VEGEnotes
Your levy @ work

Pesticide resistance management

Insecticide resistance is a problem of modern agriculture. Since the 1950s and the introduction of synthetic organic insecticides, insect resistance to insecticides has required more frequent applications, higher doses and the substitution of newer, more expensive compounds.

While chemical insecticides remain the mainstay method of pest control (and they will continue to into the foreseeable future), resistance will continue to threaten sustainable agriculture.

Insecticide resistance is an evolutionary phenomenon caused by a genetic change. It results directly from insecticide use and its evolutionary selection for resistance. Management requires the slowing and preferably stopping of resistance. Resistance management currently aims to reduce the resistant individual's fitness when insecticide is applied or reduce the total amount of selection pressure applied.

Effective resistance management is complex, requiring the integration of many disciplines including pest ecology, farming systems and crop/pest phenology, bioassay, statistics, chemistry, application technology, formulation technology, biochemistry and most recently molecular biology. For this reason, resistance management is often best tackled by a team. The amalgamation of the various disciplines is essential to understand the many aspects of the evolutionary process and to implement successful resistance management.

With the progressive introduction of more stringent government regulations worldwide, insecticide development costs have increased exponentially and chemical development has slowed.

Tanya James, Technical Officer Scientific, prepares to test thrips for insecticide resistance with the aid of a Potter precision spray tower.

It was clear by the 1960s that there would be a time when there would be no chemicals left to control specific pests without documented resistance. This occurred in Australian horticulture for the two-spotted mite in the late 1980s, western flower thrips in the early 1990s and melon (cotton aphid) in the late 1990s.

The Bottom Line

- **Resistance management is a National, across comodity issue.**
- **Synergists can help in the fight against resistance.**
- **Resistance management is best tackled by a team.**
- **Monitoring is a vital element of any resistance management program.**
- **Resistance management programs evolve over time.**

Summer 2005

Williams Pears were made uneconomic when cyhexatin resistance was first dected in twospotted mite and replacement chemistry was still being developed.

Resistance in these three major agricultural pests has caused whole cropping systems to be abandoned. The sustainability of modern agriculture is now intricately linked to effective resistance management.

The rapid development of insecticide resistance to various pesticides after 1950 stimulated an interest in the genetic basis of resistance. Some consider that understanding the genetics of resistant mite populations will allow the development of improved integrated controls.

Studies of the genetic basis of resistance in insects and mites are often complicated by their method of reproduction. For instance, the major agricultural pests, two-spotted mite and western flower thrips, reproduce through virgin-birth (males are not needed for reproduction), which may favour the rapid development of resistance.

In this method of reproduction virgin females produce eggs that develop into males, while mated females deposit a mixture of eggs that develop into males and females. Male offspring always possess the genotype of the mother.

The degree of fertilisation or non-fertilisation determines the sex ratio of the offspring.

For managing resistance, it is important to know how dominant or recessive the resistance is, as well as the number of genes involved.

A completely recessive resistance allele will increase in a population at a much slower rate than the dominant allele.

It has long been considered that resistant genotypes must be at some fitness disadvantage, however small.

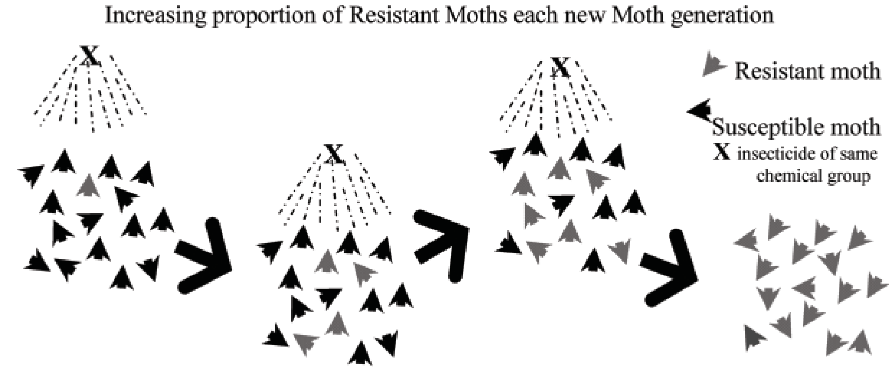
In the absence of the test pesticide or resistant alleles this would be very common prior to selection. The relative fitness of each genotype is environment dependent.

In the presence of pesticide the resistant genotype has a selective advantage over the susceptible. Conversely, newly evolved resistant strains reportedly show disadvantages in the absence of selection.

If pesticide use continues until resistance is widespread, it is probable that resistant genotypes, with high fitness, will evolve making reversion unlikely when pesticide use is discontinued.

Most fitness studies compare the resistant genotype with the susceptible genotype. However, it is more critical to know if differences in fitness exist. This is because heterozygotes will be the most common carriers of resistance during the early stages of its development.

Arthropods have three basic resistance mechanisms: decreased cuticular penetration, increased metabolic detoxification, and target site insensitivity. Decreased cuticular penetration usually confers resistance



Insecticide resistance develops in target insects when a larva carrying a resistance mutation survives the application of a particular insecticide and subsequently breeds as a resistant insect. If a large proportion of the breeding population is then exposed to an insecticide of the same group, then selection for the resistance mutation will increase and the population of resistant insects will increase with time.

