RURAL INDUSTRY RESEARCH FUNDS

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Project Title: Monitoring resistance levels in *Heliothis* spp.

Field of Research: Entomology Field Code 1.

Organisation: Department of Agriculture, New South Wales

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The Department of Agriculture, NSW has provided the salaries of a full-time Entomologist and two Assistants who worked on this project. Small allocations from Consolidated Fund were provided for stores items and travel.
Schering Pty. Ltd. and CIBA-GEIGY Australia have funded some ovicide studies.

Monitoring Resistance Levels in Heliothis Spp. 1984-1987.

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Introduction

Heliothis spp are arguably the most important agricultural pests in Australia. There are two pest species *Heliothis armigera* (the cotton bollworm) and *Heliothis punctigera* (the native budworm). *H. armigera* has a long history of insecticide resistance in Australia, first to DDT in the early 1970s (Wilson 1974). High level DDT resistance was widespread throughout Australia and *H. armigera* could not be controlled by DDT. DDT resistant *H. armigera* caused a severe economic threat to the Australian cotton industry. More recently, in 1983, *H. armigera* were diagnosed as resistant to the pyrethroid insecticides (Gunning *et al* 1984). A pyrethroid resistance management strategy was successfully implemented and up to the present, resistance although widespread, is of a low order and commercial rates of pyrethroids can still be successfully used to control *H. armigera*.

In 1974, following the occurrence of DDT resistant *H. armigera*, a resistance monitoring program for *Heliothis* spp. was started at the Tamworth laboratories of the Department of Agriculture, NSW. All insecticide management decisions require a solid platform of reliable data and this can only be achieved by a long-term commitment to pesticide studies. Resistance monitoring has involved obtaining of baseline susceptibility data for *H. armigera* and *H. punctigera*, monitoring of changes in resistance levels and cross resistance patterns. The routine monitoring and testing programs at Tamworth has extended naturally to studies in depth of resistance mechanisms and genetics, since they are basic to a fuller understanding of resistance problems, and to the development of practical responses.

The function and goals of the *Heliothis* resistance monitoring program have been:

(a) to establish baseline data for variation in, and susceptiblity to insecticides in natural populations

(b) to check for cross resistance patterns

(c) to anticipate field resistance problems

Specific achievements of the Tamworth Heliothis resistance testing centre 1984-1987 have been:

1. Monitoring of pyrethroid resistance levels in non-sprayed populations of *H. armigera*.

2. Provision of a pyrethroid monitoring service for the Queensland DPI and extension officers of the Department of Agriculture, New South Wales

3. To monitor the resistance status in *H. armigera*, of currently used and potential control chemicals. During the three year period of this project larval resistance to endosulfan and some carbamate insecticides have been diagnosed.

4. Innovative bioassay methods are being developed for chemicals with novel modes of action or unusual methods of entry into *Heliothis*.

5. A solid platform of baseline data to several chemicals has been accumulated for the native budworm, *H. punctigera*.

RESULTS AND DISCUSSION

Pyrethroid resistance in non-sprayed cropping areas of NSW

The long-term management of pyrethroid resistance in Australia is based on the underpinning assumption that after pyrethroid spraying ceases resistance levels will drop, partly due to immigration dilution and breeding with the vast majority of pyrethroid-susceptible *H. armigera* in non-sprayed populations outside major cotton growing areas.

The degree of contamination of refugia by pyrethroid resistant *H. armigera* has been monitored in the last three years. *H. armigera* have been collected since 1983/84 on unsprayed dairy fodder maize mainly in the Hunter Valley and North Coast of NSW 300-400 km distant from the Namoi/Gwydir irrigation areas. The sampling locations are shown in Fig. 1. Each district was visited and *H.armigera* collected during stages 1, 2 and 3 of each year. *H. armigera* were collected reared and pyrethroids were tested against 1st lab. generation by topical application of a dose designed to kill all susceptibles. The mean percentage of pyrethroid resistants are plotted in Fig. 2 for each stage and year. During 1983/84 resistance levels were very low; 6% (Stage 1); 15% (Stage 2) and 4.0% (Stage 3) and showed no significant differences between stages.

