

STATUS OF RESISTANCE TO FENVALERATE IN TOMATO FRUITWORM, *HELICOVERPA ARMIGERA*

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ABSTRACT

Trends in resistance of tomato fruitworm, *Helicoverpa armigera*, showed decreasing susceptibility to the synthetic pyrethroid fenvalerate from 1991 to 1994. In 1995, susceptibility of pheromone-trapped adult males to 1 µg residues of fenvalerate remained at 1994 levels, but susceptibility decreased at 10 and 90 µg. Five percent of the population were resistant to a discriminating dose of 90 µg. In 1995, increased survival occurred earlier than in 1994, coinciding with earlier commercial spraying for *H. armigera* in tomato crops. Topical application tests with larvae showed significant increases in LD₅₀s from January to March 1995, and levels of resistance similar to those reached in tomatoes were recorded in larval populations from sweet corn and lucerne. Survival of adults and larvae at discriminating doses associated with control failures in Australia suggest the potential for future control failures in New Zealand.

Keywords: *Helicoverpa armigera*, tomato fruitworm, insecticide resistance, fenvalerate, tomatoes

INTRODUCTION

Helicoverpa armigera (Hübner) (Lepidoptera: Noctuidae) has developed resistance to synthetic pyrethroids in Egypt, India, Indonesia, Thailand and Zimbabwe (Denholm and Rowland 1992), and in Australia resistance occurred approximately 5 years after the introduction of synthetic pyrethroids (Gunning *et al.* 1984). In New Zealand, tomatoes and sweet corn are major host plants of *H. armigera*, and since 1979 insecticidal control has primarily relied on the use of pyrethroids. An integrated pest management (IPM) programme was developed in 1989 to reduce reliance on insecticides (Walker and Cameron 1990) and from 1991 to 1994 resistance monitoring documented declining susceptibility of *H. armigera* to fenvalerate (Cameron *et al.* submitted). This paper updates trends in resistance using both residue and topical application techniques. It emphasises the use of diagnostic doses as recommended by Roush and Miller (1986) for detecting the onset of resistance.

METHODS

IPM procedures

Pheromone traps were used by consultants to monitor moth flights and initiate crop scouting (Walker and Cameron 1990). Together with temperature accumulations from meteorological data, pheromone traps also indicated the commencement of the second generation. Commercial crops were scouted weekly and insecticides applied only when larval populations exceeded the economic threshold of 1 larva/plant. This work has been carried out in Gisborne and Hawkes Bay from 1991-1995 and results from 1995 in Gisborne are reported here.

Adult vial assays

Adult males were collected at monthly intervals from Gisborne tomato fields using two or three hollow cone pheromone traps (Scentry Inc) baited with a lure consisting of a 10:1 mixture of (Z)-11-hexadecenal and (Z)-9-hexadecenal acetate. Moths were removed daily and only fresh adults capable of normal movement were used for assays. Single males were exposed to residues of fenvalerate using techniques

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based on those of Plapp *et al.* (1987) and Daly and Fitt (1990). Fenvalerate (Sumicidin EC), 49 g/litre, residues were formed by rolling 0.25 ml of acetone containing the insecticide inside 40 ml glass vials until it evaporated. Adults were placed in treated vials, fed water by moistening the cork stoppers, and held at room temperature for 24 h. An average of 60 adults (minimum of 30) were treated at each of three diagnostic doses: 1, 10 and 90 µg. Individuals that did not move when the vial was inverted were considered to be dead. Trends in survival were analysed using a generalised linear model with a logistic link and binomial errors.

Larval assays

Larvae were collected from tomato, lucerne or sweet corn crops in Gisborne from January to March 1995 and reared on a standard bean diet (Teakle and Jensen 1985) to obtain pupae and adults. A reference strain was collected from unsprayed tomatoes in Canterbury in February. For vial tests the F₁ progeny from each collection were reared to second instar (7-10 mg) and held in treated vials at 25 °C for 48 h. Thirty larvae were exposed to each of five or six residues from 0.03 to 10 µg/vial. Larvae that did not change position when touched were considered to be dead. For topical assays larvae were reared to third or fourth instar (30-40 mg) and fenvalerate applied to the dorsum in 1 ml of acetone. Thirty larvae were treated at each of five or six doses from 0.001 to 0.2 µg/larva. Larval mortality was assessed at 48 h as above. Dose-response curves were analysed and compared using logit transformation.

