A sunflower maze planted over an old citrus grove clearly shows the old rows and aisles as undulations caused by poor plant growth in the old rows.

The fate of pesticides

By Juanita Popenoe

Editor's note: This article grants one continuing education unit (CEU) in the Core category toward the renewal of a Florida Department of Agriculture and Consumer Services restricted-use pesticide license when the accompanying test is submitted and approved.

I have had several problems brought to me recently that were caused by pesticide residues in the orchard environment. What happens to pesticides after they have done their work for you? Do pesticides just fade away, get washed away or stay as unwelcome guests in your fields? Responsible pesticide use requires thinking about where the pesticide is going once it leaves the container. Some basic information about pesticides is necessary first.

We all have heard about the issues out West where unexpected spray droplet, vapor or particle drift moves pesticides off target in some bad ways. However, if you keep the pesticide on target, with no off-target movement, what happens to it? Pesticides that are taken up by the plant do not run off or leach, but what about the rest? That depends on the characteristics of the pesticide, including its solubility, adsorption, volatility and persistence.

PESTICIDE CHARACTERISTICS

Solubility

Solubility is the ability of a pesticide to dissolve in whatever solvent you are using. Pesticides that dissolve easily in water (and hence are easy to mix and apply) are very likely to move when water percolates down into the soil or washes off with heavy rains or irrigation into the nearest water body. Whether that pesticide remains active in its new site is determined by its breakdown characteristics.

Adsorption

Adsorption is the process where the pesticide is bound by molecular attraction to the soil. Clay particles and organic matter have lots of binding sites and a negative charge that attracts and binds pesticides, especially ones with a positive charge. Pesticides bound in this way are likely to stay on site in the soil unless something is added to the soil to dislodge the chemical attraction or something, like erosion, dislodges the soil particles and moves them off site. The ability to be adsorbed is dependent on the chemical characteristics of the pesticide (whether they are weak acids or bases), the pH of the soil and the presence of water because water competes for binding sites.

Volatility

Volatility is the chemical property of a pesticide to turn into a gas or vapor. The higher the vapor pressure value of a pesticide, the more volatile that pesticide is and the more likely it is to move off site. This has been illustrated by the problems with Dicamba in the West where many susceptible fields have been destroyed by vapor movement. Problems are usually worse with high temperatures, wind and low relative humidity. Label instructions can help the applicator avoid these issues, and special training is required for some of these types of pesticides.

Persistence

Persistence is a measure of the ability of the pesticide to hang around without breaking down to an inactive form. Scientists measure this as half-life: how long it takes for half of the pesticide to break down. Remember half is not all. The larger this measure, the longer the pesticide remains active. A persistent pesticide may be useful if you want it to act for a long time (like as a termiticide around your house), but it can be very dangerous if the pesticide gets moved off target in some way, remains on a product that will be eaten or stays in a field you want to replant. Nonpersistent pesticides have a typical half-life of less than 30 days. A persistent pesticide in a typical soil has a half-life of more than 100 days.

DEGRADATION MECHANISMS

How do pesticides degrade? Chemical degradation, microbial action and photodegradation are the mechanisms whereby pesticides are broken down in the environment. Some pesticides break down quickly, others may take years, and some that contain metals may remain in the environment indefinitely.

Chemical Degradation

In chemical degradation, the pesticide reacts with molecules — usually water — in the environment that cause the pesticide to break up into smaller, often less toxic molecules. Water, carbon dioxide and minerals are the ultimate degradation products of any organic chemical, but there may be intermediate degradation products that are not so nice. Water reacts with chemicals via hydrolysis, which breaks bonds in the chemical structure of the pesticide. Hydrolysis may occur in any part of the environment where the pesticide molecule comes into contact with water. Temperature will affect the speed of this reaction. Hydrolysis happens faster closer to the surface, where water is warmer. Deeper in the soil, where groundwater resides, reactions are much slower.

