investigated as part of the project.

Spray application is always important in achieving control with insecticides, and a possible reason for poor control of *P. operculella* may be poor spray penetration of the dense trellised crop. A small trial was done to test if different plant spacings (and hence crop densities) affected spray penetration, and so the level of control.

Male *P. operculella* moths are attracted by female-produced pheromones. This attraction has been widely used for monitoring populations of the moth (e.g. Shelton and Wyman 1979), and the use of pheromone traps to monitor field populations of the pest has been promoted in the Bundaberg district. The design of pheromone traps is an important factor in their efficiency in catching moths. Even small variations in trap design can have a large effect on moth catch (Kennedy 1975). Trials were conducted to test the relative trapping efficiency of several trap designs, and to test whether the position of the traps relative to crop height was important in trapping *P. operculella* moths.

Anecdotal reports abound of tomato varieties differing in the amount of *P. operculella* damage they suffer. If proved, such varietal differences could be useful in managing the *P. operculella* problem, and if the plant characteristics that produce the differences could be identified then those characters could be selected for in other varieties. A trial with seven varieties was done to test some of the reports, and a number of plant characters were measured to see if they were important. (Related work using primitive *Lycopersicon* spp. accessions is being done as part of the QFVG/HRDC funded Queensland Fresh Market Tomato Breeding Project).

Research Methodology

a) Insecticide trials

Two insecticide screening trials (Trials 1 and 2) were done at Bundaberg in 1990 and 1991 respectively to investigate control of both *P. operculella* and *Helicoverpa* spp. The tomatoes were trellised to approximately 1 metre. Both trials were randomised block designs, Trial 1 with three replicates and Trial 2 with four, with plots of 3 rows by 5m. Table 1 gives treatment details. In Trial 1 applications were made either weekly (7 d separation) or three times a fortnight (4-5 d) while in Trial 2 they were made twice a week (3-4 d) except for one which was applied weekly (7 d). Insecticides were applied in 1000 L water per sprayed plant ha using a motorised knapsack sprayer fitted with hollow cone nozzles operated at 665 kPa. Both trials were sprayed regularly with mancozeb and dicofol for disease and tomato russet mite *(Aculops lycopersici* (Massee)) control. Fruit were harvested from nine plants in the central row of each plot on a number of occasions, weighed, inspected for insect damage and counted. *Helicoverpa* eggs were collected in Trial 2 and reared to moths for identification.

For each trial the data from the harvests were combined for analysis of variance.

The effect of insecticides on *Helicoverpa* eggs was investigated during Trial 2. Treatments were applied one morning and that afternoon 20 eggs per plot were collected using the leaf punch and holding card method of Hoffman *et al.* (1970). They were held at 25°C to determine the percentage that hatched (i.e. the larva completely emerged from the egg). The few infertile and parasitised eggs were omitted from the data which were analysed by analysis of variance.

b) *T. urticae* resistance testing

T. urticae adults and nymphs collected from a commercial tomato crop in May 1991 were sent to the Biological and Chemical Research Institute at Rydalmere, N.S.W., for resistance testing. B.C.R.I. were conducting a mite resistance monitoring program, and included the colony in the testing program (for a fee).

A standardised testing procedure, based on that of Edge and James (1982), was used. Three batches of 25 individual mites were sprayed at each miticide concentration, with two replicates, and a water-only control was used. The concentrations used were a discriminating dose (i.e. a dose that kills 100% of susceptible individuals) and multiples of the discriminating dose. All results were corrected for control mortality (Abbott 1925).

c) Plant spacing

A simple preliminary experiment was done to test the effect of plant spacing on insecticidal control of *P. operculella* and *Helicoverpa* spp..

