

**PYRETHROID RESISTANCE MECHANISMS IN
*HELIOTHIS ARMIGERA***

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Introduction

A complex of pests attacks the Australian cotton crop, none more important than the cotton bollworm, *Heliothis armigera*, and insecticides are considered necessary for its control. *H. armigera* has a long history of insecticide resistance in Australia. To DDT in the early 1970's and more recently, in 1983, to the synthetic pyrethroids. Since 1983, *H. armigera* insecticide resistance has been the subject of an insecticide resistance management program in NSW and Queensland. A knowledge of resistance mechanisms is fundamental to the resistance management strategy, so management can be targeted at avoiding or counteracting the mechanisms.

Pyrethroid resistance is common amongst insects, and resistance mechanisms are varied. The resistance mechanisms fall into three types; reduced nerve sensitivity to poisoning, reduced pyrethroid penetration through the cuticle and its enhanced metabolism. Resistance has been found, usually to be due to a combination of these factors

In this paper, we discuss our investigations of pyrethroid resistance mechanisms in *H. armigera*. We also present results of a 1987-1990 survey of the frequencies of the pyrethroid resistance mechanisms in resistant populations.

1983 Resistance Mechanisms

In 1983, at the onset of pyrethroid resistance, we found three mechanisms of resistance in *H. armigera*. Resistant larvae had reduced pyrethroid penetration, a nervous system that was less sensitive to the insecticide attack and another factor, synergisable by piperonyl butoxide (Pbo), that gave an extra degree of resistance. *Kdr* was the most important mechanism, shown by a 100% frequency in resistants and their ability to withstand injected large doses of fenvalerate. *Pen* and the *Pbo* factor, were minor factors, probably only important as modifiers of the *Kdr* resistance gene.

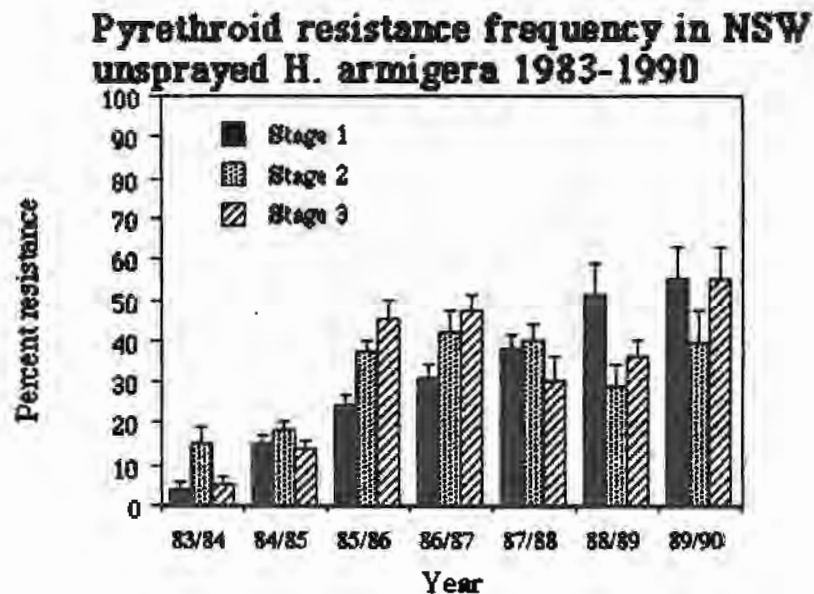
Field Survey of the frequency of pyrethroid resistance mechanisms in NSW and Queensland 1987-90

Following the 1983 diagnosis of pyrethroid resistant *H. armigera* and the identification of three resistance mechanisms, a *Heliothis* resistance management strategy was started. The strategy has restricted pyrethroid use on all crops in inland northern NSW and Queensland to approximately one of the 4-5 generations of *H. armigera* that can occur each year. The effectiveness of the strategy has been monitored by resistance monitoring and a field survey of the frequencies of resistance mechanisms in resistant individuals.

