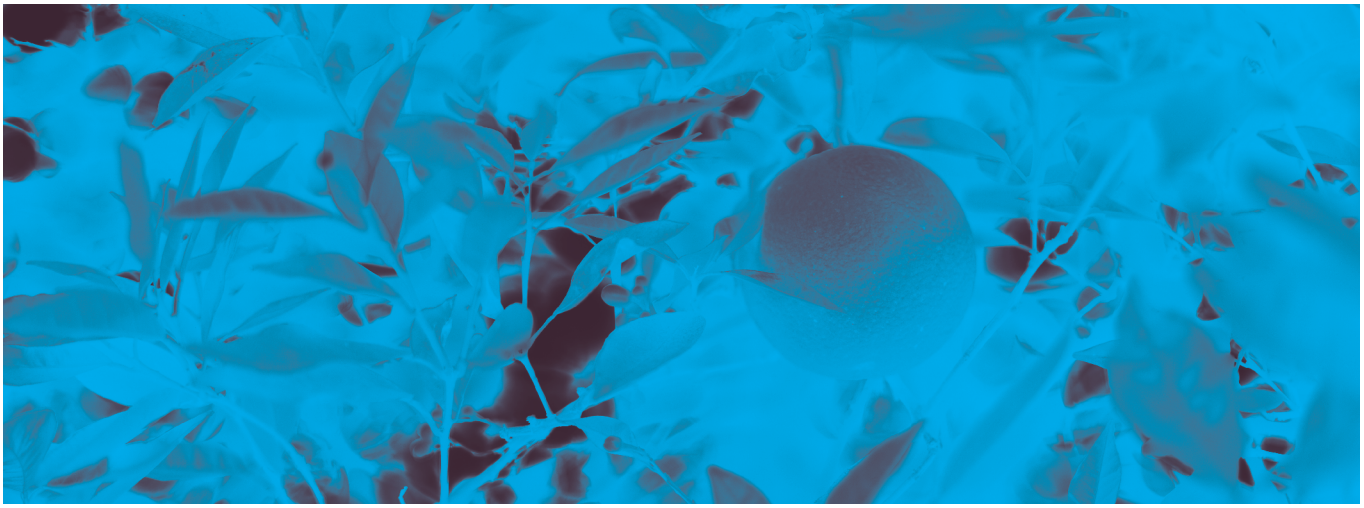

Diverse roles of adjuvants in crop protection

By Timothy Ebert and Stephen H. Futch

Editor's note: This continuing education unit (CEU) article grants one general standards (core) CEU when submitted and approved toward the renewal of a Florida Department of Agriculture and Consumer Services restricted-use pesticide license.

A pure active ingredient in a pesticide may be very toxic or may not mix well with the diluent in the spray tank. The diluent (water or oil are most common) in the spray tank makes it easier for the grower to safely handle and apply the spray material, and could make the pesticide safer to store and ship from the manufacturer. Other chemicals could be added to the formulation to improve safety, increase the ability to mix into solution, increase the ability of the spray solution to spread/adhere to the plant surface and/or improve biological activity. For products applied as sprays, this could also include features like controlling droplet size to minimize drift as well as improving the number of droplets that adhere to the intended target versus the number that bounce or run off and land on the ground. These chemicals are collectively called formulation components.

No formulation is ideal under all conditions. But it is sometimes possible for growers to enhance the performance of a pesticide application by adding special chemicals to the spray tank. These chemicals are collectively termed adjuvants. Adjuvants add value to pesticides (fungicides, herbicides and insecticides) by making the pesticide work better, handle more easily, improve application characteristics or be safer. In many cases, adjuvants are the same kinds of chemicals that manufacturers use as formulation components. Adjuvants improve emulsifying, dispersing, spreading, wetting or other properties of liquids.

The realization that formulation components and adjuvants are often the same or similar chemicals is important if you tank-mix several products. For example, you might mix Treevix® and Roundup® for weed control. The formulation components in Roundup® are then adjuvants for Treevix®. If you had been using Treevix® alone and adding surfactant, you might not need as much additional surfactant in the tank mix of Treevix® + Roundup® because the Roundup® formulation supplies some of the additional surfactant.

The issue with adjuvants versus formulation components also means that you might not get the same effect if you substitute products with the same active ingredient but with a different formulation. Roundup Weathermax® has the same active ingredient as UltraMax® or GlyphoMax®, but the different formulation components may affect the performance of the final

tank mix. There is no statement on the label that will assist with this problem because all the formulation components are combined under the heading "inert ingredients."

In addition to problems with efficacy, changing formulation may affect the chemistry of the applied products. Many labels will have a statement that suggests doing a jar test to make sure all products can be combined without mixing problems.