RESULTS AND DISCUSSION

IPM programme

The IPM programme for tomato fruitworm was implemented for the majority of tomato crops in the Gisborne area in 1992/93 and produced a distinct decline in the average number of insecticide applications (Table 1). By comparison with 1991/92, the cooler weather and later development of tomato fruitworm in 1992/93 and 1993/94 assisted with this decline. The predicted date of emergence for second generation moths in the 1994/95 season in Gisborne was approximately 2 weeks earlier than recorded in the previous two seasons. This earlier emergence, and the associated occurrence of larval populations above the treatment threshold of 1 larva/plant, led to the commencement of synthetic pyrethroid applications to commercial crops in January. Reinfestation of some crops in February required further control measures, resulting in two synthetic pyrethroid treatments being applied in most Gisborne cropping areas in 1994/95.

TABLE 1: Seasonality of tomato fruitworm and synthetic pyrethroid (SP) applications in Gisborne.

	1991/92	1992/93	1993/94	1994/95
Predicted emergence of 2nd generation moths	27 Jan	11 Feb	4 Feb	25 Jan
Number of SP applications	4	1	1	1-2

Adult resistance

Increasing survival of adults exposed to 1 and 10 µg doses of fenvalerate was demonstrated from 1992 to 1994 (Fig. 1)(Cameron *et al.* submitted). This trend included patterns of increasing survival within each cropping season and a decline overwinter. Increases in survival were attributed to selection for resistance as a result of commercial spraying. A discriminating dose of 90 µg, used by Daly and Fitt (1990) to distinguish resistant and susceptible populations, was introduced to the testing procedures in 1994 to allow for increasing adult survival. Although the use of pheromone-trapped adults is subject to responses that vary with adult age (Daly 1992), survival at the 90 µg discriminating dose provides a convenient estimate of long-term trends in resistance.

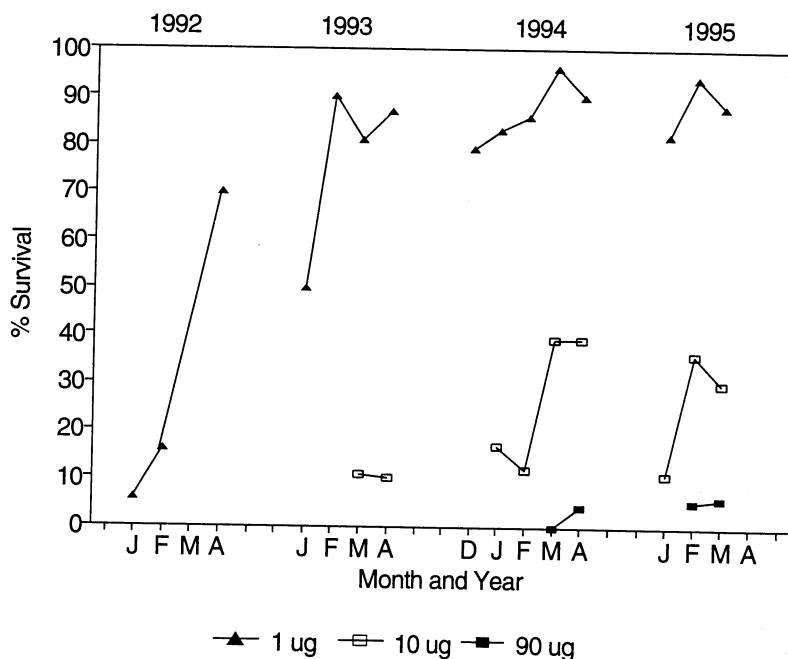


FIGURE 1: Survival of tomato fruitworm adults exposed to fenvalerate residues, Gisborne 1992 to 1995.