Tomato plants (var. Floradade) were planted in 5m plots in the guard rows of a variety trial at spacings of 0.25, 0.5, 0.75 and 1.0 m between each plant. There were two replicates with treatments randomised in each. Plants were trellised and were grown under standard agronomic conditions. The plants were sprayed three times a fortnight with sulprofos (72 g a.i./100L water) using a tractor mounted boom fitted with droppers each with three hollow cone nozzles. Fruit were harvested in six picks, weighed, examined for insect damage, and counted. Data were bulked before analysis of variance.

d) Pheromone trapping

i) Trap design. The efficacy of four trap designs in catching *P. operculella* males was evaluated in a series of trials. The traps used were:

- a horizontal water trap, made from a 200mm length of 90mm PVC stormwater pipe, with the bottom half of each end blocked. The reservoir so formed was filled with water plus detergent, with the lure suspended above the water midway along the pipe;
- a sticky trap, triangular in cross-section with a base 165 x 100mm covered in a sticky substance ("Tack Trap"), and with the lure suspended in the middle of the trap;
- a commercial funnel trap obtained from Biological Control Systems;
- a water pan trap, similar to that described by Bacon *et al.* (1976), which

consisted of a plastic dish (175 x 175mm) fitted with a two sided metal hood. The dish was filled with water plus detergent, and the lure was suspended under the middle of the hood.

The first three traps were suspended on posts just above the plants while the water pan trap was placed on the ground.

Four traps of each design were used. The traps were placed in a tomato field in a latin square design, with at least 20m between traps. The traps were cleared and the moths counted every two days, and the traps were then moved so that each trap type was used at each position in the field. Analysis of variance was done on the data. The trials were repeated three times.

ii) Horizontal versus vertical water traps. After the design trials had been completed, a trap of a new design was introduced and used in the district. Here called the vertical trap, it consists of two parts. The top section is a 150mm length of 500 x 100mm PVC downpipe, with a circular hole cut in the centre of the bottom side. The vertical reservoir is a 220mm length of 90mm PVC stormwater pipe with the bottom end covered by an end cap. The top fits into the hole in the top section and is held in place with a wire pin. The reservoir is filled with water and detergent and the lure is suspended above it.

This experiment was done to compare the trapping efficiency of the vertical trap with that of the horizontal water trap.

Ten positions were marked within a 2ha (approx) block of tomatoes. There were three positions along two rows and four positions along a third. The positions along a row were separated by at least 40m, and between row by a minimum of 20m.

Five traps of each design were used. The 10 traps were allocated at random to the field positions and attached to trellis posts. The trap open ends were aligned along the row. At the end of the trapping period the moths were sieved from each trap, placed in alcohol, and counted in the laboratory. The traps were re-randomised for the next trapping period, and this was done five times. Periods 1 and 4 ran for three nights and periods 2, 3 and 5 ran for two nights.

A t-test was done on the mean trap catches for each period to test for significant differences between catches in the two trap types.

iii) Height of pheromone traps. Trials to test if the height of the pheromone trap relative to the height of the tomato crop is important were done in crops with plants approximately 0.3, 0.6 and 1.0m high. Horizontal water traps were used. In each trial, four traps were placed at each of 0.3, 0.6, 0.9 and 1.2 m heights above the ground in a latin square design, with at least 18m between traps. The traps were cleared and the moths counted every two days, at which time the traps were moved so that each trap height was used at each position in the field. The data were analysed using analysis of variance. The trials were repeated three times at each crop height.

e) Varietal trial

This trial tested seven varieties to try to confirm reports of differing susceptibility to *P. operculella*.

The varieties tested were Floradade, Kestrel, Summertaste, Tornado, Solarset, Mountain Pride and FDA 3. The varieties were grown in separate sprayed and unsprayed trials during the summer of 1991/92 when *P. operculella* populations were high. Each trial was a 7 x 4 replicated block design, with plot size of 1 row x 10m. The plants were trellised. The sprayed trial was sprayed regularly with sulprofos, and both were treated with fungicides and miticides. The unsprayed trial was treated with heliothis nuclear polyhedrosis virus. Fruit were harvested from 5m per plot, weighed, assessed for heliothis and potato moth damage and counted. The height of fruit was measured, and the size of the calyx scar was measured. Other plant characteristics were noted.