The resistance levels of 1984/85; 14% (1); 17% (2) and 14% (3) showed no trend within the season and were not significantly higher than the resistance levels of the previous year. In 1985/86, resistance levels had increased; 23% (1); 37.5 (2) and 45% (3). Levels in Stages 2 and 3 were significantly higher than those of the previous 2 years. The last season of study 1986/87 showed continued high resistance levels; 32% (1); 43% (2) and 50% (3).

The data indicate that there is significant contamination in unsprayed populations of *H. armigera* in New South Wales. The long-term implications of these data to pyrethroid resistance management may be serious. The management strategy is most effective when increases in pyrethroid resistance are restricted mainly to crops sprayed with pyrethroids, and this should not lead to a significant contamination of the unsprayed populations. Immigration from unsprayed susceptible populations is required to reduce the resistance frequency of resistant individuals in sprayed *H. armigera* populations. The relatively low levels of pyrethroid resistance from the unsprayed populations in the first two seasons of this study may have caused the drops of pyrethroid resistance following the cessation of spraying in the Namoi Valley (Forrester and Cahill, 1987). With pyrethroid resistance levels in the unsprayed populations very much increased in 1985-87, levels in the sprayed cotton populations have risen also (Forrester pers. comm.).

The reasons as to why high levels of pyrethroid resistance were found in *H. armigera* in districts and crops never sprayed with pyrethroids, may be explained by significant migration of resistant *H. armigera* from the sprayed cotton areas. Although these data cannot prove this assumption, it can be supported by the observation of Daly and Gregg (1985) that gene flow between populations of *H. armigera* was sufficient to produce genetic homogeneity between all populations. Farrow and Daly (1987) have also concluded that *H. armigera* is a facultative long-distance migrant (although conditions under which migration occurs are not understood). Resistant *H. armigera* appear to have the ability to disperse widely, certainly into the non-sprayed populations.

These data indicate that resistant individuals, at least since 1986, have not been at a competitive disadvantage compared to susceptible *H. armigera*.

Endosulfan resistance in *H. armigera*
Endosulfan susceptibility of *H. armigera* has been monitored (by topical application) for a number of years. Ample baseline data exists. Data accumulated since 1979 for *H. armigera* collected in eastern Australia is summarised in Figure 3. Average LD_{50}'s and slopes of dosage mortality lines have been plotted for each year. Endosulfan resistance is evident. A significant increase in the mean LD_{50} occurred in 1983 and LD_{50} values have remained high since. A study of the slope values of the dosage mortality data plotted in Fig. 3 shows decreasing slope values. The low slope values showed there was considerable heterogeneity in the response of the population towards endosulfan.

Since 1986, a discriminating dose technique has been adopted to screen *H. armigera* cultures for endosulfan resistance. Resistance 1986/87 in New South Wales (unsprayed sites) and from Queensland (sprayed crops) are contained in Table 1. They show increasing endosulfan resistance during the season, rising to 25% of *H. armigera* sampled.

Carbamate Resistance in *H. armigera*
Since 1983 a large amount of baseline data for the carbamate methomyl has been obtained. *H. armigera* collected in eastern Australia were bioassayed as third instar larvae for methomyl susceptibility. Mean LD_{50}'s for each year are plotted in Fig. 4. They show during this period there has been significant increases in the mean LD_{50}s. In 1986 larval resistance was proven in field strains from crops where methomyl had failed to control *H. armigera*. By selection of heterozygous field strains, it was estimated that the level of resistance in the resistant component of the population was about 30x (Fig. 5). In 1986/87, resistance frequency in the population was estimated using the discriminating dose technique. Results in NSW (unsprayed) and Queensland (sprayed crops) are shown in Table 1. They show approximately 30% of *H. armigera* in NSW and Queensland are resistant to methomyl.

