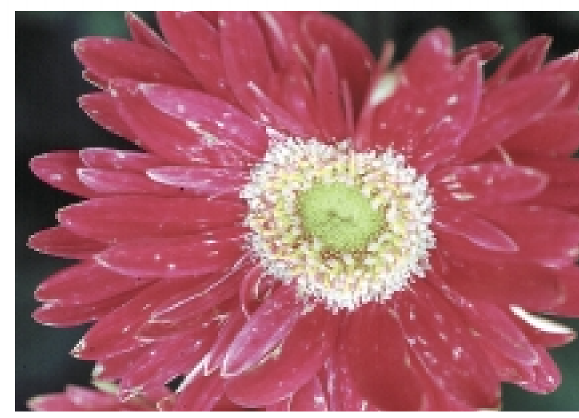
A New Mode of Resistance Management



Western flower thrips (center) quickly develop resistance with repeated chemical use, causing unsalable plants with brown spots, on anthurium (l), and flower damage, on gerbera (r).

With insecticide numbers shrinking and population resistance growing, resistance management is more important than ever. A new method of rotation could be the solution we've all been waiting for.

By Jim Bethke

The management of insecticide resistance is a somewhat controversial subject, and not because we are ignorant of the problem. In fact, scientists have a good handle on the mechanisms of pesticide resistance development. It is controversial because scientists do not have a good handle on the solutions to insecticide resistance. At several recent conferences, there were varying opinions on the subject, with many extension scientists begging for answers they could take to growers. The growers, like my uncle in suburban Seattle, just want the pests dead and gone — although my uncle wants them to suffer and, with their last dying breath, tell their bug buddies never to return.

Professional opinions on the best way to manage insecticide resistance range from those that suggest we need to stop using pesticides altogether to those that recommend tank-mixing the most efficacious products. Of course, these two examples are at the extremes and neither is likely to be an appropriate solution, especially in the world of ornamentals where nothing is simple. Few studies have actually tested the theories of insecticide resistance in practical applications. So in most cases, people can only make educated guesses at which strategies should work best for each product and each pest.

Through the 1990s, more detailed investigations of the mechanisms involved in pesticide resistance have shown that insects have an innate ability to develop resistance to most pesticide chemical classes, and some insects have the ability to develop resistance to many classes simultaneously. Everyone is aware of the classic example of cross-resistance between carbamates and organophosphates. However, with the development of new insecticide chemistries, new forms of cross-resistance (resistance to more than one pesticide with the same or similar mode of action) and multiple-resistance (resistance to two or more pesticides with different modes of action) have been exhibiting themselves, such as multiple-resistance to both a chitin synthesis inhibitor and a carbamate or an imidacloprid resistant whitefly that is more tolerant to bifenthrin. Many of the highly resistant insects we see today are a result of overuse or off-label use of pesticides.

So why is insecticide resistance management important, especially since it seems so difficult? Primarily because the number of pesticides registered is dwindling, and the cost and time required to develop and register new ones is high. In addition, resistance management is important to manufacturers so that their products have a long life in the industry. Therefore, they are imposing user restrictions on the label or recommending a specific IPM program on the label to delay or reduce the chance of resistance buildup.

Table 1. The mode of action or method of kill for some of the common chemical classes of insecticides.

Chemical class	Mode of Action	Common Name	Trade Name
Carbamates	Acetylcholine esterase inhibitor	carbaryl	Sevin
Organophosphates	Acetylcholine esterase inhibitor	acephate	Address, Orthene TT&O, Pinpoint, 1300 Orthene TR
Pyrethrins/Pyrethroids	Depolarizes the sodium (NA^+) channel	permethrin	Astro
Chloronicotines	Acetylcholine mimic	imidacloprid	Marathon
Spinosyns	Induces acetylcholine activity	spinosyns	Conserve
Glycoside	GABA inhibitor	abamectin	Avid
Insect Growth Regulators	Juvenile hormone mimics Chitin synthesis inhibitors	fenoxycarb	Preclude TR, Precision IGR
Microbials	Varies/includes insect diseases	BTs/Beauvaria	Naturalis-T&O, BotaniGard
Oils and Soaps	Desiccates and suffocates	Insecticidal soap	M-Pede

CLASSIFYING CHEMICALS

Understanding insecticide resistance management requires some knowledge of pesticide chemistry and mode of action. The actual chemical structure, or molecular structure, of the active ingredient in the pesticide determines the chemical class. Unfortunately, the chemical class is not on the pesticide label, and in many cases it is not on the MSDS. Researchers have been telling growers to rotate by chemical class for a long time, but until recently, there's not been an easy way to identify a pesticide's chemical class. This information is available from many sources, including Olympic Horticultural Products' Chemical Class Chart, various Web sites and the *GPN Resource and Buyer's Guide*. The EPA has been listening and now has an extensive chemical class list for pesticides used in the industry (see appendices, http://www.epa.gov/opppmsd1/PR_Notices/).