Detailed Results

a) Insecticide trials

Table 1 shows the yields (weight and number of fruit) and percentages of insect damaged fruit in Trials 1 and 2, and the percentage of *Helicoverpa* spp. eggs that hatched after an insecticide treatment in Trial 2. The *Helicoverpa* spp. population in Trial 2 was 94% *H. punctigera* and 6% *H. armigera*.

b) *T. urticae* resistance testing

The results of resistance testing of the *T. urticae* strain are shown in Table 2. The mites were susceptible to fenbutatin-oxide and to propargite. Dicofol resistance was common within the strain, with only 5% of mites killed at the discriminating dose. The mites were highly resistant to monocrotophos. Only 10% died when treated at 10 times the discriminating dose.

c) Plant spacing

Yield (weight and number of fruit) and the percentage of fruit damaged by *P. operculella* and by *Helicoverpa* spp. are given in Table 3. There were no significant differences between treatments for any of the parameters measured. Significant differences were not expected, given the few treatments and limited replication.

d) Pheromone trapping

i) Trap design

The catches of *P. operculella* moths in each trap type in the three trials are shown in Table 4. There were significant differences in the numbers of moths caught by the different traps, although the differences varied somewhat between trials.

ii) Horizontal versus vertical water traps

The mean catches per trap, standard deviations, ranges, and t-values for the five trapping periods are given in Table 5. The horizontal traps caught significantly ($P<0.05$) more moths than the vertical traps in all trapping periods.

iii) Height of pheromone traps

Catches in traps placed at different heights are shown in Table 6 for tomato crops at three heights. In small crops (0.3m) trap height had no significant effect ($P>0.05$) on trap catch. In mid height crops (0.6m) there was a trend, in one trial significantly so, for traps higher than the crops to catch more moths than the lower traps. In tall crops (1.0m), traps above the crop tended to catch more moths than did lower traps.

e) Varietal trial

Yield data are shown in Table 7, and the percentages of fruit damaged by *Helicoverpa* spp. and by *P. operculella* are given in Table 8.

Heliothis control was good in the sprayed trial, and reasonable in the unsprayed trial. Kestrel had a significantly higher ($P<0.05$) percentage of heliothis damaged fruit than the other varieties in both the sprayed and unsprayed trials. There were no differences between the other varieties in the sprayed trial, but differences were recorded in the unsprayed trial.

There were significant differences in the percentage of *P. operculella* damaged fruit between varieties, although overall levels were high. Summertaste had less damage than the other varieties apart from Solarset in the sprayed trial, and apart from Solarset and Mountain Pride in the unsprayed trial.

Measurement of the proportion of fruit set in each 25cm increment above the ground showed no significant differences ($P>0.05$) between varieties, except at 75-100cm and >100cm where Summertaste had a higher proportion of fruit than the others - it is a tall plant and was the only one to carry fruit so high. There were no significant regressions between damage and fruit height in the sprayed trial. In the unsprayed trial, regressions of percent damage against percent fruit below or above 50cm were significant (P=0.04) with positive and negative slopes respectively. The varieties differed in fruit diameter and calyx scar diameter (Table 9). The parameter calyx % (calyx/fruit x 100) was calculated to account for fruit size differences, and the varieties differed in this. Solarset, Summerset, Tornado and Mountain Pride had smaller calyx scars than the other varieties. Regressions of sprayed and unsprayed damage against calyx % were not significant (P=0.17, 0.18 respectively).

Table 1 Mean percentage of heliothis and potato moth damaged fruit and mean fruit yield - Trials 1 and 2. Mean percentage hatch of heliothis eggs - Trial 2.

Treatment (gai ha^{-1}; days between application)	Percent heliothis damaged fruit*	Percent potato moth damaged fruit*	Yield		Percent hatched heliothis eggs
			Wt (kg)	Number	
Trial 1					
unsprayed check (-)	25.86 b+	28.72 a	14.48 a	96.0 a	
B. thuringiensis (500; 4-5)	34.94 a	26.04 a	36.63 b	223.7 b	
monocrotophos (600; 4-5)	14.34 c	38.43 a	48.71 c	272.3 bc	
thiodicarb (375; 4-5)	11.47 cd	31.68 a	59.37 de	336.3 de	
thiodicarb (375; 7)	9.86 cd	31.82 a	56.49 cd	322.0 d	
thiodicarb (525; 7)	7.59 d	31.05 a	58.31 de	306.3 cd	
sulprofos (720; 4-5)	6.92 d	25.68 a	58.55 de	329.3 de	
thiodicarb (525; 4-5)	6.18 d	29.20 a	65.29 a	373.3 e	
Trial 2					
unsprayed check (-)	76.79 a	23.71 c	10.70 a	126.2 a	99.66 a
methamidophos (377; 3-4)	46.17 b	35.16 b	44.40 b	377.5 b	88.20 b
azinphos ethyl (440; 3-4)	45.84 b	36.32 b	41.35 b	355.0 b	52.87 c
methamidophos (1102; 3-4)	22.42 c	32.29 b	58.20 c	491.5 cd	72.08 bc
sulprofos (720; 7)	22.02 c	36.45 b	59.80 c	468.5 c	-
methomyl (450; 3-4)	19.05 cd	37.30 b	69.52 d	509.7 cd	5.21 e
monocrotophos (1000; 3-4)	16.68 d	47.97 a	60.72 c	478.5 c	15.82 de
thiodicarb (525; 3-4)	10.46 e	38.39 b	71.90 d	540.5 d	15.86 de
sulprofos (720; 3-4)	4.77 f	33.06 b	73.50 d	545.2 d	19.11 d