HANDLE WITH CARE

Care is needed when handling adjuvants. A surfactant used to improve insecticide activity could act as an herbicide if used improperly. While adjuvants are less toxic than active ingredients and they are listed as "inert ingredients," adjuvants should not be regarded as harmless. Always read the label and follow the directions for safe handling of the product.

The diversity of growing conditions means that the manufacturer sells a formulation that works well under most conditions in the market targeted by the company, but the formulation may be improved under specific growing conditions with the addition of an adjuvant. Just because a formulation lists citrus on the label does not mean that the company has optimized the formulation for every crop listed on the pesticide label. It only means that the citrus market was large enough that the company tested the product on citrus, passed all the regulatory requirements and has approval to market the product by regulatory authorities. This often means that the company developed the product for multiple crops, and then funded research that found the same formulation had utility in citrus. It also means that the company feels the product works well enough that it can afford to market it in citrus.

The pesticide company does not want growers complaining about a pesticide they just tried. However, university scientists, adjuvant companies, pesticide companies and growers may conduct tests to further improve product performance. This may result in recommendations to add specific adjuvants prior to application of some products in some situations.

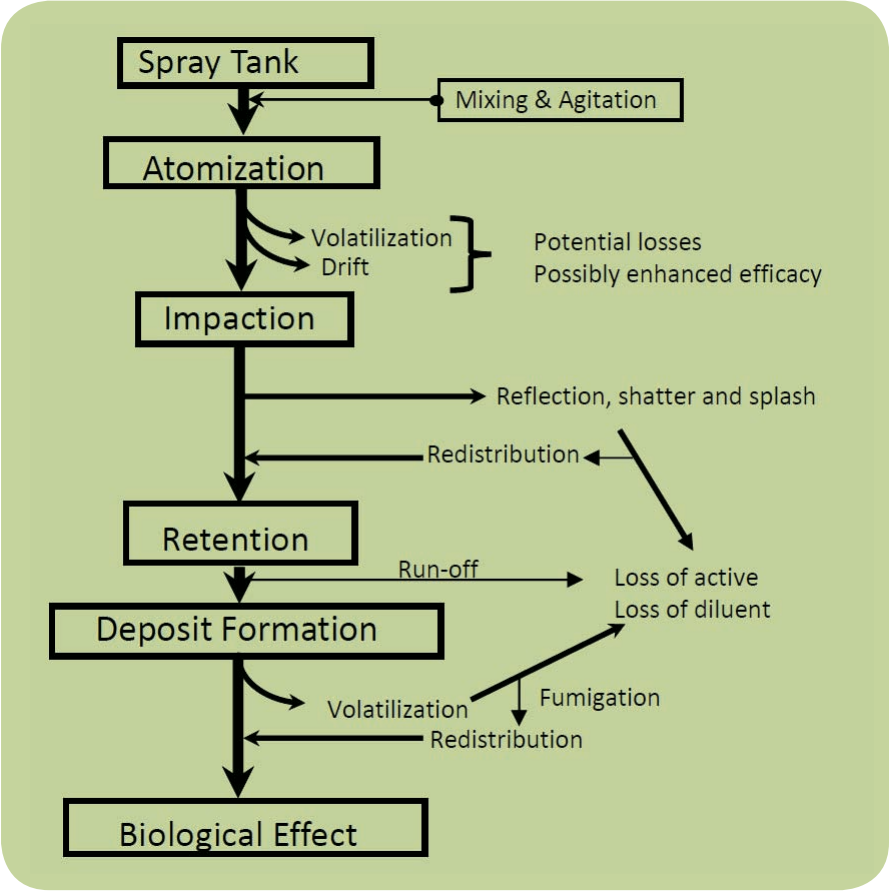

Figure 1. The dose transfer process from spray tank to biological effect. Small arrows show factors that influence the process as one moves down the path. All steps in this process influence the efficacy of the application.

DOSE TRANSFER PROCESS

Knowing the different classes of adjuvant and having an understanding of the dose transfer process may help make more effective pesticide applications in the grove. What is the dose transfer process? The dose transfer process is the path a pesticide's active ingredient takes from the point of manufacture to the target site within the pests in the grove. All steps in this process affect the grower's profitability, either as it affects the market price of the pesticide, the effectiveness of the pesticide once it is applied or grower risk related to legal issues associated with pesticide drift and groundwater contamination.

The dose transfer process is easily visualized as a flowchart (Figure 1). We will return to this flowchart after introducing the different classes of adjuvants.

ADJUVANT CLASSES

Adjuvants are grouped into different classes based on their use and sometimes their chemistry. Some adjuvants are restricted to one kind of pesticide: herbicide, fungicide or insecticide, but others are used throughout the agriculture industry. Below are listed 18 classes of adjuvants used in pest management. Consult with your local county Extension agent or pesticide distributor and read product labels before using adjuvants. When used inappropriately, an adjuvant may harm the performance of the active ingredient or cause crop injury.