The mode of action is the mechanism by which the pesticide kills the pest. The reason for suggesting rotation based on chemical classes is that the chemical class usually denotes the mechanism of action of the pesticide, i.e., the way the chemical works (See Table 1, page 34) It is important to note, however, that it is possible for different chemical classes to have the same or similar modes of action, such as with organophosphates and carbamates. Back-to-back rotation of these chemical classes would not be recommended. For a more technical description of insecticide mode of action, see the following Web site: http://ipmworld.umn.edu/chapters/bloomq.htm.

Figure 1, above, is a simple representation of the nervous system in animals. Nerve cells are connected by synapses. The nerve impulse moves along the axon (sodium NA+ and chlorine CL^- channels) until it reaches the synapse and Acetylcholine (ACh) is produced to carry the impulse to the next nerve cell. Once the Acetylcholine has done its job, it is metabolized by Acetylcholine esterase (AChE) to empty the synapse for the next nerve impulse. You will note that the majority of the modes of action listed in Table 1, page 34, affect the nervous system in some way.

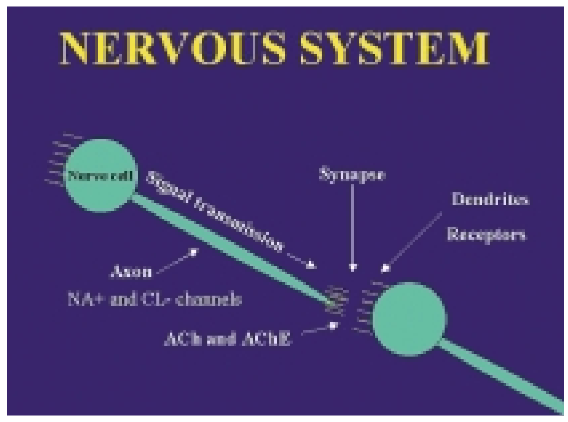


Figure 1. Simple representation of the nervous system in animals. Most insecticides affect the nervous system, usually through ACh or AChE production.

Top: Magnified image of a spider mite. Bottom: Spider mite webbing, such as this on marigolds, signals a severe infestation, at which stage most insecticides become ineffective.

MECHANISMS OF RESISTANCE

Resistant pest populations that can no longer be controlled by a pesticide usually develop over several generations. Resistance develops fastest in insects that have a high rate of reproduction and are under heavy pesticide pressure. The more you spray, the more you increase the proportion of resistant individuals in the population. This fact has been demonstrated many times. Insecticide resistance is genetically based, and a resistant population may have developed one or more of the following resistance mechanisms:

- They may have a different behavior.
- They may have changed the outer cuticular layer so the pesticide can't penetrate.
- They may produce an increased amount of pesticide insensitive ACh.
- They may produce an increased amount of pesticide insensitive AChE.
- They may have increased the number of types and quantities of detoxifying enzymes.

The insect cuticle and blood are full of many different types of enzymes called mixed function oxidases (MFOs) and cytochrome p450s. The latest research shows that some resistant insects have the ability to produce increasing amounts of and different types of detoxifying enzymes. In addition to the metabolic enzymes, resistant insects have the ability to produce pesticide-tolerant or increasing quantities of ACh and AChE, so much so that the pesticide is rendered ineffective. Unfortunately, some of the highly resistant insects (leafminer, western flower thrips, etc.) use several of these mechanisms at the same time. This is known as multiple resistance.

It is important to understand the basic biology of the pests in question. How long does it take for the pest to complete one generation? With aphids, it's very short, so rotation should occur in approximately two weeks. However, whiteflies take about 25 days to develop into an adult. Their generation time is much longer.

RESISTANCE FACTORS

Before we can discuss pesticide resistance, we should investigate the other potential causes for control failure. Control failure may not be a result of resistance. It may be due to some other factor in the pest management scheme.

Possible reasons for control failure include:

- failure to initiate other parts of an overall integrated pest management program;
- failure to intensively monitor for pest species;
- misidentification of pest species;
- wrong choice of pesticide;
- incorrect rates/off-label use/use of an old or degraded pesticide;
- poor choice of tank mixes, adjuvants, pH, water quality, etc.;
- misuse of equipment, inadequate agitation, improper calibration, inadequate maintenance, etc.;
- inadequate coverage, improper placement of the pesticide; and/or
- very high pest populations, tolerant or resistant populations.