* Equivalent means. Inverse sine transformation carried out before analysis.

\+ In each trial, in each column, numbers followed by the same letter are not significantly different at the 5% level.

Table 2. Mortality of *T. urticae* treated with miticides in the laboratory.

Miticide		Concentration sprayed % a.i.	% Corrected mortality
Active ingredient	**Trade name**		
fenbutin-oxide	Torque	0.002 *	100
propargite	Omite	0.01 *	100
dicofol	Dicofol	0.01 *	5
		0.05	56
		0.1	81
monocrotophos	Nuvacron	0.03 **	10
		0.1	53
		0.25	100

* discriminating dose
** 10 x discriminating dose

Table 3. Mean percentage of *P. operculella* and *Helicoverpa* spp. damaged fruit and mean fruit yield:- plant spacing trial.

Plant spacing (m).	Percent *P. operculella* damaged fruit	Percent *Helicoverpa* damaged fruit	Yield of fruit	
			Wt. (kg)	Number
0.25	70.91	4.16	39.25	365.5
0.5	79.09	2.78	42.4	342.0
0.75	80.23	4.70	38.2	316.0
1.0	79.73	5.00	34.5	280.5

* Equivalent means. Inverse sine transformation carried out before analysis.

Table 4. Mean number of *P. operculella* moths caught per pheromone trap per 8 days.

Trap design	Number of moths caught*		
	Trial 1	Trial 2	Trial 3
sticky	306.12 a+	505.31 b	137.02 a
horizontal	150.44 b	797.42 a	113.16 b
water pan	114.63 b	306.83 c	59.44 c
funnel	44.69 c	226.73 c	38.24 d

* Equivalent means. $\sqrt{x + 0.5}$ transformation carried out before analysis.

\+ In each column, numbers followed by the same letter are not significantly different at the 5% level.

Table 5. Number of *P. operculella* moths caught in horizontal and vertical pheromone traps in five trapping periods.

	Trapping period									
	1		**2**		**3**		**4**		**5**	
	Horiz	**Vert**	**Horiz**	**Vert**	**Horiz**	**Vert**	**Horiz**	**Vert**	**Horiz**	**Vert**
Mean moths/trap	494.2	90	63.6	19.2	14.4	1.8	87.2	9	25	2.4
Standard dev.	135.9	34.4	31.2	5.9	6.2	1.5	24.4	3.5	15.2	0.6
Range	306-657	50-142	32-109	12-25	7-23	0-4	52-121	3-12	8-47	2-3
t-value	6.449		3.127		4.400		7.079		3.319	
p<	0.001		0.05		0.01		0.001		0.02	

Table 6. Number of *P. operculella* moths caught in pheromone traps at 4 heights per 8 days at the 3 plant heights.

Trap height (m)	Number of moths caught*		
	Trial 1	Trial 2	Trial 3
Plants approx 0.3m high			
0.3	110.30 a+	63.57 a	335.42 a
0.6	135.20 a	82.52 a	329.22 a
0.9	138.92 a	66.73 a	420.97 a
1.2	134.98 a	56.82 a	382.53 a
Plants approx 0.6m high			
0.3	77.86 a	43.14 a	21.55 a
0.6	102.54 a	39.18 a	28.49 a
0.9	138.84 a	45.38 a	41.91 b
1.2	127.72 a	51.29 a	49.03 b
Plants approx 1.0m high			
0.3	152.64 a	151.67 a	82.96 a
0.6	127.98 a	183.44 a	166.58 b
0.9	204.36 a	227.82 ab	319.07 c
1.2	200.94 a	298.61 b	488.70 d

* Equivalent means. $\sqrt{x + 0.5}$ transformation carried out before analysis.

