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CONTROL OF HELIOTHIS SPP. (LEPIDOPTERA: NOCTUIDAE) LARVAE ON FLUE-CURED TOBACCO IN NORTH QUEENSLAND

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SUMMARY

Insecticidal control of *Heliothis* spp. on tobacco residues in North Queensland was investigated in ten randomized block screening trials during the 1972-73 to 1975-76 seasons. Methomyl at 0·025% a.c. and 0·05% a.c. monocrotophos were efficacious. Other promising insecticides included 0·1% a.c. acephate, 0·05% a.c. carbofuran, a 0·05% a.c. chlordimeform-hydrochloride—0·05% a.c. *Bacillus thuringiensis* mixture, 0·75% a.c. chlorpyrifos, 0·06% a.c. endosulfan, 0·075% a.c. mephosfolan, 0·03% a.c. permethrin, 0·06% a.c. prothiophos[a] 0·06% a.c., sulprofos[b], and 0·03% a.c. fenpropathrin[c].

Triazophos, at 0·05% and 0·1% a.c., 0·06% a.c. mevinphos, and 0·05% a.c. phosfolan exerted moderate control of *Heliothis* spp. larvae, while 0·05% a.c. *B. thuringiensis* 0·05% a.c. chlordimeform-hydrochloride and 0·1% a.c. methoxychlor caused little larval mortality.

I. INTRODUCTION

Tobacco budworms (*Heliothis armigera* (Hübner) and *Heliothis punctigera* Wallengren) are major pests of flue-cured tobacco in the Mareeba-Dimbulah district of North Queensland (Broadley 1975). Consequently, a report (Twine and Kay 1973) of resistance to DDT in one species, *H. armigera,* in southern Queensland caused some concern, since DDT had formed one of the main bases for *Heliothis* spp. larval control on tobacco for some years (Smith 1953).

As a result, and also because of consumer and cigarette manufacturer preferences for insecticide-free cured leaf, a series of trials evaluating alternatives to DDT were carried out. These trials are reported in this paper.

II. METHODS AND MATERIALS

Tobacco crop residues, comprising stalks, axillary suckers, a small number of unharvested leaves and flowerheads, are attractive as egg laying sites for *Heliothis* spp. moths. Sites with heavy *Heliothis* spp. larval infestations were prepared for trial purposes by removing unharvested leaves, and all but one axillary sucker per plant.

Nineteen insecticides (including *Bacillus thuringiensis* with a potency of 16 000 I.U. mg^{-1}) were tested at 29 rates in ten trials. All trials employed the randomized block design, each treatment having four replicates. Plot size varied between eight and fifteen plants, with at least two guard rows separating blocks, and five guard plants between plots. A pre-treatment count of all *Heliothis*

a. O(2,4-dichlorophenyl)-O-ethyl-S-propyl phosphorodithoate.
b. O-ethyl O-(4-(methylthio) phenyl) S-propyl phosphorodithoate.
c. alpha-cyano-3-phenoxybenzyl 2,2,3,3-tetramethyl cyclopropane carboxylate.

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spp. larvae per plot, a single spray application, and three post-treatment counts of larvae, at 1 day, 3 or 4 days and 6 or 7 days were involved. *Heliothis* spp. eggs deposited on the flowerheads were not counted.

All sprays were applied using a knapsack sprayer equipped with a twin nozzle and hand held lance, during the cool, calm conditions of early morning.

Collections of *Heliothis* spp. larvae from each trial site one day prior to spraying, were made for identification purposes and to determine the approximate age structure of populations. Counts of *Microplitis* sp. (Braconidae) cocoons on datum plants in untreated plots were used to estimate a source of non-insecticidal mortality of larvae (Endoparasitic *Microplitis* larvae emerge from fourth instar *Heliothis* spp. larvae, and form oblong, brown cocoons adjacent to the paralysed hosts. One *Microplitis* sp. larva normally develops to maturity in each *Heliothis* larva).

III. RESULTS AND DISCUSSION

H. armigera was the dominant species in trials II, III, IV, V, VI and X. It occurred in approximately equal proportions to *H. punctigera* in trials I, VII and IX, but *H. punctigera* predominated in trial VIII. (See tabulated data for percentages of *H. armigera* present at each trial site)

Populations were composed of a range of larval instars (also presented with tabulated data) and in no instances were insecticides tested against only young larvae.