Pyrethroid resistance frequency in *H. armigera* has been monitored, via the discriminating dose technique. Following concern in 1987 about the increasing resistance frequency in NSW and Queensland (Fig. 1), a survey of pyrethroid resistance mechanisms in *H. armigera* was undertaken. Eggs and small larvae were collected throughout the summer cropping season from unsprayed NSW and sprayed populations (Namoi / Gwydir and Emerald)

and bioassayed with a discriminating dose of fenvalerate. Survivors were tested, for pyrethroid penetration resistance (*pen*) and nerve insensitivity (*Kdr*), with ^{14}C fenvalerate and via electrophysiology. The weekly *pen* and *Kdr* frequencies were counted and percentages calculated for Stages 1, 2 and 3 of the *Heliothis* resistance strategy season. The frequency of the *Pbo* factor in unsprayed NSW populations was determined, by pre-treating *H. armigera* with *Pbo* prior to application of the fenvalerate discriminating dose. Mortality, caused by the fenvalerate / *Pbo* mix, was assessed.

Fig. 1



Survey Results

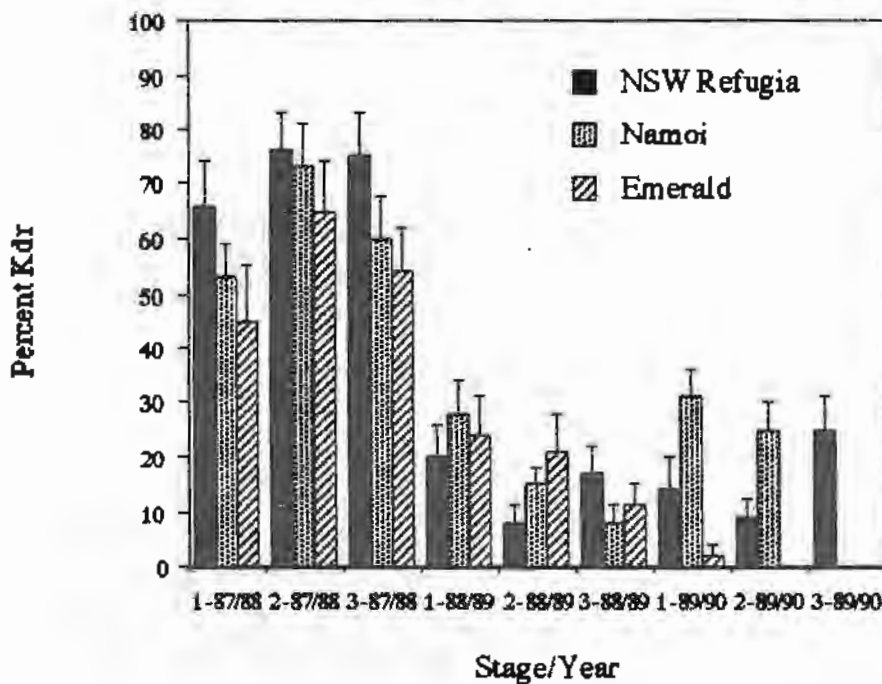
Our survey data show that there have been considerable changes in the nature and frequency of *H. armigera* pyrethroid resistance mechanisms since the resistance management strategy was begun.

Since 1983, the *Kdr* mechanism has fallen in population frequency (Fig 2), and declined in potency. In 1983, *super-Kdr* was the major cause

of resistance, but now there is only a low order, low frequency *Kdr* factor, that delays nerve poisoning and alone confers no resistance. The partial withdrawal of pyrethroid insecticides from use against *H. armigera* since 1983 has lessened the selection pressure on the *Kdr* resistance mechanism, causing the decline in its frequency.

Fig. 2

Kdr frequency in Py-R *H. armigera*



The *Pen* and *Pbo* resistance factors were present in resistant sprayed and unsprayed populations at high frequencies during 1988-90, there is some evidence of a decline in the 1989/90 season. In 1983 *Pen* and *Pbo* were minor contributors to resistance. Today, in the absence of a strong nerve insensitivity factor, *pen* and *Pbo* are responsible for the present high resistance frequencies in NSW (Fig. 1) and Queensland. Present day resistant *H. armigera* are not strongly pyrethroid resistant ($\sim x20$) compared to the 1983 strain ($\sim x100$). This supports our observations that *pen* and the *Pbo* factor do not cause high order pyrethroid resistance.