There was no sign of resistance to another carbamate, the newly introduced thiodicarb, during the time of this project.

Methomyl is used as an ovicide against *H. armigera*. It was considered necessary to ascertain whether methomyl resistance, as found in *H. armigera* larvae, was also expressed in the egg stage. A bioassay method was developed to test the efficacy of methomyl against *H. armigera* eggs. No differences were found in the toxicity of methomyl toward the eggs of selected resistant and susceptible e.g. (Fig. 6). Methomyl resistance did not appear to be expressed in the egg stage of *H. armigera*.

Organophosphorous Insecticides against *H. armigera*
Several organophosphate insecticides, including sulprofos and profenfos, were tested by topical application against third instar *H. armigera* larvae from 1983-1987. Valuable baseline susceptibility data have been obtained. During the period of this project *H. armigera* remained susceptible to the organophosphorous compounds.

Response of *Heliothis punctigera* to insecticides
Heliothis punctigera have been monitored for susceptibility to the pyrethroids (fenvalerate and deltamethrin) and to endosulfan since 1983. Consistent baseline data have been accumulated and these have shown that *H. punctigera* are susceptible to all chemicals.

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<u>Relevant Publications</u>

Gunning, R.V., Easton, C.S., Greenup, L.R. and Edge, V.E. (1984). Pyrethroid resistance in *Heliothis armigera* (Hubner) (Lepidoptera:Noctuidae) in Australia. *J. Econ. Entomol.*, 77: 1283-87.

Gunning, R.V. and Easton, C.S. (1987). Inheritance of resistance to fenvalerate *Heliothis armigera* (Hubner) (Lepidoptera: Noctuidae). *J. Aust. Entomol. Soc.* 26: 2149-250.

<u>Manuscripts in preparation</u>

Gunning, R.V. and Easton, C.S - Pyrethroid resistance in *Heliothis armigera* (Hubner) collected from unsprayed crops in New South Wales 1983-1987.

Gunning, R.V. Electrophysiological responses of chemosensory receptors in pyrethroid resistant and susceptible *Heliothis armigera* (Hubner) (Lepidoptera:Noctuidae).

Gunning, R.V. First instar bioassay of contact insecticides against *Heliothis* spp.

Gunning, R.V. and Ferris, I.G. The penetration and distribution of ^{14}C insecticides in pyrethroid susceptible or resistant *Heliothis armigera* (Hubner) (Lepidoptera:Noctuidae).

Gunning, R.V. and Easton, C.S. Toxicity of insecticides against *Heliothis punctigera* (Wallengren).

Gunning, R.V. and Easton, C.S. and Balfe, M.E. Organophosphate and carbamate resistance studies in *Heliothis armigera* (Hubner) in Australia.

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Daly, J.C. and Gregg, P. (1985). Genetic variation in *Heliothis* in Australia: species identification and gene flow in the two pest species *H. armigera* (Hubner) and *H. punctigera* Wallengren (Lepidoptera: Noctuidae). *Bull. Entomol. Res.* 75: 169-184.

Farrow, R.A., and Daley, J.C. (1987). Long range movements as an adaptive strategy in the genus *Heliothis* (Lepidoptera:Noctuidae): a review of its occurrence and detection in four pest species. *Aust. J. Zool* 35: 1-24.

Forrester, N.W., and Cahill, M. (1987). Management of insecticide resistance in *Heliothis armigera* (Hubner) in Australia in *Combating Resistance in Zenobiotics, Biological and Chemical Approaches* Ford *et al.* eds. Ellis Horwood, U.K (in press).

Gunning, R.V., Easton, C.S., Greenup, L.R., and Edge, V.E. (1984). Pyrethroid resistance in *Heliothis armigera* (Hubner) (Lepidoptera: Noctuidae) in Australia. *J. Econ. Entomol.* 77: 1283-1287.