The decline in larval numbers observed in untreated plots in the majority of trials was attributed mainly to pupation. However, significant rainfall (104 mm) probably also contributed to a decrease in larval populations in trial IV. Increase in numbers recorded on some occasions followed hatching from observed but unrecorded eggs.

Mortality of *Heliothis* spp. larvae in the untreated plots due to *Microplitis* sp. ranged from 1·0% in trial VI to 16·8% in trial I, data being collected in all except trial II.

Effects of insecticide treatments, and analyses of larval counts, for trials I to X, are presented in tables 1 to 5.

Methomyl at 0·025% a.c., a standard recommendation for *Heliothis* spp. larval control on tobacco in Queensland, exerted good control in all trials. Mortality of larvae was equivalent to that obtained from 0·1% DDT application, and more rapid, where both insecticides were used in trials I and II.

Mortality caused by 0·025% a.c. methomyl was always maximized by the second post-treatment count, 3 or 4 days after spraying. On the other hand 0·05% and 0·1% a.c. monocrotophos treatments (trials I, IV and V) were significantly superior to 0·025% a.c. methomyl after 7 days in trials I and V ($P < 0·05$ and $P < 0·01$). This result supports that of Whitlock (1973) who recorded that monocrotophos had a delayed action against early third instar *H. armigera* larvae.

Bacillus thuringiensis at 0·05% a.c. ($= 8 \times 10^6$ I.U. l^{-1}), was markedly ineffective in trial II. It is possible that high intensity U.V. light in north Queensland affected the *B. thuringiensis* preparation. Chlordimeform-hydrochloride at 0·05% a.c. was slightly more efficacious than 0·05% a.c. *B. thuringiensis* in the same trial. It appeared to be effective against eggs and/or small larvae, which hatched between the second and third post-treatment counts. These results are consistent with other reports (for example Clift 1976) for *H. armigera.*

TABLE 1

TRIALS I AND II: NUMBERS OF *Heliothis* SPP. LARVAE ON TOBACCO RESIDUES BEFORE AND AFTER TREATMENT WITH INSECTICIDES

Treatment	Mean Number of *Heliothis* spp. Larvae* per Plot							
	Count 1 (One Day Pre-treatment)	Count 2 (One Day Post-treatment)		Count 3 (Three Days—Tr. I, Four Days—Tr. II Post-treatment)		Count 4 (Seven Days Post-treatment)	
TRIAL I, 1972–73—							
1. Control	48·50	3·755	(41·73)	3·739	(41·06)	3·575	(34·70)
2. Methomyl 0·025%	56·50	1·984	(6·27)	1·370	(2·94)	2·059	(6·84)
3. DDT 0·1%	38·25	2·554	(11·86)	2·384	(9·85)	2·404	(10·06)
4. Triazophos 0·05%	42·75	1·344	(2·83)	1·857	(5·41)	1·748	(4·75)
5. Triazophos 0·1%	41·25	2·204	(8·06)	1·818	(5·16)	1·997	(6·36)
6. Monocrotophos 0·05%	44·75	1·543	(3·68)	1·024	(1·78)	1·096	(1·99)
7. Monocrotophos 0·1%	45·00	1·811	(5·12)	0·576	(0·78)	0·448	(0·57)
L.S.D. 0·05	N.S.	0·839		0·638		0·653	
0·01	..	1·150		0·873		0·894	
TRIAL II, 1973–74—							
1. Control	23·00	3·074	(20·64)	3·276	(25·47)	3·550	(33·80)
2. Methomyl 0·025%	29·75	1·984	(6·27)	1·929	(5·88)	2·379	(9·79)
3. DDT 0·1%	32·50	2·615	(12·66)	1·936	(5·93)	2·256	(8·55)
4. *Bacillus thuringiensis* 0·05%	20·25	2·905	(17·26)	3·322	(26·72)	3·313	(26·48)
5. Chlordimeform-hydrochloride 0·05%	25·50	3·238	(24·49)	2·858	(16·43)	2·715	(14·10)
L.S.D. 0·05	N.S.	0·605		0·589		0·356	
0·01	..	0·825		0·825		0·498	

The $\log_e (x + 1)$ transformation was performed on data from all post-treatment counts. Numbers in parenthesis are equivalent means.