Microbial Action

Microbes in the environment may also break down pesticides. Microbes, which include fungi, bacteria, algae and protozoa, live in healthy soils and will break apart pesticide molecules as they feed and grow. Soils high in organic matter have more active microbes. Also, the soil in the upper foot or so has the best temperature, moisture and organic matter for microbe growth and thus has the most pesticide-degrading activity. Conditions are much less favorable for microbe growth below the root zone, and very little microbial breakdown occurs once the pesticides get to that level. There are commercial products that claim to provide microbes that break down pesticides, but little research has been done on these. Microbial activity decreases with soil pH extremes, but these conditions may favor more rapid chemical degradation.

Photodegradation

Photodegradation or photolysis is the breakdown of pesticides by the action of sunlight. Energy from sunlight causes molecules to become "excited," resulting in organic chemical reactions that oxidize the functional groups in a pesticide molecule. Ultraviolet light has the greatest potential to photodegrade pesticides, but the intensity, spectrum, length of exposure and characteristics of the pesticide affect the rate of photolysis. This type of degradation can occur wherever the pesticide is exposed to light. The type of surface the pesticide is on (a soil particle or a waxy leaf surface) and temperature will impact the oxidation rate and ultimate breakdown products of the reaction.

PESTICIDES THAT DO NOT DEGRADE

Some pesticides do not degrade, and levels that build up in the field can become a problem for replanting. Copper in various forms is a commonly used pesticide for organic as well as conventional agriculture. Copper acts by altering the protein structure of cell membranes by binding to the proteins. Cells disrupted in this way die, whether they are bacteria, fungi, algae or snails. Copper is also an essential mineral (in small amounts) for humans and plants and is widely found in the environment. However, it is a metal that does not break down in the environment; it accumulates at the soil surface where it binds tightly to the soil and persists. At high levels, copper is toxic to plants because it inhibits photosynthesis. Copper is very toxic to aquatic life at low levels.

Arsenic has a similar fate. Arsenic is no longer a licensed pesticide but was used widely in apple orchards in the West and has been linked to "apple replant disease," in which newly planted trees do not thrive when planted in the old rows. If you have noticed after pushing a grove that cover crops and other plants in the old rows do not do so well, consider testing the soil for persistent pesticide molecules or pests that have built up in that soil. Alternatively, you can move all the rows over a bit and plant the new crop in the old aisle.

WATER PROTECTION

What about the pesticides that are not persistent and did not get a chance to degrade before they were moved off site by water? Surface water provides approximately 38 percent of the state's water withdrawals. Groundwater contamination is more serious because once underground, none of the degradation processes are likely to occur. Groundwater supplies 62 percent of Florida's water withdrawals and is the source of drinking water for most Floridians. The state's sandy soils are the best soils for leaching because there are few binding sites.

How can our water be protected from leaching pesticides? Determine the depth of the water table and relative permeability of the soil. If sinkholes are present, runoff can quickly reach groundwater with little soil filtering. The slope of the field and proximity of water bodies or the water table to the application site also determines the vulnerability to contamination.

Do not handle pesticides in the vicinity of wells and other water sources. Maintain wells properly with cases, caps and grouting. Close abandoned wells. Do not apply pesticides if heavy rain is predicted. Do not irrigate right after an application, unless required by the label. Control the amount of irrigation water to minimize leaching and runoff. Use integrated pest management techniques to reduce the number of necessary pesticide applications.

REDUCING RUNOFF

Creating berms or banks between the application site and water bodies and planting well vegetated buffer strips with high organic matter will help to keep runoff from taking pesticides into water sources and other vulnerable areas. To reduce leaching, read the pesticide labels and select ones that are less likely to leach. Some pesticides, including aldicarb and bromacil, are restricted by Florida-specific laws to certain soil types. These restrictions will be clearly marked on the label.

Soils high in organic matter or clay are less likely to leach. One good way to prevent leaching is to increase the organic matter of the soil, which will also lead to better soil health and improved growth of crop plants.

