CONTAINING RESISTANCE

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Introduction

The world's population depends for survival on an adequate food and fibre supply and, as our population increases, so too, does our need to control the pests that threaten this production.

Unfortunately, recent agricultural production techniques have come to rely almost completely, on the use of insecticides for this purpose. Now we find that, as a consequence to this approach, our ability to control many of the important insect pests is seriously threatened by widespread resistance to insecticides, particularly in the warmer regions of the world. In fact, the probability that insects will exhibit resistance is the single biggest, most complex and intractable problem to the prolonged use of insecticides.

Resistance is seen as a manifestation of the most basic property of life, namely the capacity of organisms to evolve in response to changing environmental conditions and to adapt to new circumstances. Despite the detection of severe resistance as far back as the 1940's-60's, the relative abundance of new insecticides in the 1950's, 60's and 70's circumvented the need to delay or prevent resistance. New chemicals were always available to replace those to which the pests had become resistant. Only recently, has the realisation emerged that the discovery of new insecticides will not keep pace with the development of resistance in many of our major insect pest species.

What is Resistance?

The term resistance is commonly used when it is found that insects survive normally lethal doses of chemicals previously used to control them. A logical reaction to this situation is to increase the dose rate. This may be partially successful for a while. Ultimately, however, the survivors of higher doses are "more resistant" and their control poses an even greater problem.

The term "tolerance", often used in a discussion of resistance, usually refers to the natural ability of a susceptible population to the normally lethal dosages of the insecticides. As such, it is a term that is often used to describe the beginning of a resistance problem.

Why and How do Insects Become Resistant?

The development of resistance is really a response to some changes in the environment of the insect. In any insect population there is usually a great genetic diversity caused by mutations. Commonly these mutations are disadvantageous to the insect and so tend to disappear and persist at very low levels. In the case of resistance to insecticide, once the chemical has been applied, the most susceptible individuals would be killed leaving an increased proportion of resistant mutants. Continuous use of the insecticides will then lead to a build-up of these resistant individuals. Their offspring breed strains of insects which increase the number of resistant types in the population. It will be appreciated therefore, that resistance to a chemical is not developed in an insect during its lifetime. Nor is it caused by continued exposure to sub-lethal doses. Nor is it the result of genetic mutation induced by the insecticide. The potential for resistance is present before a pesticide is even used and it is an inevitable result when a particular insecticide is used continuously over a long period of time. There are two general ways in which these mutations can confer resistance:-

(i) Behavioural

(ii) Biochemical/morphological. Penetration / Metabolism / Nerve insensitivity

In the case of behavioural resistance some species can evade treatments by hiding or avoidance. This is not recognised as a common mechanism of resistance.

More importantly, the resistant insect can render the insecticide harmless. This can be done firstly by allowing minimum penetration of the organic insecticides through the insect's cuticle (skin). In nature, insects have to contend with an extreme range of naturally occurring toxicants and so, in general, have evolved a very effective screen to them. Secondly, there can be an increase in the natural metabolic activity of the insect which could completely detoxify the poison. Most insecticides have low water solubility and conversion to a water soluble type often facilitates their excretion from the insect. This action is brought about by altered enzymes or amounts of detoxifying enzymes. Finally, resistance can be associated with the altering of the structure of the nervous system (most modern day insecticides are nerve poisons) to decrease its senstivity to the insecticide (also known as Kdr or Knock down resistance).

Resistance levels conferred by individual mechanisms vary enormously, from those barely detectable with sensitive techniques to others conferring virtual immunity. From a practical point of view, resistance is a problem only when the cost of control becomes unjustified, or when excessive use of the control agent presents health and environmental hazards. Thus, levels of resistance unacceptable in practice are very variable, and are rarely specified precisely.

For the pyrethroid resistance in *H. armiger* it would seem that all three mechanisms are involved. However, if the data from other insect species can be taken as a guide there is a strong possibility that the present resistance problem could be associated with a Kdr-like mechanism, presumably selected through widespread and prolonged use of DDT. In other words, the pyrethroid resistance could be conferred because of cross-resistance associated with the use of other products and not through the prolonged use or misuse of the pyrethroids.

The present situation as has evolved in Australia, is surely an example of why the introduction of a new insecticide should not be gauged simply on relatively short term economic or environmental factors.