Source: McDougall, Sandra (2002) Integrated Pest Management in Lettuce: Information Guide.

levels less than three times. However, it is to a wide range of compounds and probably only delays the onset of symptoms.

Enzymatic detoxification is achieved by mono-oxygenases, hydrolases, glutathione-S-transferases and DDTases. Target site insensitivity reduces the amount of toxin reaching the vulnerable target.

Target site insensitivity is common in pyrethroid and organophosphorus pesticide resistance. Organophosphate insensitivity involves alterations of acetylcholinesterases, leading to decreased sensitivity to acetylcholinesterase inhibitors. Another mechanism of organophosphorus insecticide resistance is increased metabolism of insecticides, which can often be blocked by adding synergists. Synergists are compounds that enhance the toxicity of a pesticide, although they are relatively non-toxic.

Jeanette Rophail, Senior Technical Officer, scores a resistance test under a stereo microscope.

Synergists can be useful when comparing susceptible and resistant strains. By testing the response to the test chemical with or without synergist, it may be possible to narrow down which metabolic pathway is involved in the resistance. Synergism data can then be confirmed with biochemical assays.

This is essential when selecting alternative chemicals. For example, as pyrethroids are often detoxified by mono-oxygenases, a pyrethroid would not be selected as an alternative chemical if the established resistance mechanism involved mono-oxygenases. Adding the appropriate synergist to the particular pesticide may render the resistance mechanism ineffective.

Rick Roush defines resistance management as “the use of methods that extend the number of generations that a given pest population can be controlled economically by a pesticide”. An earlier management strategy proposed by Georghiou was based on insecticide use, and divided management into three use categories:

1. Moderation (dosage to give less than 100% mortality of susceptibles);
2. Saturation (overwhelm the resistance mechanism with high doses or synergists);
3. Multiple attack (mixing or alternating pesticides).

Later strategies, such proposed by Roush, consider resistance management from a genetics perspective and consider underlying genetic similarities in pesticide use, rather than how pesticides are employed (operational factors). They propose ten management strategies to either reduce the fitness of resistant individuals or reduce total selection pressure:

1. Increase insecticide dose to kill heterozygotes or resistant homozygotes;
2. Use compounds that confer lower levels of resistance;
3. Treat the most vulnerable life stage of the pest;
4. Use synergists to suppress detoxification mechanisms;
5. Mix pesticides with differing modes of action and metabolism;
6. Decrease concentration of insecticide to ensure some of the susceptible individuals exposed to the pesticide survive;

7. Reduce the number of pesticide applications;
8. Use pesticides with short residual activity and avoid slow release formulations;
9. Use spot treatments;
10. Rotate pesticides so not all generations are exposed to the same chemical.

The implementation of such strategies can require very detailed information to be effective. The whole strategy requires that the heterozygotes are killed by the pesticide. However, without detailed knowledge of the genetics of resistance it may be difficult to work out what the dose should be, and if all the heterozygotes are not killed, resistance is aggravated.

This strategy also requires that susceptibles migrate from a refugium to breed with the surviving resistant homozygotes, thus diluting resistance. Without immigration, resistance is again exacerbated. Additionally, it is necessary to know the reproductive potential of the pest, because this management strategy is not effective against pests with high reproductive potential.

Even so, resistance management programs can be effectively implemented based on relatively little information. As more information on the pesticide and pest becomes available, the initial resistance management program can be improved and fine tuned. Roush believes a resistance management program can evolve over time, without ever making a serious error in recommendations.

This is certainly the case for western flower thrips management, where resistance management was implemented without resistance being confirmed.

Resistance monitoring then detected ubiquitous pyrethroid resistance and subsequently the management strategy was changed so pyrethroids were no longer recommended.

Monitoring still underpins the recommended resistance management strategy for western flower thrips. Abamectin, methiocarb and pyrazophos are now the only chemicals recommended for use against western flower thrips for which resistance is not detected.

Unfortunately, monitoring has recently detected resistance to the Group 2B GABA gated compound fipronil and the Group 5 acetylcholine receptor modulator spinosad.

This research has shown that, except for the newly emerging fipronil and spinosad resistances, there is little variation in response to the older chemistries between crops. This possibly relates to these resistances already being present in the western flower thrips that arrived in Australia.

The practical outcome is that individual industry sectors (e.g. vegetables, ornamentals, cotton etc) cannot isolate themselves when considering western flower thrips, and resistance management should continue to be considered on a national and across-commodity basis.

Further Reading

G.P. Georghiou and T Saito eds (1983) Pest Resistance to Pesticides. Plenum Press, NY

R.T. Roush and Tabashnik, B.E. eds (1990) Pesticide Resistance in Arthropods. Chapman and Hall, NY.

Acknowledgements

Grant Herron PhD
Senior Research Scientist
(Insecticide Resistance)
NSW Department of Primary Industries
grant.herron@dpi.nsw.gov.au

NSW DEPARTMENT OF
PRIMARY INDUSTRIES

ISSN: 1449 - 1397

VEGE*notes* is coordinated, edited & printed by:
ARRIS Pty Ltd, ph 08 8303 7247 fax 08 8303 6752

Level 1, 50 Carrington Street
Sydney NSW 2000 Australia
Telephone (02) 8295 2300
Facsimile (02) 8295 2399
www.horticulture.com.au

HAL
Know-how for Horticulture™