Wilson, A.G.L. (1974). Resistance of *Heliothis armigera* to insecticides in the Ord River irrigation area, north western Australia. *J. Econ. Entomol.* 67: 256-258.

Table 1. *H. armigera* larval resistance levels from New South Wales (unsprayed) and Queensland 1986/87

Location	Insecticide	Mean % Resistance*		
		Stage		
		1	2	3
New South Wales	endosulfan	15.0 ± 1.9	16.0 ± 3.5	26.7 ± 5.3
Queensland	endosulfan	26.0 ± 5.6	14.3 ± 6.5	35.3 ± 8.0
New South Wales	Methomyl	21.6 ± 1.5	24.8 ± 5.6	37.5 ± 8.0
Queensland	Methomyl	20.1 ± 3.3	33.5 ± 8.5	~30

* calculated by a discriminating dose technique ± standard errors.

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Figure 1. Sampling sites of non-sprayed H. armigera

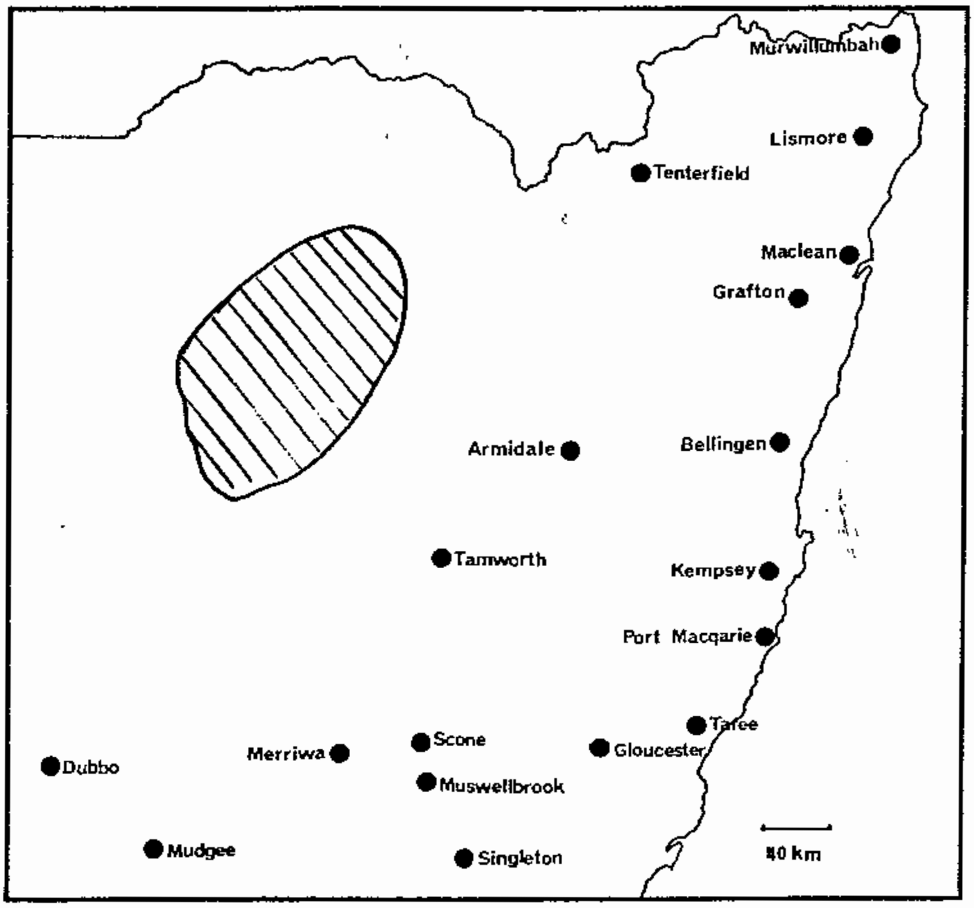

Figure 2. Pyrethroid resistance from non-sprayed *H. armigera* populations 1983-1987.

