Pesticide Mixtures

Understanding Their Use in Horticultural Production Systems

Pesticides such as insecticides and miticides are still the primary means of controlling or regulating many arthropod (insect and mite) pests in horticultural production systems. Major pests include greenhouse whitefly (*Trialeurodes vaporariorum*), sweet potato whitefly (*Bemisia tabaci*), green peach aphid (*Myzus persicae*), melon aphid (*Aphis gossypii*), twospotted spider mite (*Tetranychus urticae*), western flower thrips (*Frankliniella occidentalis*), American serpentine leafminer (*Liriomyza trifolii*), citrus mealybug (*Planococcus citri*), and species of soft and hard scales.

Regulations such as the Food Quality Protection Act (FQPA), and manufacturers' voluntary withdrawal or cancellations have resulted in the loss or registration changes associated with older, broad-spectrum insecticides and miticides. This has led to an increase in the development and availability of alternative pesticides that are more selective in the types of arthropod pests controlled or regulated. These alternative pesticides control a narrow-spectrum of insect and mite pests. Alternative pesticide categories include insect growth regulators, insecticidal soaps (potassium salts of fatty acids), horticultural oils (petroleum- and neem-based), selective feeding inhibitors, and microbial agents (bacteria, fungi, and related microorganisms).

In addition to their selectivity, many alternative pesticides are less toxic to humans, leave minimal residues, are short-lived in the environment, and have minimal direct or indirect impact on natural enemies including parasitoids and predators. Although selective pesticides may be desirable, using them creates a dilemma when dealing with multiple insect and mite pests in horticultural production systems. To regulate or control the myriad of insect and mite pests such as thrips, aphids, fungus gnats, leafminers, whiteflies, mealybugs, spider mites, and scales that feed on horticultural crops, producers often mix, or *tank mix*, several alternative pesticides into a spray solution. It may be necessary to tank mix two or more insecticides or miticides to obtain the same spectrum of control for multiple pests that a single broad-spectrum pesticide might provide.

Tank Mixing

Tank mixing involves combining two or more pesticides into a single spray solution. This mixture exposes individuals in an arthropod pest population to each pesticide simultaneously. This procedure is popular because of the potential for improved pest control. Although there are benefits to tank mixing, several issues must be considered in advance. Applicators should read labels and understand why certain pesticides are being mixed together. The goal is to develop pesticide mixtures that are appropriate based on each pesticide's mode of action and the developmental stage(s) of the target pest(s) on which it is most effective. For example, tank mixing two pesticides that have miticidal properties, such as abamectin and bifenazate, is not recommended because both are active on twospotted spider mite adults. Tank mixing abamectin with clofentezine or etoxazole is legitimate because abamectin is primarily active on adults. Clofentezine or etoxazole are active on the eggs, larvae, and nymphs. This pesticide mixture targets all life stages of the twospotted spider mite.

Producers should tank mix pesticides with different modes of action. For example, acequinocyl, bifenazate, pyridaben, fenpyroximate, fenazaquin, and tolfenpyrad are in different chemical classes—naphthoquinone, carbazate, pyridazinone phenoxypyrazole, quinazoline, and pyrazole—but have the same mode of action. All are mitochondria electron transport inhibitors (METI's) that disrupt the production of energy or ATP. These pesticides should never be mixed in a spray solution.

Similarly, acephate and methiocarb, despite being in different chemical classes (organophosphates and carbamates), have identical modes of activity. These pesticides block the action of acetylcholinesterase (AChE), an enzyme that deactivates the neurotransmitter acetylcholine (ACh). As a result of AChE deactivation, nerve signals continue to send impulses, resulting in insect exhaustion and death. Avoid tank mixing acephate and methiocarb, which expose the insect pest population to the same mode of action and can accelerate resistance.

Reasons For Mixing Pesticides

Convenience is one reason for mixing pesticides. It is less time consuming, costly, and labor intensive to mix two or more pesticides and spray once. Another reason is potential for improved pest control. Tank mixing two pesticides may result in greater mortality than applying either of them separately. Pesticide mixtures may be more effective on certain types and developmental stages of arthropod pests.

This type of activity is often referred to as synergism or potentiation. *Synergism* is when the combined toxicity of

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two compounds is greater than the sum of the toxicities of each individual compound. In this case, one of the compounds has little to minimal toxicity when applied separately. This compound is usually a synergist, as described below.

Potentiation occurs when the activity of one compound enhances the activity of another. In this case, both compounds are pesticides, which may have toxic effects if applied individually. For example, insecticides containing the active ingredient azadirachtin, an insect growth regulator, and *Beauveria bassiana,* an insect-killing fungus, appear to be more effective when mixed. During the summer, insect pests such as thrips and aphids shed skins so rapidly that insect-killing fungi are unable to penetrate. Azadirachtin, which slows the molting process, allows *Beauveria bassiana* to enter, initiate an infection, and eventually kill the insect pest.

Some compounds are true synergists, which are chemicals that enhance the effectiveness of the active ingredient. For example, piperonyl butoxide or PBO, which is not a pesticide, may be mixed with pyrethroid-based insecticides including bifenthrin, cyfluthrin, and fenpropathrin. It works by blocking enzymes within an insect that are capable of breaking down the active ingredient so it no longer has insecticidal properties. Similarly, organophosphate insecticides are useful synergists for pyrethroid-based insecticides because they bind to particular enzymes responsible for detoxification. This is one reason manufacturing companies formulate organophosphate and pyrethroid insecticide mixtures to manage arthropod pests and counteract resistance.