Managing pests should begin with the basics of integrated control. For instance, all efforts should be made to exclude or inhibit the development of pest populations using cultural or environmental controls. Biological control should be considered where possible, and an intensive monitoring or scouting program should be in place so that one can treat or spot treat when necessary. Another good reason to intensively monitor for pests is that a very heavy pest infestation is very difficult, if not impossible, to control before damage occurs. Ten aphids on a terminal today can become 250 in a week. If spider mite webbing is visible, the population is probably enormous. Very high pest populations should be avoided at all costs. Concentrating on ➧

Jim Bethke will be part of the *GPN*/Syngenta Educational Symposium during 2002. You can hear him speak about mode of action, chemical screening and other insect-related topics at the following venues:

Southeast Greenhouse Conference
Saturday, June 22, 2002
www.sgcts.org

Ohio Florists' Association Short Course
Saturday, July 13, 2002
www.ofa.org

Ornamentals Northwest Seminars/ FarWest Show
Dates to be announced
www.farwestshow.org

integrated methods of control will reduce the reliance on chemical control. When chemical control is necessary, proper application of the chemicals is the next best method of avoiding or delaying pesticide resistance.

Some of the most critical components of successful pesticide applications are coverage, timing and placement. Not spending enough time covering dense foliage will, in all likelihood, allow some pests to survive. Sub-lethal doses due to inadequate coverage may increase the chance of pesticide resistance. The timing of pesticide application must coincide with a stage of the pest that is vulnerable to the application. For instance, whiteflies are most susceptible when they are in the early nymphal stages. They are most tolerant when they are in the redeye stage. Therefore, monitoring to establish the pest stage will help determine which pesticide to use and when to use it. In addition, whitefly nymphs are located on the lower surface of the leaves. So, the application should be directed to the undersides of the leaves for effective coverage. Knowing where to direct the pesticide is just as important as proper coverage.

Magnified silver-leaf whitefly.

USING THE NEW MODE

Rotation of pesticides with different modes of action is a very important concept. Research has shown that pests can develop high levels of resistance, like western flower thrips, which can detoxify more than one chemical or mode of action per generation. Quite simply, this means that treating insect populations with tank mixes of insecticides that have several modes of action can result in a pest population with multiple resistance mechanisms and produce what seems to be a superbug. Therefore, it is important to use the pesticide according to the label and to rotate by both chemical class and mode of action. Rotation should occur every one or two pest generations so that the new chemical will kill surviving individuals tolerant to the previous pesticide.

So what is the best approach to manage pests without enhancing pesticide resistance? We cannot in good conscience suggest that everyone just stop using pesticides. We also cannot suggest enhancing the problem by adding a greater amount of pesticide or a greater number of pesticides to the tank. Minimizing chemical control by incorporating other pest management tactics is a more sensible solution. I have observed that successful growers monitor their crop very closely and treat hot spots. On the other hand, growers who are treating on a scheduled basis and tank mixing more than one

Because whiteflies live on the undersides of leaves, an extensive scouting program should precede any chemical application.

mode of action at one time are usually less successful. If you want to examine a recent example of how things can go wrong, see "The Return of the Leafminer," in the June 2001 issue of *GPN*. The products that successful growers use are highly effective because the pests they treat are sensitive to the pesticides.

Tank mixing insecticides with different modes of action is risky and, in my opinion, should be avoided. It exposes the pest population to several modes of action at the same time, enhancing the potential for resistance development. There are a few successful tank mixes that are well-known such as the mix of an OP with a pyrethroid (e.g., acephate + permethrin), or avermectin with insecticidal soap. In my opinion, it would be risky to rely on the OP-pyrethroid mix religiously without rotation. However, resistance to soaps and oils is unlikely, so the inclusion of soaps and oils to a rotation or a tank mix is an option to keep open.

Many have asked me about tank mixing to kill both the adult (e.g., a pyrethroid) and immature (e.g., an IGR) at the same time. Again, this is where I believe some growers have gotten into trouble with resistant pests. All stages of the pest are being exposed to two modes of action at the same time. It is possible, with an effective monitoring program, to know which stage the population is in and treat only that stage. It is also possible to treat the untreated stage with another pesticide at a different time, thereby delaying the exposure of both stages to both modes of action.

If a resistance problem occurs, then it's time to take a step back and review the overall integrated pest management program. The tendency is to seek a new chemical solution rather than looking at the entire program. There is evidence that reversion can occur. That is, if the use of pesticides against a resistant insect is curbed, in time, that chemical can be used again. This needs more study in ornamentals. GPN

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