In 1995, survival of male moths exposed to 1 µg of fenvalerate was similar to that measured in 1994 (Table 2), indicating that there was no further increase in resistance at this dose. However, in February 1995 there was a significant increase in survival at both 10 µg and 90 µg. This increase coincided with the increased applications of insecticides in commercial tomato crops in 1995 in response to the earlier development in tomato fruitworm populations. As a result, growers were notified that further applications of synthetic pyrethroids may increase resistance in March and lead to control failures. Subsequent insecticide applications were minimised, and survival did not alter significantly at either 10 or 90 µg from February to March 1995 (Fig. 1; Table 2). Although the levels of survival in March were not greater than those recorded in the same month in 1994, the earlier occurrence of resistance contributed to a greater number of survivors for the season. For example, at 90 µg mean survival from all tests for the season increased from 0% in 1993 to 1.3% in 1994, and in 1995 5.2% in Gisborne and 2% in Hawkes Bay.

TABLE 2: Percent survival (± SE) of field collected male tomato fruitworm moths from Gisborne, estimated from exposure to fenvalerate residues in vials.

Year	Jan	1 µg		Jan	10 µg		90 µg	
		Feb	Mar		Feb	Mar	Feb	Mar
1994	83 ± 5.6	86 ± 5.9	96 ± 7.3	17 ± 5.6	12 ± 5.6	39 ± 5.8	0	4 ± 2.3
1995	82 ± 7.3	94 ± 2.3	87 ± 2.5	11 ± 6.0	36 ± 4.1	30 ± 3.4	5 ± 1.8	6 ± 1.8

The survival rates for adults in 1995 were much lower than those recorded for *H. armigera* from sweet corn in Australia where Glenn *et al.* (1994) recorded 27-68% survival at 90 µg. However, the trends in adult survival support the suggestion by Roush and Miller (1986) that once the frequency of resistant individuals reaches 1% loss of field control can develop rapidly. The adult vial technique provides a useful method for monitoring resistance in crops such as tomatoes where *H. armigera* populations are too low to test individual eggs or larvae collected directly from the field. Campanhola and Plapp (1989) have used this method to monitor adult resistance in *Helicoverpa virescens* (F.), and Plapp *et al.* (1990) used it to monitor the effects of resistance management strategies.

Larval resistance

Dose-response tests using the vial technique showed no significant change in the LD₅₀s for the progeny of larvae collected from Gisborne tomatoes in 1995 by comparison with 1994 (Table 3). This is consistent with the failure of 1 and 10 µg diagnostic doses to detect trends in larval survival from 1992 to 1994 (Cameron *et al.* submitted). The presence of a low level of resistance in larvae at tomato sites was demonstrated by significant variation between sprayed cropping areas and an unsprayed reference area (Table 3). Comparisons of the same populations using topical applications produced resistance ratios similar to those obtained with the vial technique.

By March, larval collections from sprayed areas showed significant increases in LD₅₀ and resistance ratios for these populations reached 4 to 5.3. The application of a 0.2 µg topical dose also differentiated larval populations from sprayed and unsprayed areas (Table 3). It also demonstrated that within commercial cropping areas such as Gisborne or Hawkes Bay, resistance occurs in populations on relatively unsprayed crops such as sweet corn and on alternative host plants such as lucerne. The inclusion of a 0.2 µg dose in topical application tests provided a comparison with tests in Australia where Forrester *et al.* (1993) used 0.2 µg as a discriminating dose to determine the frequency of resistant larvae. These results indicate the presence of larvae with levels of resistance that have been associated with control failures in Australia.

The combined use of adult and larval resistance assays with discriminating doses provides the best option for detecting resistance levels associated with potential control failures.

TABLE 3: Larval response to vial and topical tests.

