Insecticide Resistance: Causes and Action

A joint effort between the Southern Region Integrated Pest Management Center and the Insecticide Resistance Action Committee

Mode of Action (MOA) Initiative

Resistance to insecticides was first documented by A. L. Melander in 1914 when scale insects demonstrated resistance to an inorganic insecticide. Between 1914 and 1946, 11 additional cases of resistance to inorganic insecticides were recorded. The development of organic insecticides, such as DDT, gave hope that insecticide resistance was an issue of the past. Unfortunately, by 1947 housefly resistance to DDT was documented. With the introduction of every new insecticide class – cyclodienes, carbamates, formamidines, organophosphates, pyrethroids, even *Bacillus thuringiensis* – cases of resistance surfaced within two to 20 years.

Colorado Potato Beetle

Genetics and intensive application of insecticides are responsible for the rapid development of resistance in many insects and mites. Selection by an insecticide allows some insects with resistance genes to survive and pass the resistance trait on to their offspring. The proportion of resistant insects in a population continues to increase as the susceptible insects are eliminated by the insecticide. Eventually, resistant insects outnumber susceptible insects and the insecticide is no longer effective.

The rate at which insecticide resistance develops depends on several factors, including how rapidly the insects reproduce, the insects' level of resistance, the migration and host range of the insects, the insecticide's persistence and specificity, and the rate, timing and number of applications of insecticide made. Resistance increases faster in situations such as greenhouses, where insects or mites reproduce rapidly, there is little or no immigration of susceptible insects and growers may spray frequently with the same insecticide or insecticides from the same chemical class.

Insecticide resistance adds to the total insecticide bill due to additional treatment costs and lost yields. Better season-long management of pesticides by growers and the crop experts assisting them can reduce this bill and lead to more effective use of insecticide products. Furthermore, insects have developed widespread resistance to many traditional insecticides, and the industry may not have enough resources to continually develop and supply the market with new insecticide products to replace older ones. Growers with resistance problems do not have the time to wait for new chemistries. It is imperative that the effectiveness of available insecticides be conserved by growers through adoption of insecticide resistance management practices.

Whitefly

What Causes Insecticide Resistance?

Insecticide resistance is a reduction in the sensitivity of an insect population to an insecticide. This is reflected in repeated failure of an insecticide to achieve the expected level of control of insects when used according to the product label recommendations and where problems of product storage, application and unusual climatic or environmental conditions can be eliminated as causes of the failure. There are several ways insects can become resistant to crop protection products, and pests often exhibit more than one of these mechanisms at the same time.

- **Behavioral resistance.** Resistant insects may detect or recognize a danger and avoid the toxin. This mechanism of resistance has been reported for several classes of insecticides, including organochlorines, organophosphates, carbamates and pyrethroids. Insects may simply stop feeding if they come across certain insecticides, or leave the area where spraying occurred (for instance, they may move to the underside of a sprayed leaf, move deeper in the crop canopy or fly away from the target area).
- **Penetration resistance.** Resistant insects may absorb the toxin more slowly than susceptible insects. Penetration resistance occurs when the insect's outer cuticle develops barriers which can slow absorption of the chemicals into their bodies. This can protect insects from a wide range of insecticides. Penetration resistance is frequently present along with other forms of resistance, and reduced penetration intensifies the effects of those other mechanisms.
- **Metabolic resistance.** Resistant insects may detoxify or destroy the toxin faster than susceptible insects, or quickly rid their bodies of the toxic molecules. Metabolic resistance is the most common mechanism and often presents the greatest challenge. Insects use their internal enzyme systems to break down insecticides. Resistant strains may possess higher levels or more efficient forms of these enzymes. In addition to being more efficient, these enzyme systems also may have a broad spectrum of activity (i.e., they can degrade many different insecticides).
- **Altered target-site resistance.** The site where the toxin usually binds in the insect becomes modified to reduce the insecticide's effects. This is the second most common mechanism of resistance.

What Can You Do About Insecticide Resistance?

The best strategy to avoid insecticide resistance is *prevention*. More and more pest management specialists recommend insecticide resistance management programs as one part of a larger integrated pest management (IPM) approach.