Fig. 3

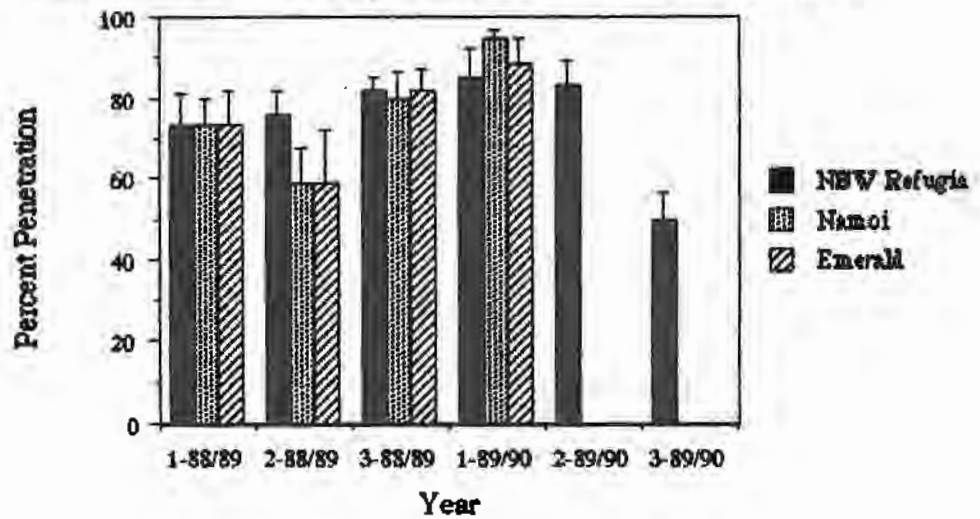
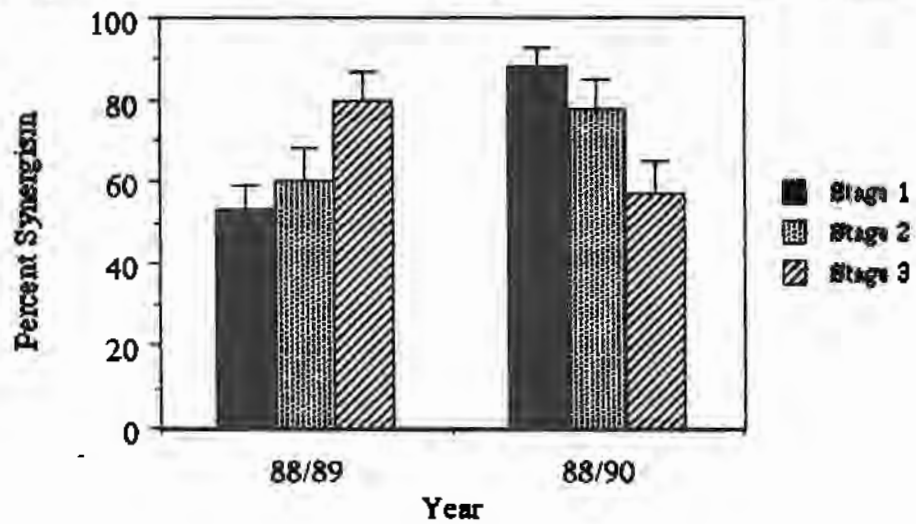
Pen resistance frequency in Py-R *H. armigera*

Fig. 4

Pbo synergism of Py-R unsprayed *H. armigera* from NSW

Our work has shown that the *Heliothis* insecticide resistance management strategy has altered the nature of the *H. armigera* pyrethroid resistance mechanisms. *Super-Kdr* has been replaced as the major resistance mechanism of by *pea* and the *Pbo* factors. These changes have coincided with increases in pyrethroid resistance frequency in the field despite decreased pyrethroid use. The increasing resistance frequency has been accompanied by the selection of *pea* and *Pbo* resistance mechanisms. The reasons for this are not clear, as cross resistance selection by other insecticides seems improbable.

By the removal of pyrethroid selection pressure, the *Heliothis* resistance management strategy has been responsible for the loss of a *Super-Kdr* mechanism. *Kdr* is normally an intractable mechanism, conferring such high order resistance that the resistants are difficult to control. *Pea* and *Pbo* although common, produce much lower order resistance in *H. armigera* and are still controlled by the normal field rates of pyrethroids. Yet the obvious dynamic nature of the *H. armigera* pyrethroid resistance system is a cause for concern. Future research must be directed toward understanding it, if adequate pyrethroid resistance management is to be maintained.