Site	N ¹	LD ₅₀	(95% CI)	Slope ± SE	RR ²	Survival @ 0.2 µg (%)
Vial tests, Gisborne tomatoes						
1994	192	1.61	(1.1-2.2)	1.72 ± .25	2.7	-
1995	186	1.21	(0.6-1.7)	2.12 ± .61	1.8	-
Reference strain	179	0.60	(0.4-0.8)	2.83 ± .37	1.0	-
Topical tests, Gisborne 1995						
Tomatoes, Jan.	150	0.07	(0.05-0.11)	3.01 ± .43	2.3	7
Tomatoes, Mar.	133	0.09	(0.06-0.11)	2.39 ± .38	3.0	55
Sweet corn, Mar.	127	0.16	(0.11-0.30)	1.60 ± .33	5.3	47
Lucerne, Mar.	150	0.12	(0.09-0.15)	3.34 ± .64	4.0	20
Reference strain	180	0.03	(0.02-0.04)	2.39 ± .33	1.0	0

¹ = number tested, ² = resistance ratio of test/reference strain

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REFERENCES

- Cameron, P.J., Walker, G.P. and Herman, T.J.B. (submitted). Development of resistance to fenvalerate in *Helicoverpa armigera* in New Zealand. *N.Z. J. Crop and Hort. Sci.*
- Campanhola, C. and Plapp, F.W., 1989. Pyrethroid resistance in the tobacco budworm (Lepidoptera: Noctuidae): insecticide bioassays and field monitoring. *J. Econ. Entomol.* 82: 22-28.
- Daly, J., 1992. Decline in survival with age of resistant adult *Helicoverpa armigera* (Lepidoptera: Noctuidae) at a discriminating dose of the pyrethroid fenvalerate. *J. Econ. Entomol.* 85: 1583-1586.
- Daly, J.C. and Fitt, G.P., 1990. Monitoring pyrethroid resistance in relation to body weight in adult *Helicoverpa armigera* (Hübner) (Lepidoptera: Noctuidae). *J. Econ. Entomol.* 83: 705-709.
- Denholm, I. and Rowland, M.W., 1992. Tactics for managing pesticide resistance in arthropods: Theory and practice. *Ann. Rev. Ent.* 37: 91-112.
- Forrester, N.W., Cahill, M., Bird, L.J. and Layland, J.K., 1993. Management of pyrethroid and endosulfan resistance in *Helicoverpa armigera* (Lepidoptera: Noctuidae) in Australia. *Bull. Ent. Res., suppl. 1*; 132 p.
- Glenn, D.C., Hoffmann, A.A. and McDonald, G., 1994. Resistance to pyrethroids in *Helicoverpa armigera* (Lepidoptera: Noctuidae) from corn: adult resistance, larval resistance, and fitness effects. *J. Econ. Entomol.* 87: 1165-1171.
- Gunning, R.V. Easton, C.S., Greenup, L.R. and Edge, V.E., 1984. Pyrethroid resistance in *Heliothis armigera* (Hübner) (Lepidoptera: Noctuidae) in Australia. *J. Econ. Entomol.* 77: 1283-1287.
- Plapp, F.W., Jackman J.A., Campanhola, C., Frisbie, R.E., Graves, J.B., Lutrell, R.G., Kitten, W.F. and Wall, M., 1990. Monitoring and management of pyrethroid resistance in the tobacco budworm (Lepidoptera: Noctuidae) in Texas, Mississippi, Louisiana, Arkansas, and Oklahoma. *J. Econ. Entomol.* 82: 335-341.
- Plapp, F.W., McWhorter, G.M. and Vance, W.H., 1987. Monitoring for pyrethroid resistance in the tobacco budworm in Texas - 1986. *Proc. 1987 Beltwide Cotton Production and Res. Conf., Dallas*: 220-224.
- Roush, R.T. and Miller, G.L., 1986. Considerations for design of insecticide resistance monitoring programs. *J. Econ. Entomol.* 79: 293-298.
- Teakle, R.E and Jensen, J.M., 1985. *Heliothis punctigera*. Pp. 313-322 In: Handbook of insect rearing, vol. 2, Singh, P.; Moore, R.F. (eds) Elsevier, Amsterdam.
- Walker, G.P. and Cameron, P.J., 1990. Pheromone trapping and field scouting for tomato fruitworm in tomatoes and sweet corn. *Proc. 43rd N.Z. Weed and Pest Control Conf.*: 17-20.