* At pre-treatment, larvae in Trial I comprised 23·3% first and second instars, 58·1% third and fourth instars, and 18·6% fifth and sixth instars. 48% of larvae were *H. armigera*.

At pre-treatment, larvae in Trial II comprised 14·3% first and second instars, 38·1% third and fourth instars, and 47·6% fifth and sixth instars. 100% of larvae were *H. armigera*.

TABLE 2

TRIALS III AND IV: NUMBERS OF *Heliothis* SPP. LARVAE ON TOBACCO RESIDUES BEFORE AND AFTER TREATMENT WITH INSECTICIDES

Treatment	Mean Number of *Heliothis* spp. Larvae* per Plot							
	Count 1 (One Day Pre-treatment)	Count 2 (One Day Post-treatment)		Count 3 (Four Days—Tr. III, Three Days—Tr. IV Post-treatment)		Count 4 (Seven Days Post-treatment)	
TRIAL III, 1973–74—							
1. Control	81·75	4·402	(80·61)	4·698	(108·72)	4·502	(89·23)
2. Methomyl 0·025%	68·25	2·453	(10·62)	2·629	(12·87)	3·178	(23·00)
3. Methoxychlor 0·1%	76·75	4·424	(82·44)	4·516	(90·46)	4·425	(82·55)
4. Endosulfan 0·06%	69·75	3·213	(23·84)	2·661	(13·32)	2·789	(15·26)
5. Phosfolan 0·05%	69·25	3·634	(36·88)	3·891	(47·98)	3·575	(34·71)
L.S.D. 0·05	N.S.	0·436		0·255		0·380	
0·01	..	0·611		0·358		0·532	
TRIAL IV, 1973–74—							
1. Control	75·50	4·339	(75·65)	3·999	(53·55)	3·457	(30·73)
2. Methomyl 0·025%	75·75	1·946	(6·00)	1·929	(5·88)	2·716	(14·13)
3. Monocrotophos 0·05%	90·25	2·922	(17·59)	2·738	(14·46)	2·472	(10·85)
4. Chlorpyrifos 0·05%	78·50	2·992	(18·92)	2·549	(11·79)	2·587	(12·29)
5. Triazophos 0·05%	87·75	3·524	(32·94)	3·396	(28·84)	3·104	(21·28)
L.S.D. 0·05	N.S.	0·471		0·497		0·596	
0·01	..	0·660		0·697		0·836	

The $\log_e (x + 1)$ transformation was performed on data from all post-treatment counts. Numbers in parenthesis are equivalent means.

* At pre-treatment, larvae in Trial III comprised 36·3% first and second instars, 33·6% third and fourth instars, and 30·1% fifth and sixth instars. 65% of larvae were *H. armigera.*

At pre-treatment, larvae in Trial IV comprised 26·8% first and second instars, 37·5% third and fourth instars and 35·7% fifth and sixth instars. 83% of larvae were *H. armigera.*

TABLE 3

TRIALS V AND VI: NUMBERS OF *Heliothis* SPP. LARVAE ON TOBACCO RESIDUES BEFORE AND AFTER TREATMENT WITH INSECTICIDES

Treatment	Mean Number of *Heliothis* spp. Larvae* per Plot							
	Count 1 (One Day Pre-treatment)	Count 2 (One Day Post-treatment)		Count 3 (Three Days Post-treatment)		Count 4 (Seven Days Post-treatment)	
TRIAL V, 1974–75—							
1. Control	103·25	4·599	(98·38)	4·519	(90·77)	4·056	(56·77)
2. Methomyl 0·025%	87·25	2·030	(6·61)	2·042	(6·71)	1·952	(6·05)
3. Monocrotophos 0·05%	91·00	2·625	(12·80)	2·350	(9·49)	1·517	(3·56)
4. Mephosfolan 0·05%	93·75	3·407	(29·18)	2·897	(17·13)	2·534	(11·61)
5. Acephate 0·05%	82·50	3·132	(21·91)	2·967	(18·44)	2·546	(11·75)
L.S.D. 0·05	N.S.	0·416		0·712		0·422	
0·01	..	0·583		0·999		0·591	
TRIAL VI, 1974–75—							
1. Control	101·75	4·283	(71·45)	4·140	(61·80)	3·835	(45·30)
2. Methomyl 0·025%	78·50	1·213	(2·36)	1·314	(2·72)	2·021	(6·54)
3. Acephate 0·1%	90·25	1·874	(5·51)	1·472	(3·36)	1·242	(2·46)
4. Chlorpyrifos 0·05%	94·25	2·414	(10·18)	2·467	(10·79)	2·926	(17·65)
5. Mephosfolan 0·075%	83·50	2·370	(9·70)	2·040	(6·69)	1·902	(5·70)
6. Prothiophos 0·1%	67·25	1·929	(5·88)	0·347	(0·41)	1·758	(4·80)
7. Mevinphos 0·06%	91·75	1·573	(3·82)	2·230	(8·30)	2·845	(16·20)
L.S.D. 0·05	N.S.	0·670		0·558		0·579	
0·01	..	0·918		0·764		0·793	