SUMMARY

Pesticides break down via photolysis, hydrolysis and microbial decomposition, but not all components, such as metals, will break down. It is the responsibility of the applicator to be sure to read the label directions to choose the proper pesticide for the site and to see that the pesticide is applied as safely as possible. There are best management practices that can be performed to minimize potential leaching and runoff with the use of berms, vegetated buffer strips and increased organic matter in the soil. The protection of both surface water and groundwater is imperative for sustainable agriculture.

Sources: Applying Pesticides Correctly, 7th Edition by Fred Fishel; Understanding pesticide persistence and mobility for groundwater and surface water protection by E.A. Kerle, J.J. Jenkins and P.A. Vogue

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‘The fate of pesticides’ test

To receive one Core continuing education unit (CEU), read “The fate of pesticides” in this issue of Citrus Industry magazine. Answer the 20 questions on the magazine’s website (www.CitrusIndustry.net) or mail the answers and application information to the address at the end of the article. You must answer 70 percent of the questions correctly to receive one Core CEU. The article and test set are valid for up to one year from the publication date. After one year, this test will no longer grant a CEU.

1. Solubility means the ability of the pesticide to solve your pest issue. **T F**
2. Adsorption is the process whereby the pesticide moves into the soil pore spaces. **T F**
3. Volatility is the chemical property of a pesticide to turn into a gas or vapor. **T F**
4. Persistence is a measure of how long a pesticide remains active in the environment. **T F**
5. Chemical degradation is usually done by hydrolysis. **T F**
6. In microbial degradation, the soil microbes are killed by the pesticides. **T F**
7. In photodegradation, the pesticide is energized by light to remain active. **T F**
8. Water and temperature both affect the breakdown of pesticides. **T F**
9. Copper is tightly bound to soil and rarely leaves the site of application. **T F**
10. Surface water provides the majority of water withdrawals in the state. **T F**
11. Sinkholes are surface water leading directly to the aquifer groundwater. **T F**
12. Pesticides are safe to handle near wells as long as they are capped. **T F**
13. Replant problems may be linked to persistent pesticides used. **T F**
14. To reduce runoff, you can:
    a. Create a berm to contain water movement. **b.** Plant a well vegetated buffer strip between the field and water sources.
    c. Increase organic matter in soil to help bind pesticides in place. **d.** All of the above
15. Pesticides that are restricted to certain soil types by Florida-specific laws include:
    a. Imidacloprid **b.** Bromacil **c.** Glyphosate **d.** None of the above
16. The soils most susceptible to leaching are:
    a. Clay **b.** Loam **c.** Sand **d.** High organic matter
17. Microbes that live in healthy soils and will break apart pesticide molecules as they feed and grow include:
    a. Fungi, bacteria and earthworms **b.** Bacteria, fungi and insects
    c. Algae, bacteria, protozoa and fungi **d.** Earthworms
18. Below the root zone, conditions are:
    a. Much less favorable for microbe growth **b.** Much more favorable for microbe growth
    c. Warmer and drier than above **d.** Warmer and wetter than above
19. Problems with volatility are usually worse with
    a. High humidity, high wind and low temperatures **b.** Low humidity, low wind and low temperatures
    c. High humidity, high wind and high temperatures **d.** Low humidity, high wind and high temperatures
20. Persistence is usually measured as:
    a. The time it takes for the pesticide to be completely degraded
    b. The time it takes for the pesticide to move off site
    c. The half-life, the time in which half of the pesticide has broken down
    d. The lifetime, the time the pesticide remains in the environment

Please circle the number below to rate this article and test:

Not very useful	1	2	3	4	5	6	7	8	9	10	**Very useful**

Pesticide Applicator CEU Form

First Name:________________ **Last Name:** ________________

E-mail: ________________ **Phone:** ________________

Pesticide License Number: ________________

Address: ________________

City: ________________ **State:** ________ **Zip:**________________