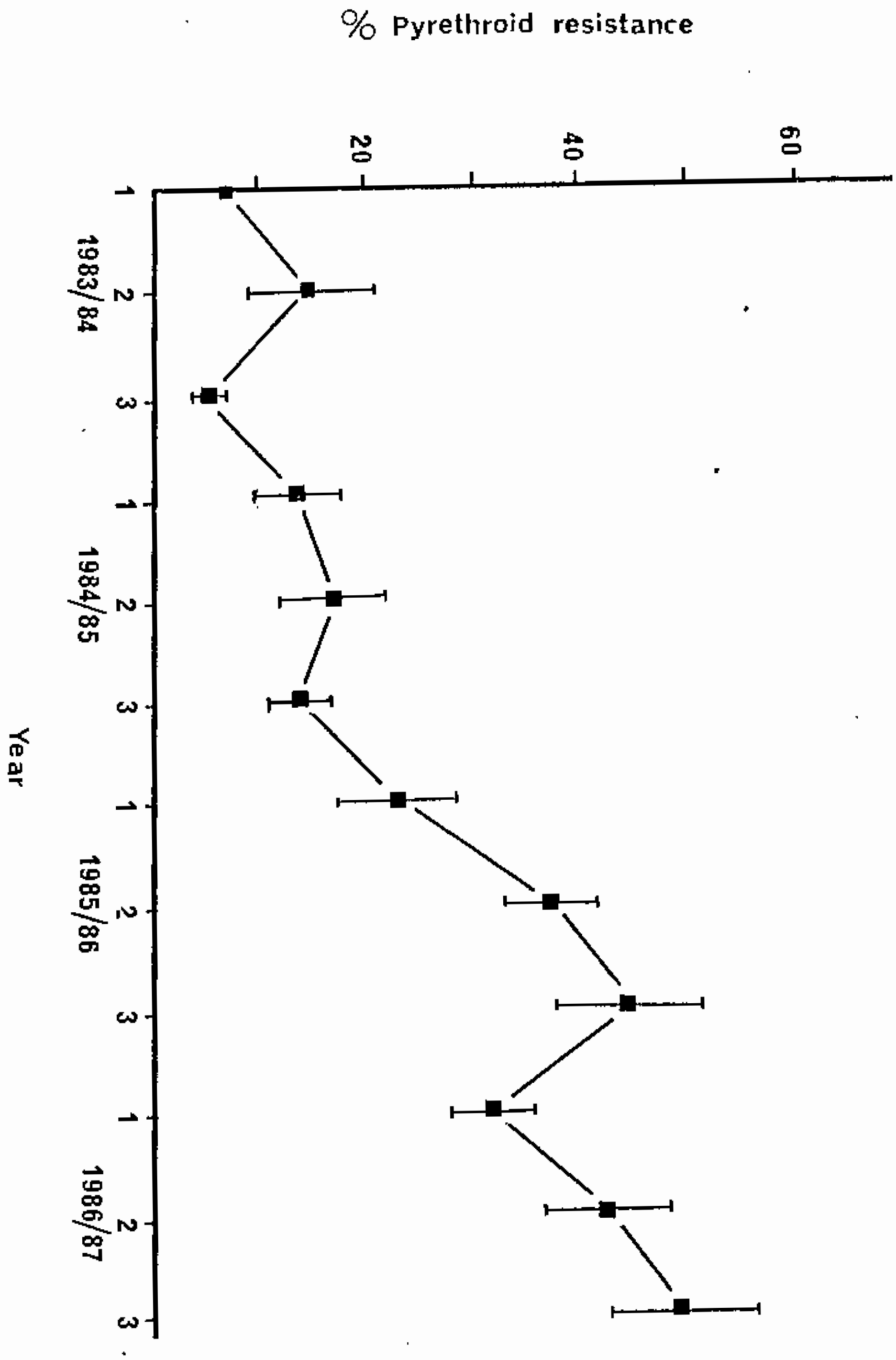

Figure 3. Endosulfan resistance in *H. armigera* in 1979-1986