\+ For each plant height, in each column, numbers followed by the same letter are not significantly different at the 5% level.

Table 7. Yield of fruit in the sprayed and unsprayed variety trials.

Variety	Sprayed		Unsprayed	
	Wt (kg)	Number	Wt (kg)	Number
Summertaste	35.3 a*	242 a	24.3 a	173 ab
Tornado	33.6 a	224 ab	26.4 a	183 ab
FDA 3	31.8 a	210 b	28.8 a	195 ab
Solarset	31.7 a	206 b	23.1 ab	158 bc
Kestrel	30.8 ab	216 ab	27.0 a	204 a
Floradade	29.6 ab	230 ab	25.4 a	206 a
Mountain Pride	25.2 b	158 c	17.2 b	122 c

* In each column, numbers followed by the same letter are not significantly different at the 5% level.

Table 8. Percent *Helicoverpa* spp. and *P. operculella* moth damaged fruit in the sprayed and unsprayed variety trials.

Variety	% *Helicoverpa* damage		% *P. operculella* damage	
	Sprayed	Unsprayed	Sprayed	Unsprayed
Summertaste	1.5 a*	9.7 ab	52.0 a	37.6 a
Solarset	2.7 a	17.4 c	55.1 ab	45.3 abc
Kestrel	5.4 b	25.2 d	61.4 bc	53.6 d
Mountain Pride	1.4 a	7.8 a	62.7 c	42.1 ab
Floradade	2.2 a	15.8 c	64.5 c	46.2 bcd
Tornado	2.0 a	15.8 c	66.7 c	51.5 cd
FDA3	1.2 a	14.0 bc	75.1 d	46.5 bcd

* In each column, numbers followed by the same letter are not significantly different at the 5% level.

Table 9. Fruit and calyx diameter (mm), and calyx %.

Variety	Fruit	Calyx	Calyx %
Kestrel	68.2 d*	16.9 a	24.8 a
FDA3	68.6 d	16.2 ab	23.61 a
Floradade	69.7 bcd	16.3 ab	23.38 a
Mountain Pride	72.7 a	15.3 bc	20.97 b
Tornado	69.5 cd	14.5 c	20.86 b
Summertaste	71.1 abc	14.4 c	20.18 b
Solarset	71.9 ab	14.1 c	19.61 b

* In each column, numbers followed by the same letter are not significantly different at the 5% level.

Discussion of Results

a) Insecticide trials

The results of Trial 1 reinforce earlier evidence that sulprofos and thiodicarb are very effective against *Helicoverpa* spp. There were no significant differences ($P > 0.05$) between sulprofos, applied three times a fortnight, and thiodicarb at 375 and 525 gai ha^{-1} applied weekly or three times a fortnight. The bacterial insecticide *Bacillus thuringiensis* (as "Dipel") increased the yield of fruit compared to the unsprayed check, indicating that it exerted some *Helicoverpa* spp. control but many of the remaining fruit were damaged. It was not effective at the rate used. None of the treatments controlled *P. operculella*.

None of the insecticides controlled *P. operculella* in Trial 2. In fact the percentage of *P. operculella* damaged fruit was lower ($P < 0.05$) in the unsprayed check than in any of the insecticide treatments. This aberration probably was caused by the few fruit and large amount of *Helicoverpa* damage in the check. Monocrotophos treated plots had significantly ($P < 0.05$) more *P. operculella* damage than the other insecticide treatments. Smith (1978) reported that methamidophos and methomyl, at 7 d intervals, were effective against *P. operculella* while Hargreaves and Cooper (1979) showed that sulprofos was effective. J. Hargreaves (pers. comm) found sulprofos applied every 4 days was the most effective of the insecticides he tested. None of these insecticides were effective in these trials. The lack of control of *P. operculella* reflects the situation in commercial crops. A possible reason for the poor control is the difficulty of contacting the insect with insecticides as eggs are laid in protected positions and the larvae feed within the leaves and fruit. Insecticide resistance also is a possibility.