The Development of Resistance

The actual development of the resistance trait in field populations depends on many complex interactions between the insect, the insecticide we use and the area in question. Basically, the potential for an insect such as *H. armiger* to develop resistance depends on the length of the life cycle, the reproductive potential of the pest and its movement or migratory habits. The nature of the inheritability of the resistance and the fitness

(1) Genetic
(2) Biological
a) Biotic
b) Behavioural
(3) Operational
a) Chemical
b) Application

of the resistant type also play a part. All these factors are really outside our control. However, the type of the insecticide use and the rate of application are but a couple of the many factors that man does control, which can affect the development of resistance.

Counteracting Resistant Populations

Counteracting resistance problems can be seen in several ways. The first of these involves the use of alternative insecticides. This can be useful if there is no cross resistance operating between the two groups in question. In this case then the alternative insecticide must have either a different mode of action, or a different method of detoxification in the insect. Synergists have been useful in limiting the resistance problem. The synergists principally act by stopping the activity of some of the normal enzymatic detoxification processes. By stopping these, the insects are then left to contend with the insecticide before it is detoxified. Unfortunately, most synergists are not available for use under field conditions. Furthermore, it would seem that, enzymatic metabolism of the pyrethroids is not the main mechanism of resistance involved with *H. armiger*, the success of the use of synergists may not be promising. The use of mixtures is an idea brought in several years ago and has some promise as a delaying process so far as the evolution of possible resistance is concerned. Basically, the success of this program relies on the unlikely event that an individual will exist in the pest population which is resistant to both of the chemicals used in the mixture.

The final countermeasure involves the rotation of insecticides. The success of this technique further assumes that the individuals resistant to any one of the insecticides involved in the rotation, have a low level of fitness compared to the susceptible types, thereby helping to reduce the frequency of the resistant gene in the period before the next application of this insecticide.

Australian Strategy

Unfortunately, the development of any reliable resistance strategy must be built on a knowledge of the mode of action, mechanism of resistance and its genetic control. With a couple of exceptions, such details are completely unknown for most insects and particularly for most of the major agricultural pests in the world. Even more importantly, the implementation of any such strategy relies heavily on a good understanding of the biology and ecology of the insect. For the local situation, much of this type of information is not available in any great detail and the format of the strategy must be regarded as flexible to allow for new information as it comes to hand.

The strategy to limit the further development of resistance to pyrethroids in Australia is, in a way, of the rotation type. Basically, it attempts to limit the period during which pyrethroid selection can take place, to only one generation of the four or five generations that may occur in the area. Furthermore, the selection of the period during which pyrethroids can be used often ensures that any subsequent generations of *H. armiger* will be subjected to insecticides of other chemical groups, principally the organophosphates to which no real cross resistance factor has yet been described. In limiting the use of pyrethroids, the value of this insecticide group in *Heliothis* control has been duly acknowledged, with the pyrethroid use period coinciding with the time when a majority of the crops in the area are at a most vunerable stage to uncontrollable insect attack.

The strategy also specifically addresses a potential problem of cross resistance between endosulfan and the pyrethroids. In cotton, where endosulfan is used frequently (and even more so when the availability of pyrethroids is limited), the generations of *H. armiger* following the pyrethroid use period, are no longer subjected to endosulfan pressure. For the 1984/85 season, there has been some even further restriction on the use of endosulfan.

But, whilst the strategy particularly addresses the problem of pyrethroid resistance, it does create a forum through which the concept of insecticide management can be pursued. It is now most obvious that good insecticides, and particularly groups of insecticides, are a very scarce commodity. Any attempt to negotiate a strategy to limit the possible development of resistance to any insecticide then should be given top priority by all involved parties. The strategy should be based primarily, on the technical evidence available at the time. Whilst other considerations may be involved to ensure widespread acceptance of any strategy, it must be ensured that modifications do not compromise this technical base.

STRATEGIES
(1) Manag. by Moderation – level – frequency
(2) " " Saturation – High Dose
(3) " " Multiple Attack

In conclusion, it is worth pondering over just how much we rely on the present day insecticides to produce our crop. The problems posed by resistance are unlikely to become less serious and probably could get out of hand unless steps are taken now to reduce the dependence on conventional chemical control. Common sense suggests that the most obvious way of slowing down resistance build-up is to use insecticides judiciously, and to rely on other forms of control to help prevent crop losses. Unfortunately, these alternatives are not always cheap or simple to use. Modern agriculture is virtually impossible without insecticides, so it is essential to prolong the life of the insecticides we do have by ensuring their judicious and rational use.