Corn Earworm (Cotton Bollworm)

- **Monitor pests.** Scouting is one of the key activities in the implementation of an insecticide resistance management strategy. Monitor insect population development in fields (with the assistance of a crop consultant or advisor if necessary) to determine if and when control measures are warranted. Monitor and consider natural enemies when making control decisions. After treatment, continue monitoring to assess pest populations and their control.
- **Focus on economic thresholds.** Insecticides should be used only if insects are numerous enough to cause economic losses that exceed the cost of the insecticide plus application. An exception would be in-furrow, at-planting treatments for early season pests that usually reach damaging levels each year. Consult local crop advisors about economic thresholds for target pests in your area.
- **Take an integrated approach to managing pests.** Use as many different control measures as possible. Effective IPM-based programs will include the use of synthetic insecticides, biological insecticides, beneficial arthropods (predators and parasites), cultural practices, transgenic plant varieties, crop rotation, pest-resistant crop varieties and chemical attractants or deterrents. Select insecticides with care and consider the impact on future pest populations and the environment. Avoid broad-spectrum insecticides when a narrow-spectrum or more specific insecticide will work.
- **Time applications correctly.** Apply insecticides when the pests are most vulnerable. For many insects this may be when they have just emerged. Use application rates and intervals recommended by the manufacturer or a local pest management expert (i.e., university insect management specialist, county Extension agent, or crop consultant).
- **Mix and apply carefully.** As the potential for resistance increases, the accuracy of insecticide applications in terms of dose, timing, coverage, etc. assumes greater importance. The pH of water used to dilute some insecticides in tank mixes may need to be adjusted to the product manufacturer's specifications. In aerial application, the swath widths should be marked, preferably by permanent markers. Sprayer nozzles should be checked for blockage and wear, and should be able to handle pressure adequate for good coverage. Spray equipment should be properly calibrated and checked on a regular basis. In tree fruits, proper and intense pruning will allow better canopy penetration and tree coverage. Use application volumes and techniques recommended by the manufacturers and local crop advisors.
- **Alternate different insecticide classes.** Avoid the repeated use of the same insecticide or insecticides in the same chemical class, which can lead to resistance and/or cross-resistance[(1)]. Rotate insecticides across all available classes to slow resistance development. In addition, do not tank-mix products from the same insecticide class. Rotate insecticide classes and modes of action (see Insert(s)), consider the impact of pesticides on beneficial insects, and use products at labeled rates and spray intervals.
- **Protect beneficial arthropods.** Select insecticides in a manner that is the least damaging to populations of beneficial arthropods. For example, applying insecticides in-furrow at planting or in a band over the row rather than broadcasting will help maintain certain natural enemies.
- **Preserve susceptible genes.** Preserve susceptible individuals within the target population by providing a haven for susceptible insects, such as unsprayed areas within treated fields, adjacent "refuge" fields, or habitat attractions within a treated field that facilitate immigration. These susceptible individuals may outcompete and interbreed with resistant individuals, diluting the resistant genes and therefore the impact of resistance.
- **Consider crop residue options.** Destroying crop residue can deprive insects of food and overwintering sites. This cultural practice will kill insecticide-resistant pests (as well as susceptible ones) and prevent them from producing resistant offspring for the next season. However, review your soil conservation requirements before removing crop residue.

[(1)] Cross-resistance occurs when a population of insects that has developed resistance to one insecticide exhibits resistance to one or more insecticide(s) it has never encountered. Cross-resistance is different from multiple resistance, which occurs when insects develop resistance to several compounds by expressing multiple resistance mechanisms.

How Do You Properly Alternate Insecticides to Avoid or Delay Resistance?

Diamondback Moth Larvae

Effective insecticide and miticide resistance management (IRM) strategies seek to minimize the selection for resistance from any one type of insecticide or miticide. In practice, alternations, sequences or rotations of compounds from groups with different *modes of action* can provide a sustainable and effective approach to IRM (i.e., where resistance results from altered target sites in the insect). This ensures that selection from compounds in the same mode-of-action group is minimized. Applications are often arranged into mode-of-action spray windows or blocks that are defined by the stage of crop development and the biology of the pest(s) of concern. Follow local expert advice with regard to spray windows and timings. Several sprays of a compound may be possible within each spray window but it is generally essential to ensure that successive generations of the pest are not treated with compounds from the same mode-of-action group.

Western Corn Rootworm

Insert(s) contains a classification scheme developed and endorsed by the industry-organized Insecticide Resistance Action Committee (IRAC) based on mode of action. It is the aim of IRAC to make insecticide and miticide users aware of mode-of-action groups and to have a sound basis on which to implement season-long, sustainable resistance management through the effective use of sequences of insecticides with different modes of action. To delay resistance, growers should also integrate other control methods into insect or mite control programs.

For more information on insecticide resistance management, contact your local county Extension agent, Land-grant university insect management specialist, or the Insecticide Resistance Action Committee website at: http://www.irac-online.org

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