Helicoverpa spp. control in Trial 2 was as expected. Pressure was high as shown by the low yield and high percentage of damage in the unsprayed check. Sulprofos and thiodicarb applied twice a week were very effective, significantly better ($P < 0.05$) than sulprofos applied weekly. Azinphos ethyl and methamidophos at the low rate of 377 gai ha^{-1} gave poor control of *Helicoverpa*. Monocrotophos gave reasonable control of *Helicoverpa* spp. in all trials.

Few *Helicoverpa* spp. (mainly *H. punctigera*) eggs from plots treated with methomyl, thiodicarb, monocrotophos and sulprofos hatched. Azinphos ethyl had some effect, but methamidophos very little, on egg hatching. Many farmers add methomyl to other insecticides specifically because of its ovicidal properties. The results of this trial indicate that there is little benefit to be gained from adding methomyl to sulprofos, monocrotophos or thiodicarb, but it would be useful in a separate application between applications of other insecticides at times of high *Helicoverpa* activity.

In summary, effective insecticides are available to control *Helicoverpa* spp. while there still is a major dependence on chemical control. That it is not the case for *P. operculella* as a large proportion of fruit is damaged despite frequent insecticide applications. Clearly there is a need for alternative effective management measures.

b) *T. urticae* resistance testing

Resistance to miticides in *T. urticae* is complex, and the resistance situation may differ from one farm to another depending on the history of pesticide use. However it is likely that the resistance levels found in the test strain are common throughout the district. The results show that *T. urticae* from the Bundaberg district are resistant to two commonly used miticides, dicofol and monocrotophos. There are few alternative miticides available, and fenbutatin-oxide is not registered for use on tomatoes at present.

T. urticae is often a secondary pest, with outbreaks induced by high levels of insecticide use that destroys natural predators. The need to control *P. operculella* and *Helicoverpa* spp. in tomatoes means that insecticide use is high. As well, the predatory mite, *Phytoseiulus persimilis* Athias-Henriot, is susceptible to many of the insecticides used in tomatoes, which precludes its use within the crop.

c) Plant spacing

This small, exploratory trial was done to see if different plant spacings had obvious effects on insect damage. The hypothesis was that the more closely spaced the plants the foliage canopy of the trellised plants would be denser, resulting in less effective spray penetration and coverage and so poorer insect control. The results indicate no trends in insect control related to plant spacing. *Helicoverpa* spp. control was good in all treatments, and levels of *P. operculella* damage were very high in all treatments. It may be the case that the insecticide used (sulprofos) was not effective against *P. operculella*, although it has been the most effective in recent trials (J. Hargreaves, pers. comm.). The only obvious trend was towards more fruit as plant spacing decreased. Changing plant spacing would have many agronomic implications which would need to be investigated.

It is not proposed to pursue research on the effect of plant spacing on *P. operculella* control at present, given the lack of any obvious effect in this trial. However if agronomic work on plant spacing is needed then it would be worth gathering data on insect control.

d) Pheromone trapping

The triangular sticky trap was the most efficient in catching *P. operculella* male moths of the four traps tested in Trials 1 and 2, followed by the horizontal trap, the water pan trap and the funnel trap. In Trial 2, moth numbers were very high and the sticky bases of the sticky traps became covered with moths and their scales so reducing their catching efficiency. Under these conditions the horizontal traps caught more moths. The water pan traps, which are commonly used to monitor *P. operculella* elsewhere (e.g. Horne 1990; Raman 1988), caught fewer moths than did the sticky or horizontal traps. However, the results of the height experiments showed that, in tall crops, traps above the canopy caught significantly more moths than low traps. The water pan traps sit on the ground, and so their intrinsic design means they will be less efficient in tall tomato crops. The commercial funnel traps were not efficient in trapping moths.

The horizontal traps had been widely used in the Bundaberg district. However, in hot weather the water in the trap reservoir can dry up quite rapidly, making them ineffective. The vertical traps, with a deeper reservoir, were introduced to overcome this problem, but they are much less efficient in catching moths (Table 5).

These experiments clearly show the importance of trap design in trapping efficacy. This has important implications in the interpretation of trapping figures.