The $\log_e (x + 1)$ transformation was performed on data from all post-treatment counts. Numbers in parenthesis are equivalent means.

* At pre-treatment, larvae in Trial V comprised 11·9% first and second instars, 48·5% third and fourth instars, and 30·6% fifth and sixth instars. 90% of larvae were *H. armigera*.

At pre-treatment, larvae in Trial VI comprised 9·4% first and second instars, 35·9% third and fourth instars, and 54·7% fifth and sixth instars. 65% of larvae were *H. armigera*.

TABLE 4

TRIALS VII AND VIII: NUMBERS OF *Heliothis* SPP. LARVAE ON TOBACCO RESIDUES BEFORE AND AFTER TREATMENT WITH INSECTICIDES

Treatment	Mean Number of *Heliothis* spp. Larvae* per Plot							
	Count 1 (One Day Pre-treatment)	Count 2 (One Day Post-treatment)		Count 3 (Three Days Post-treatment)		Count 4 (Six Days Post-treatment)	
TRIALS VII, 1974–75—							
1. Control	67·00	3·954	(51·17)	3·484	(31·60)	3·083	(20·82)
2. Methomyl 0·025%	65·50	1·298	(2·66)	0·997	(1·71)	1·635	(4·13)
3. Chlorpyrifos 0·1%	54·50	1·370	(2·94)	0·896	(1·45)	0·968	(1·63)
4. Prothiophos 0·06%	58·00	2·668	(13·40)	1·818	(5·16)	2·004	(6·42)
5. Carbofuran 0·05%	60·75	2·305	(9·02)	1·868	(5·48)	1·683	(4·38)
6. Chlordimeform-hydrochloride 0·05% + *B. thuringiensis* 0·05%	71·00	2·685	(13·66)	2·324	(9·21)	1·773	(4·89)
7. Sulprofos 0·06%	57·50	1·918	(5·81)	1·775	(4·90)	1·549	(3·70)
L.S.D. 0·05	N.S.	0·732		0·791		0·890	
0·01	..	1·003		1·083		1·219	
TRIAL VIII, 1974–75—							
1. Control	95·75	4·308	(73·31)	4·231	(67·75)	4·138	(61·66)
2. Methomyl 0·025%	93·50	1·638	(4·14)	2·346	(9·44)	3·039	(19·89)
3. Chlorpyrifos 0·075%	97·75	2·660	(13·30)	2·979	(18·67)	3·547	(33·71)
4. Prothiophos 0·075%	104·00	2·543	(11·72)	2·766	(14·89)	3·264	(25·16)
5. Sulprofos 0·075%	83·00	2·083	(7·03)	2·165	(7·71)	2·564	(11·99)
L.S.D. 0·05	N.S.	0·430		0·479		0·589	
0·01	..	0·603		0·671		0·826	

The $\log_e (x + 1)$ transformation was performed on data from all post-treatment counts. Numbers in parenthesis are equivalent means.

* At pre-treatment, larvae in Trial VII comprised 27·5% first and second instars, 54·9% third and fourth instars, and 17·6% fifth and sixth instars. 47% of larvae were *H. armigera*.

At pre-treatment, larvae in Trial VIII comprised 37·5% first and second instars, 43·8% third and fourth instars, and 18·7% fifth and sixth instars. 30% of larvae were *H. armigera*.

