K·STATE Research and Extension

Pesticide Metabolites

In horticultural systems, insect and mite pests are managed primarily through the use of pesticides. A pesticide formulation includes both active and inert ingredients, and the active ingredient is the component responsible for toxicity. For some pesticides, the active ingredient must be converted by the insect, mite, or plant into a lethal substance. These substances, known as metabolites, are the product of chemical reactions that occur naturally within cells during metabolism. Other factors that may influence metabolism of certain insecticides include plant type, plant vigor, and temperature.

Factors Associated with Pesticide Metabolites

Insecticides and miticides that work via metabolites are known as pro-insecticides or pro-acaricides. These include imidacloprid (Marathon/Merit), malathion, acephate (Orthene), indoxacarb (Provaunt), chlorfenapyr (Pylon), bifenazate (Floramite), and thiamethoxam (Flagship). Some insecticide and miticide metabolites have little or no insecticidal or miticidal activity. In contrast, other processes produce more water-soluble toxic metabolites, and these changes are necessary for some pesticides to become toxic.

The metabolism of certain systemic insecticides may involve a number of processes, including oxidation and hydrolysis. Oxidation reactions add oxygen or remove electrons. Hydrolysis is the reaction of a compound with water that breaks it into less complex compounds. Table 1 presents selected pesticides and associated metabolites.

Imidacloprid

Imidacloprid, when applied to plants, is metabolized almost completely. Approximately 95 percent of the parent compound is metabolized, depending on the plant species and time. Certain metabolites of imidacloprid are active against insect pests such as aphids. The primary metabolites are olefine, 4-hydroxy, and 5-hydroxy imidacloprid. Olefine is 10 times more active and tends to be more toxic to insects that withdraw food from the vascular tissues of plants than imidacloprid. Imidacloprid also has a higher attraction (>500 ppm) for the target site where the toxin usually binds, the nicotinic acetylcholine receptor (nAChR), in certain aphid species. In addition, the water solubility of the metabolite is higher than that of imidacloprid.

Malathion

Some insecticides, including malathion, can be converted into less toxic substances or metabolites via enzymes inside the insect. This may also occur through hydrolysis, as is the case with acephate, discussed below. Malathion — an insecticide used against aphids, leafhoppers, plant bugs, scales, thrips, and whiteflies — is converted through

Table 1. Pesticides (insecticides and miticides) used against insect and/or mite pests of horticultural crops and their associated metabolites.

Pesticide Common name (trade name)	Metabolite(s)
Acephate (Orthene)	Methamidaphos
Bifenazate (Floramite)	Diazene
Chlorfenapyr (Pylon)	AC303268
Imidacloprid (Marathon/Merit)	Olefine, 4-hydroxy, and 5-hydroxy
Indoxacarb (Provaunt)	DCJW
Malathion (Malathion)	Malaoxon
Thiamethoxam (Flagship/Meridian)	Clothianidin

oxidation into the metabolite maloxon. Maloxon is an efficient acetylcholinesterase inhibitor but is not a good insecticide, likely because of its reduced stability and inability to penetrate the insect cuticle (skin) or outer covering.

Acephate

Oxidation and hydrolysis can convert certain organophosphate insecticides into compounds that have higher insecticidal activity than the original insecticide. For example, when acephate is applied to plant leaves, hydrolysis converts it to methamidaphos. Methamidaphos is more active than acephate on insects such as whiteflies. It moves readily throughout the plant and is more toxic to insects than to mammals.

Indoxacarb

Another active ingredient, indoxacarb (Provaunt), is a pro-insecticide that is metabolized by enzymes such as esterase and amidase into the active metabolite DCJW. This metabolite works on an alternative pathway in insects by binding to certain types of sodium channels, preventing sodium ions from flowing into the nerve cell, leading to flaccid paralysis and death. This is different than the action of pyrethroid-based insecticides such as bifenthrin (Talstar), cyfluthrin (Decathlon/Tempo), and permethrin (Astro).

Other Pesticides

Chlorfenapyr (Pylon) is a pro-acaricide that is converted to the metabolite AC303268 through oxidation. This metabolite causes a decrease in the production of ATP (adenosine triphosphate), which is important for energy production. Bifenazate (Floramite) is another pro-acaricide that is converted inside mites to the principal active metabolite diazene. This metabolite may be responsible for the miticidal activity of the active ingredient against the twospotted spider mite (*Tetranychus urticae*) and may be associated with the mode of action — a mitochondria electron transport inhibitor — that suppresses the production of ATP.

Thiamethoxam (Flagship), a neonicotinoid-based insecticide that is a pro-insecticide, readily converted into the metabolite clothianidin. This metabolite is the active ingredient in a number of products, including Arena and Aloft. Although clothianidin is less water-soluble than imidacloprid (327 vs. 500 ppm), it has a higher binding affinity to the nicotinic acetylcholine receptors, which are the target sites of the neonicotinoid-based insecticides.

Clothianidin is also rapidly absorbed by plant roots because of the lipophilicity of the active ingredient. Lipophilicity refers to the ability of a compound to dissolve in fats, oils, and lipids. Compounds that are highly lipophilic are generally not systemic. Compounds that are either moderate or intermediate in lipophilicity are able to move through the xylem (water-conducting tissues) to plant shoots. Root absorption is greater when compounds are more lipophilic. Clothianidin is taken up rapidly in the transpiration stream, which is responsible for water movement through plants, and may accumulate at higher concentrations in plant parts and tissues than other neonicotinoid-based insecticides. Clothianidin has also been shown to be evenly distributed throughout leaf tissues. All of these factors may be associated with the activity of clothianidin against a wide range of insect pests.

In summary, a number of pesticides (insecticides and miticides) commonly used to manage or regulate insect and mite pest populations of horticultural crops are converted into metabolites once inside the targeted pest or plant by means of oxidation or hydrolysis. These metabolites may be more toxic to targeted insect and mite pests than the active ingredient.

Raymond A. Cloyd, Ph.D.

Professor and Specialist in Horticultural Entomology/Integrated Pest Management, Department of Entomology

Brand names appearing in this publication are for product identification purposes only.
No endorsement is intended, nor is criticism implied of similar products not mentioned.

Publications from Kansas State University are available at: *www.ksre.ksu.edu*

Kansas State University Agricultural Experiment Station and Cooperative Extension Service

MF3070 **September 2012**