Activators are a category that groups together surfactants, spreaders, stickers and penetrants. Activators alter the surface tension, wetting, retention and penetration properties of the applied solution.

Anti-foam products are added when the spray solution produces excessive foam. Foam may cause problems with the pump used for

agitation or delivery of spray liquid to the nozzles.

Buffers alter and stabilize the pH of a solution in water. Some pesticides are rapidly degraded in alkaline environments through a process called hydrolysis. While a specific buffer may alter pH to be either acidic or basic, in an agricultural context, a buffer is typically added to the spray tank to keep the spray slightly acidic.

Compatibility agents are products that aid in the application of multiple ingredients. They are most often used in application of fertilizer solutions with herbicides.

Crop oil concentrates are typically either petroleum-based or derived from vegetable oil. They typically include an emulsifier to aid with mixing in water. Crop oil concentrates (at higher rates) can suffocate insect, mite and fungal pests. They can also be penetrants to assist the active ingredient in penetrating the plant cuticle.

Deposition aids increase the quantity of spray that reaches the intended target. This is a broad class that includes penetrants, drift retardants, anti-evaporation aids and other types of adjuvants. Deposition aids are a group of adjuvants that have been combined to solve multiple application issues.

Drift retardant, sometimes called a thickener, increases viscosity of the spray solution to increase droplet size in sprayed applications. It can also reduce the volatility of some pesticides. Drift retardants may have polyacrylamides, polysaccharides, polyethylene polymers, fatty acids and other chemistries. Be aware that some drift retardants are rapidly degraded when they pass through the pump in a process known as pump sheer. The drift retardant can lose all of its efficacy in a few passes through a centrifugal pump. Some drift retardants are better at resisting pump sheer than others. Historically, the polyacrylamides were very sensitive.

Emulsifiers help water-repellent chemicals mix with water.

Fertilizer can be added to sprays for plant nutrition. This saves on the number of times one drives the tractor through the grove. As an adjuvant, the goal of the fertilizer is to give a brief boost to plant growth to facilitate uptake and movement throughout the plant. Care is needed in the choice of fertilizer to avoid interference with the pesticide or damage to the crop. A compatibility adjuvant might help here.

Humectants are adjuvants that absorb water from the air. They prevent the deposit from drying quickly and thereby can improve uptake of the pesticide.

Marker/dye adjuvants are brightly colored dyes that aid in detecting sprayed areas.

Penetrants help the active ingredient penetrate through waxy protective layers present on plant and insect surfaces. These products include petroleum-based, natural oils, long-chain alcohols and other hydrophobic materials.

Phagostimulant is a class of adjuvant that makes the pesticide residue taste good to an insect or mite. The insect then seeks out other pesticide deposits to eat more. This product is typically effective against chewing insects like caterpillars, sawflies or weevils. However, a phagostimulant is being researched for the Asian citrus psyllid.

Stabilizing agents reduce the degradation rate of pesticides when exposed to sunlight. Sunlight can cause rapid degradation of some pesticides, and a stabilizing agent will increase the residual life of the pesticide in the field.

Stenching agents include scents, fragrances and odorants. Many pesticides are clear and odorless. A stenching agent is added to help warn people that a pesticide is being used. The stenching agent is typically a part of the formulation and seldom would be considered an adjuvant.

Sticker-spreaders are adjuvants that help droplets adhere to surfaces, assist the spray to spread, and remain in place even when exposed to wind and rain.

Surfactant is short for surface active agent. These products reduce the surface tension of the applied liquid. This reduces droplet size, improves the ability of droplets to stick to the

target surface, spreads a retained droplet more evenly over the surface and reduces total quantity of pesticide that can be retained by the target or non-target surface. A surfactant can also help the spray penetrate the insect or plant surface.

In formulations that are emulsions, surfactants can be called stabilizing agents. In this case, they are stabilizing the formulation so that the emulsion does not separate into its oil and water components. In this capacity, surfactants are already present in the formulation as needed. While surfactants are used in many products, it is important to realize that surfactants are not interchangeable. The surfactant in shampoo or engine block cleaner will not work well in an agricultural context. The different types of surfactants are as follows:

1) Anionic surfactants are negatively charged molecules. They may produce large quantities of foam when agitated. An anti-foam adjuvant may be needed.
2) Cationic surfactants are positively charged and can disrupt plant cell membranes. Therefore, problems with surfactant burn can occur. These products are often used in industrial cleaners.
3) Amphoteric surfactants can be either positively charged or negatively charged depending on the solution's pH. These surfactants are more often formulation components rather than adjuvants.
4) Nonionic surfactants have no charge and are the most commonly used type of surfactant in adjuvants. They have low levels of phytotoxicity when used at label rates and remain stable. Modified sugars like alkyl polyglucosides are biodegradable and useful as sticker-spreaders. One important class of nonionic surfactants is the organosilicone surfactants. The organosilicone surfactants are very effective at increasing the spread of droplets over a waxy surface. They also have a well-documented ability to help herbicides retain efficacy following a rain event shortly after application. However, be careful of phytotoxicity when applying too much or when applying in hot conditions like those commonly found in Florida.