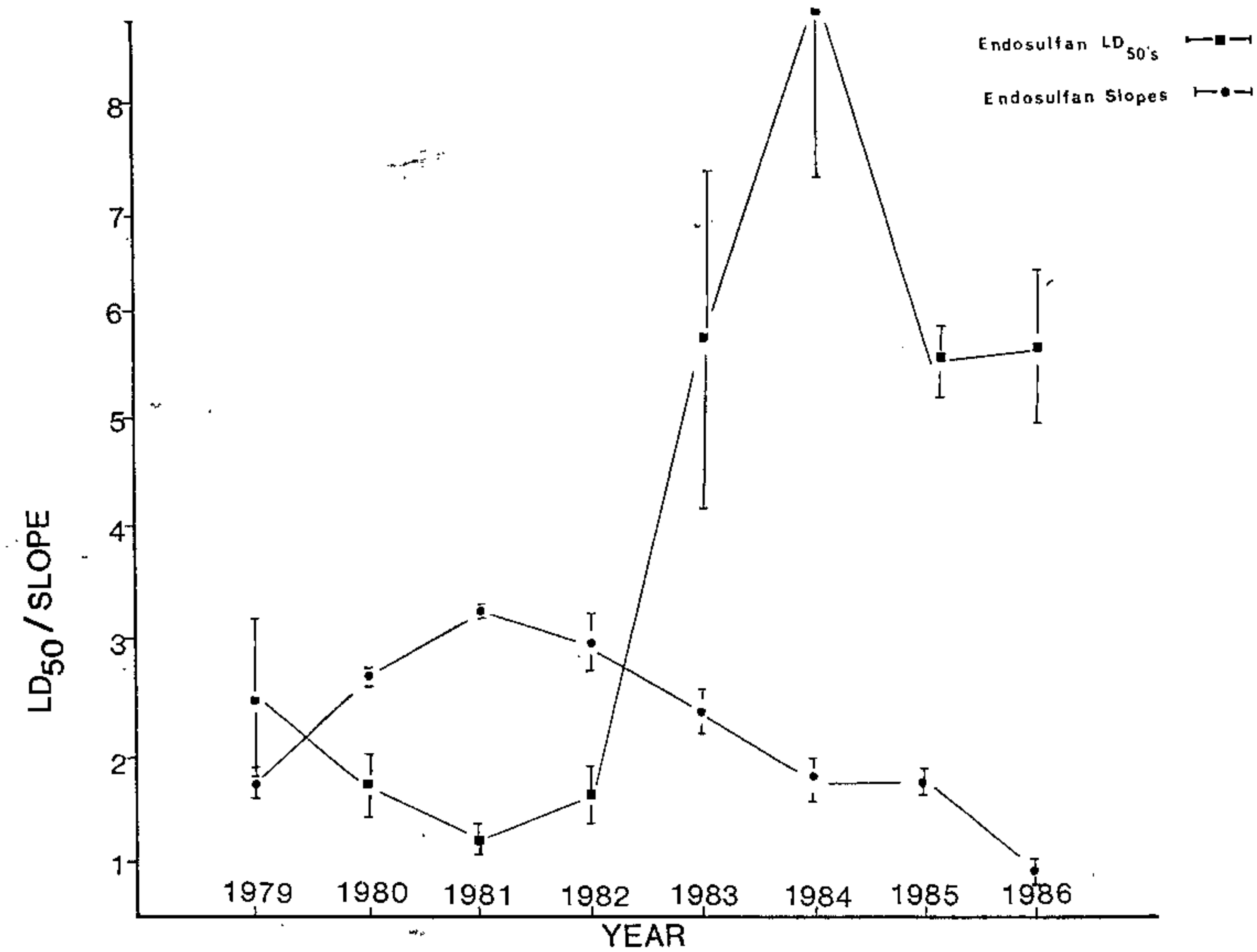

Figure 4. Toxicity of methomyl to *H. armigera* larvae 1983-1986.