Issues With Pesticide Mixtures

Just as synergism improves the efficacy of two or more pesticides, the opposite can happen. Mixing two or more pesticides can reduce the effectiveness of the mixture compared to separate applications of each pesticide. This is known as *antagonism*. For example, azadirachtin has been shown to be toxic to certain insect-killing fungi. Applying the pesticides together not only reduces effectiveness, but also can harm plants. Before tank mixing, read the label to determine if the two can be mixed together. Direct questions to the pesticide manufacturer.

Another issue with tank mixing is *incompatability*. This is a physical condition that prevents pesticides from mixing properly in a spray solution. It can reduce effectiveness or damage plants. Incompatibility may be due to the chemical or physical nature of the pesticide(s), water impurities, water temperature, or the types of formulations mixed together. To determine compatibility between two (or more) pesticides, conduct a jar test. This involves collecting a sample of the spray solution (i.e., 1 pint) into an empty jar or container and allowing the solution to remain idle for approximately 15 minutes (Figure 1). If the pesticides are not compatible there may be noticeable separation or layering, or flakes or crystals may form. If the materials are compatible, the solution may appear homogeneous or resemble milk. This procedure only determines compatibility, not synergism or antagonism.

Phytotoxicity

As new plant varieties become available they may differ in tolerance to pesticide mixtures. To avoid problems associated with phytotoxicity, or damage to plants, test a mixture on a sample of approximately 10 plants before applying to the entire crop.

Resistance

The issue of tank mixing and resistance is not well-understood, although applying two or more pesticides at different intervals is thought to offer the same advantages as a tank mixture. This is not entirely true because each individual pest in the population does not receive a lethal dose or concentration of each pesticide. As a result, resistance can evolve more rapidly than it would with a pesticide mixture. Mixing pesticides with different modes of action can delay resistance within a pest population because the mechanisms required to resist the pesticide mixture may not be widespread or exist in the population. In addition, it may be more difficult for individuals in the pest population to develop resistance to several modes of action simultaneously. Individuals in the population resistant to one or more pesticides would likely succumb to the other pesticide in the mixture.

The ability of insect and mite pests to evolve resistance depends on a number of factors. One of the most

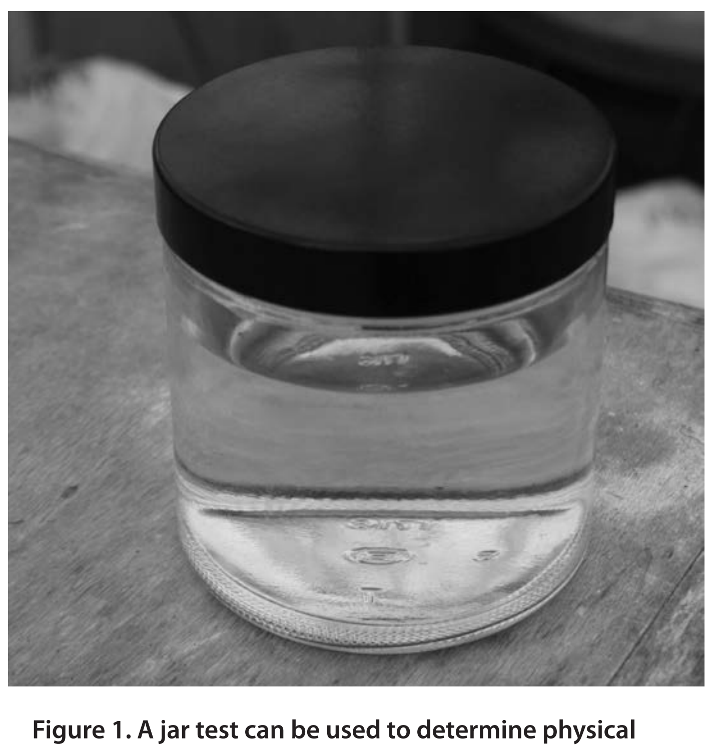

Figure 1. A jar test can be used to determine physical compatibility of pesticides.

important is previous exposure to similar modes of action. In addition, using pesticide mixtures to avoid resistance will only be successful if there is no cross resistance (resistance to pesticides with similar modes of action) among individuals in the pest population to any of the pesticides in the mixture.

Examples Of Pesticide Mixtures

Researchers have evaluated the effect of tank mixing pesticides on efficacy against western flower thrips, twospotted spider mite, and sweet potato whitefly. One study demonstrated that mixing the insecticide spinosad with other insecticides and miticides (imidacloprid, abamectin, and bifenazate) in two, three, and four-way mixtures did not negatively affect the ability of spinosad to control western flower thrips. Another study evaluated the effect of tank mixing the insecticides and miticides buprofezin, acetamiprid, chlorfenapyr, and bifenazate in two, three, and four-way mixtures on the control of both twospotted spider mite and sweet potato whitefly. Results indicated that most of the mixtures did not affect control or regulation of either arthropod pest. Most of these mixtures are recommended. The buprofezin + chlorfenapyr, and acetamiprid + chlorfenapyr + bifenazate mixtures resulted in a smaller percentage of sweet potato whitefly nymphal mortality (less than 38%) than the other pesticide mixtures. These mixtures should be avoided.

A survey to gather information on pesticide mixtures commonly used by greenhouse producers was distributed at greenhouse conferences in 2007 and 2008. The two-way mixture used most often was the combination of abamectin and spinosad for control of thrips, aphids, and spider mites. The other two-way mixtures popular among survey respondents were acephate and fenpropathrin; abamectin and either bifenthrin or cyfluthrin; abamectin and azadirachtin; spinosad and novaluron; spinosad and pymetrozine; spinosad and bifenazate; and abamectin and pymetrozine.

Tank mixing has positive and negative aspects. Although producers routinely mix pesticides to reduce labor costs associated with multiple spray applications and to improve control of arthropod pests, caution is advised to avoid problems associated with antagonism, incompatibility, phytotoxicity, and resistance.

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