The results of the trials on trap height indicate that traps should be placed above the canopy to be most efficient in catching moths. While it may be best to move traps upwards as the crop grows, this often is not practical. The results (Table 6) show that trap height is not critical in small plants, but that it can be in mid height and tall crops where the higher traps caught more moths. Hence, in practice it would be best to place traps at the top of trellis posts.

A further aspect of pheromone trap monitoring that needs evaluation is whether the attractiveness of the lures remains constant as they age or whether it deteriorates with time. Lures are being aged at present so that experiments can be done to answer this question.

e) Varietal trial

The varietal trial results indicate that varieties do differ in their susceptibility to *P. operculella*. Anecdotal reports claimed that Summertaste, Mountain Pride and Tornado suffered little damage from *P. operculella*, while Kestrel was badly damaged. The results from these trials offer some support to the claim that Summertaste is less susceptible, and data from the unsprayed trial supports the claim for Mountain Pride. However Tornado was badly damaged in both trials, as was Kestrel.

There were no clear relationships between any of the plant characteristics measured and *P. operculella* damage. However, in the unsprayed trial the regressions of percent damaged fruit against the percentage of total fruit below or above 50cm were significant, indicating that the higher the fruit is set then the less damage occurs. It is a common observation that lower leaves are more heavily mined than higher leaves, and it appears that *P. operculella* prefers to remain close to the ground. Again, it is often claimed that varieties with a small calyx scar have less *P. operculella* damage than those with a large scar. Regressions to test this were not significant, but there was a trend towards less damage with a smaller calyx scar.

Although agronomic considerations are most likely to influence a farmer's decision on which variety to grow, the susceptibility or resistance of the variety should be of importance. Even low levels of resistance may be useful. If the plant characters that confer resistance are identified than varieties that possess the characters can be chosen.

This trial will be repeated, to confirm the results and to try to further identify useful plant characters.

Extension Activities

A range of formal and informal extension activities have been undertaken as part of the project. These have included:

1. Pest and beneficial insects associated with tomatoes were displayed at Bundaberg AgroTrend, May 1991.

2. A talk on biological control of *P. operculella* was given at an IPM Seminar at Bundaberg, April 1991.

3. An article, "Pesticide resistance in twospotted mites", was written for Bundaberg Region Horticultural Magazine **8**, 9 (December 1991).

4. Articles titled "Screening insecticides for heliothis and potato moth", "Miticide resistance in twospotted mites", and "Pheromone traps to catch leafminer moths" were written for Bundaberg Research Station Research and Development 1990-1992 Magazine.

5. A talk on the project's results was given to the Tomato IPM Seminar at Bowen (March 1993).

6. Reports on progress have been made to meetings of the QDPI/Industry Coastal Burnett Horticultural Advisory Group.

7. Numerous informal discussions on the project have been held with growers, extension officers and crop consultants.

Publications from Project (to date)

Kay, I.R. (in press). Insecticidal control of *Helicoverpa* spp. and *Phthorimaea operculella* on tomatoes *in* Corey, S.A., Dall, D.J. and Milne, W.M. (eds) *Pest Control and Sustainable Agriculture*. Proceedings of the Fifth Australian Applied Entomological Research Conference, Canberra, 1992.

Conclusions (in relation to objectives)

The work undertaken has addressed most of the project's objectives.

Most insecticides registered for use against *P. operculella* in tomatoes have been evaluated, and for the most part found wanting. Whether this is due to the development of resistance to insecticides by *P. operculella*, or to problems in obtaining contact between the insecticide and the insect is not known. Further research to determine this would be worthwhile.

Pheromone traps are being used to monitor *P. operculella* population levels within the district. Experiments done as part of this project have provided data on the relative effectiveness of different trap designs and on the effect of trap height on moth catch, and the effect of the aging of lures on catch is being determined. Future work could look at relationships between pheromone trap catches and larval infestations in leaves and fruit.

Differences between tomato varieties in the percentage of fruit damaged by *P. operculella* were demonstrated during the course of this project. Such host plant resistance could be very useful in integrated pest management programs, and it warrants further investigation.

No formal work was done on the biology and ecology of *P. operculella*. It became obvious during the course of the project that there are many gaps in our knowledge of the biology and ecology of *P. operculella* in tomatoes, and that a large amount of work is needed to try to fill these gaps. Large, detailed projects are needed, and these are being planned and initiated.

Considerable effort has been put into extension activities.

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