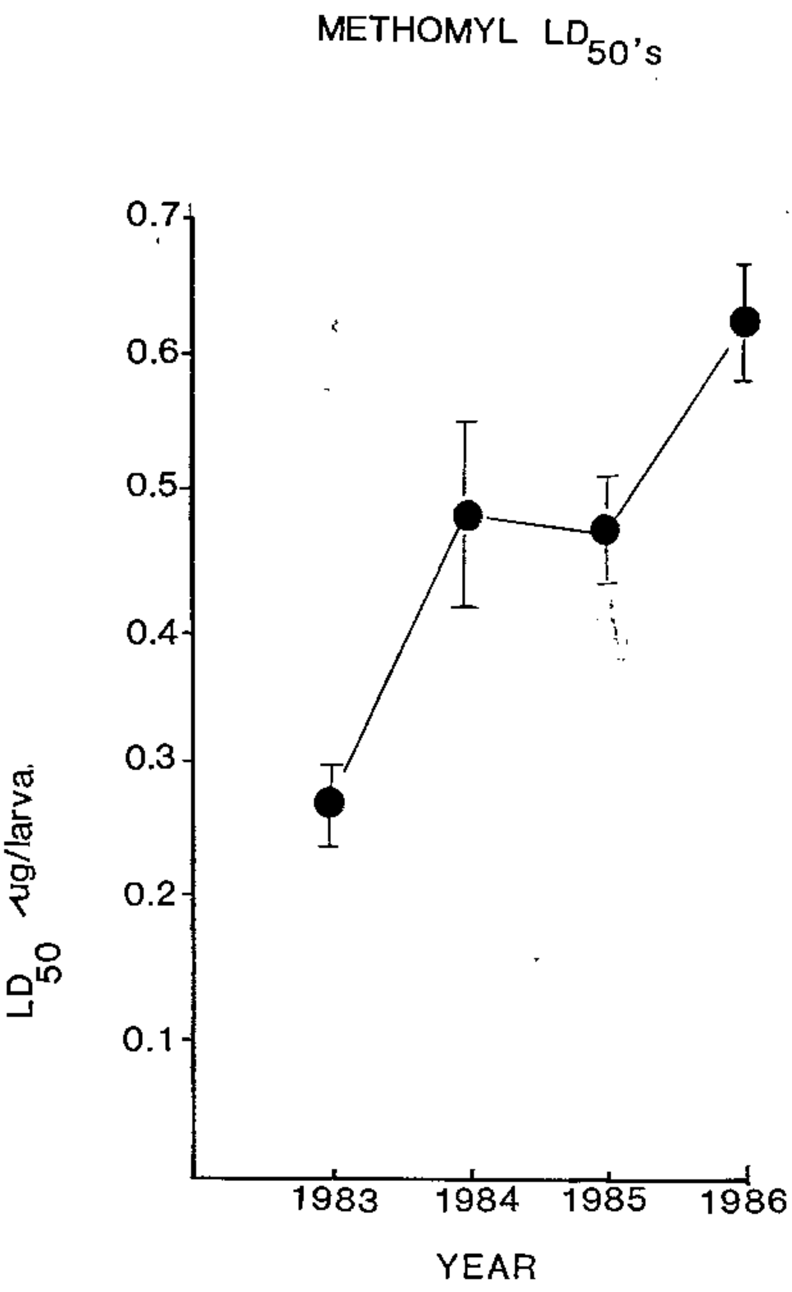

Figure 5.