TABLE 5

TRIALS IX AND X: NUMBERS OF *Heliothis* SPP. LARVAE ON TOBACCO RESIDUES BEFORE AND AFTER TREATMENT WITH INSECTICIDES

Treatment	Mean Number of *Heliothis* spp. Larvae* per Plot							
	Count 1 (One Day Pre-treatment)	Count 2 (One Day Post-treatment)		Count 3 (Four Days—Tr. IX, Three Days—Tr. X Post-treatment)		Count 4 (Seven Days Post-treatment)	
TRIAL IX, 1974–75—							
1. Control	54·00	3·772	(42·48)	3·676	(38·48)	2·890	(17·00)
2. Methomyl 0·025%	60·75	0·968	(1·63)	2·350	(9·49)	1·978	(6·23)
3. Acephate 0·1%	55·25	1·472	(3·36)	1·589	(3·90)	1·472	(3·36)
4. Sulprofos 0·075%	65·50	1·839	(5·29)	1·069	(1·91)	1·495	(3·46)
5. Carbofuran 0·1%	53·00	2·408	(10·11)	1·958	(6·09)	1·197	(2·31)
L.S.D. 0·05	N.S.	0·715		0·581		0·677	
0·01	..	1·003		0·815		0·950	
TRIAL X, 1975–76							
1. Control	72·00	4·221	(67·14)	4·294	(72·26)	3·742	(41·21)
2. Methomyl 0·025%	72·75	1·170	(2·22)	1·196	(2·31)	1·298	(2·66)
3. Chlorpyrifos 0·075%	70·75	1·611	(4·01)	1·935	(5·92)	1·856	(5·40)
4. Acephate 0·1%	72·00	1·442	(3·23)	0·519	(0·68)	1·023	(1·78)
5. Permethrin (40:60) 0·03%	75·75	0·794	(1·21)	0·000	(0·00)	0·173	(0·19)
6. Fenpropathrin 0·03%	68·75	1·352	(2·86)	0·850	(1·34)	1·124	(2·08)
L.S.D. 0·05	N.S.	1·065		0·820		0·638	
0·01	..	1·472		1·134		0·883	

The log e (x + 1) transformation was performed on data from all post-treatment counts. Numbers in parenthesis are equivalent means.

* At pre-treatment, larvae in Trial IX comprised 21·1% first and second instars, 38·5% third and fourth instars, and 40·4% fifth and sixth instars. 50% of larvae were *H. armigera*.

At pre-treatment, larvae in Trial X comprised 20·0% first and second instars, 47·1% third and fourth instars, and 32·9% fifth and sixth instars. 97% of larvae were *H. armigera*.

A 0·05% chlordimeform-hydrochloride-0·05% *B. thuringiensis* mixture (trial VII) was more effective than either used alone (trial II). This result supports the conclusions of Plapp (1976), who reported that chlordimeform synergized conventional insecticides tested against an insecticide resistant population of *Heliothis virescens* (F.).

Endosulfan at 0·06% a.c. was evaluated in trial III, and found to be efficacious, but it was slower acting than the standard recommendation, methomyl. The systemic insecticide, carbofuran at 0·05% a.c. and 0·1% a.c., produced high larval mortality in trials VII and IX.

Triazophos, at 0·05% a.c. and 0·1% a.c., although causing moderate larval mortality (trials I and IV), cannot be considered for use on tobacco because of phytotoxic effects (Fleming, personal communication 1975). Mevinphos at 0·06% a.c. (trial VI) and 0·05% a.c. phosfolan (trial III) were inferior to 0·025% a.c. methomyl. Methoxychlor at 0·1% a.c. was ineffectual (trial III).

The following materials were found to be very promising *Heliothis* spp. larvicides (only minimum effective dosages obtained in these trials are listed)—0·1% a.c. acephate (trials V, VI, IX and X), 0·075% a.c. chlorpyrifos (trials IV, VI, VII, VIII and X), 0·075% a.c. mephosfolan (trials V and VI), 0·06% a.c. prothiophos (trials VI, VII and VIII), and 0·06% a.c. sulprofos (trials VII, VIII and IX). The two photostable, synthetic pyrethroids, permethrin at 0·03% a.c. and fenpropathrin at 0·03% a.c. were highly active against *Heliothis* spp. larvae (trial X). It is recognised, however, that the pyrethroid rates are high and that commercial use of the chemicals will depend on efficacy at lower dosages.

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