The organosilicone surfactants are very effective at increasing the spread of droplets over a waxy surface.

Water conditioner can be used with some pesticides that are sensitive to specific ions in water. One of the most common examples of this issue is where divalent ions like

zinc and calcium inhibit glyphosate. Ammonium sulfate added to the spray tank helps to minimize the problem.

DIFFERENT PRODUCTS FOR DIFFERENT GOALS

The dose transfer process helps make sense of this broad range of products by focusing on the goals at each step.

In the **spray tank**, one is interested in worker safety in handling concentrated pesticides. This is done by making the product easy to detect with dyes and stenching agent. One is also interested in dispersing the pesticide evenly through the spray tank.

In **atomization**, one is interested in droplet size and how droplet size influences deposition, penetration into the canopy and overall distribution of the pesticide over the target area. Drift retardants increase droplet size, while surfactants reduce droplet size. Larger droplets have a reduced risk of pesticide drift, while small droplets improve coverage.

Drift retardants increase droplet size, while surfactants reduce droplet size.

The droplets travel to the target site and **impact** on the target surface. Droplets can stick, bounce and shatter. Rebounding from the target surface often is considered undesirable, but it may lead to better under-leaf coverage, which is considered desirable for many insecticides. All the energy that moved the droplets from the sprayer to the target surface is rapidly lost.

The spray that impacted and was **retained** by the leaf surface can spread, droplets coalesce, but some spray runs off the plant because the surface tension is insufficient to keep it on the plant.

The retained spray starts to dry into a **deposit** on the target surface. The concentration of the active ingredient, formulation components and adjuvants increases rapidly. However, the deposit is subject to degradation from wind, rain and sunlight. Other organisms contact the deposit and acquire some dose. During this process, the active ingredient is acquired by the target organism and moves to the target site within the organism.

The combined activity of the spray on all target and non-target organisms results in the **biological effect**. Actions at the very start, from the choice of sprayer to the choice of adjuvant and formulation will influence all the

steps that follow. This is not a random jumble of independent steps. Rather, it is a structured order of events that all must work to produce an effective pesticide application.

The following sources were accessed in writing this article.

- Jhala et al. (2013): http://www.bioone.org/doi/abs/10.1614/WT-D-12-00105.1
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- Phagostimulant and Psyllid: https://www.researchgate.net/publication/306307703_A_Phagostimulant_Blend_for_the_Asian_Citrus_Psyllid

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'Diverse roles of adjuvants in crop protection' test

To receive one core continuing education unit (CEU), read "Diverse roles of adjuvants in crop protection" 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. 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. One adjuvant is able to solve all pesticide application problems. **T F**
2. A surfactant reduces droplet size during atomization. **T F**
3. Many formulation components are also sold as adjuvants. **T F**
4. Adjuvants are inert and therefore cannot hurt you. **T F**
5. The dose transfer process is the path a pesticide takes from manufacturer to target site. **T F**
6. Anti-foam is used to reduce foaming action of some surfactants. **T F**
7. Adjuvants are classified based on function and sometimes chemistry. **T F**
8. Drift retardants decrease droplet size to reduce pesticide drift. **T F**
9. Dyes are added to help make pesticides colorful and attractive to small children. **T F**
10. Stabilizing adjuvants reduce degradation from sunlight. **T F**
11. Anionic surfactants are negatively charged molecules. **T F**
12. A surfactant reduces droplet size during atomization. **T F**
13. Organosilicone surfactants reduce droplet size and reduce losses from rain. **T F**
14. Organosilicone surfactants will never damage plants. **T F**
15. A water conditioner reduces the effect of ions in the water that may otherwise reduce the effectiveness of the product. **T F**
16. A surfactant will affect atomization, retention and deposit formation. **T F**
17. Spreading of retained spray over a leaf surface would be part of deposit formation. **T F**
18. The biological effect is the outcome for all individuals of the target (pest) and non-target populations. **T F**
19. A surfactant is a surface active agent because it lowers the surface tension of the spray. **T F**
20. Rain, wind and sunlight are some factors that degrade the active ingredient in pesticides. **T F**

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: _____

Pesticide License Number: _____

Address: _____

City: _____ **Street:** _____ **Zip:**_____

Phone: _____