Methomyl Resistance in H:armigera larvae

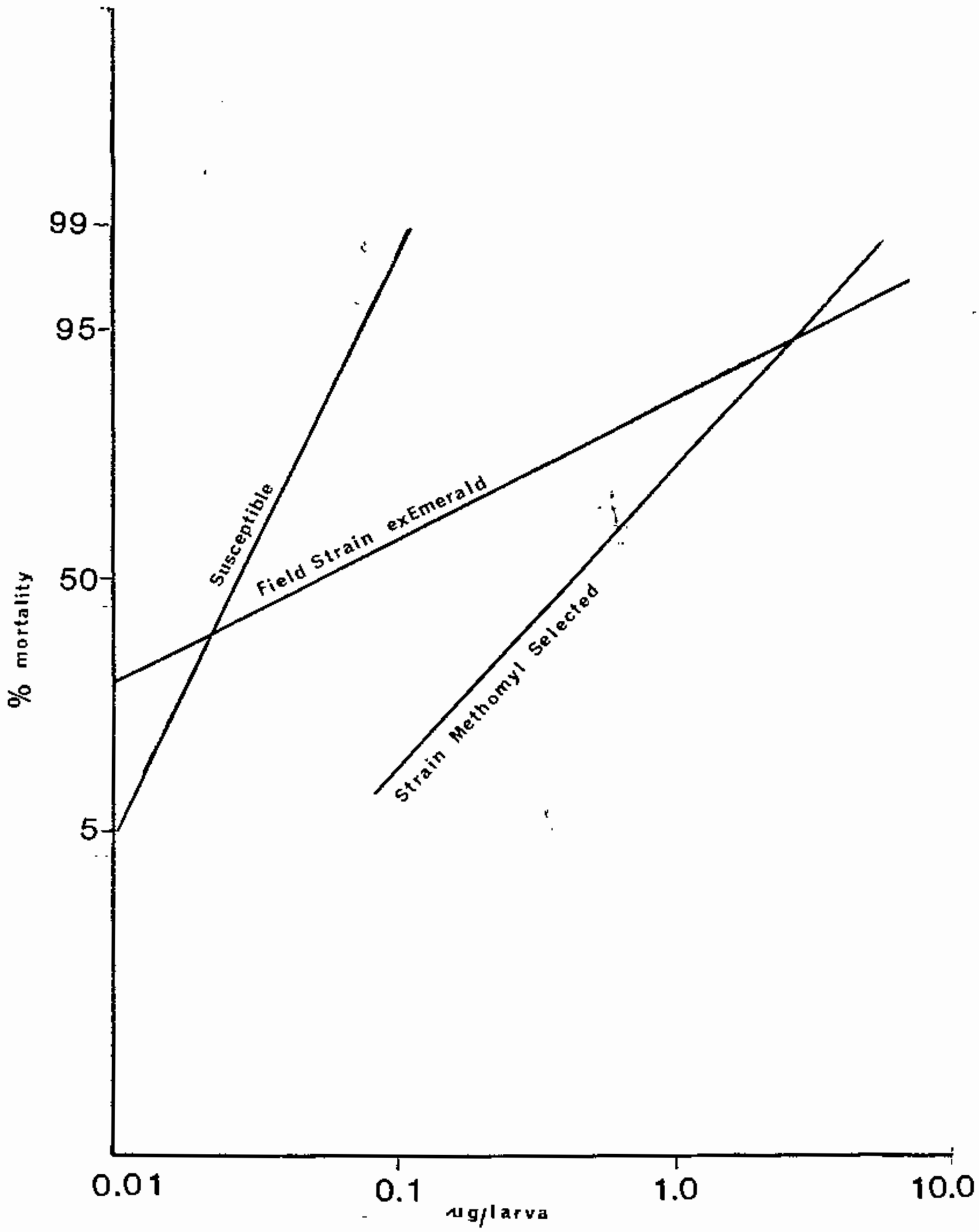

Figure 6. Toxicity of methomyl to _H. armigera_ egg. .