3.7.3 Spray Adjuvants: A User's Guide

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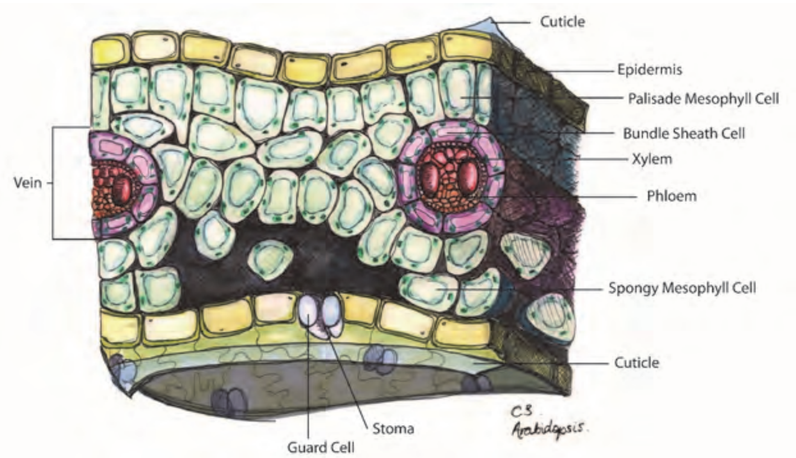
Introduction

There are a number of herbicide brands on the market, but most products are applied either as specially formulated herbicide pellets (or granules) or as a liquid spray applied to water or plant stems and foliage. Of these techniques, spraying the foliage of undesirable plants is by far the most common practice. A spray adjuvant will usually be added for foliar applications to improve herbicide performance. However, there are hundreds of different adjuvant products available, so confusion often abounds and applicators may use products they don't need or fail to use products that could be helpful.

What is an adjuvant?

According to the Weed Science Society of America, an adjuvant is "any substance in an herbicide formulation or added to the spray tank to modify herbicidal activity or application characteristics" (Herbicide Handbook – 9th edition). There are two concepts that should be drawn from this definition: 1) an adjuvant is not herbicidal in and of itself, but rather works with the herbicide to improve efficacy, and 2) some adjuvants are used simply to improve the application and handling characteristics of a given herbicide. With this in mind, adjuvants are commonly divided into two primary categories: activator adjuvants and utility adjuvants. Activator adjuvants improve herbicide retention on and absorption into the leaf, while utility adjuvants are used to reduce spray drift, foaming in the tank and other factors not directly related to herbicide absorption or penetration into the plant.



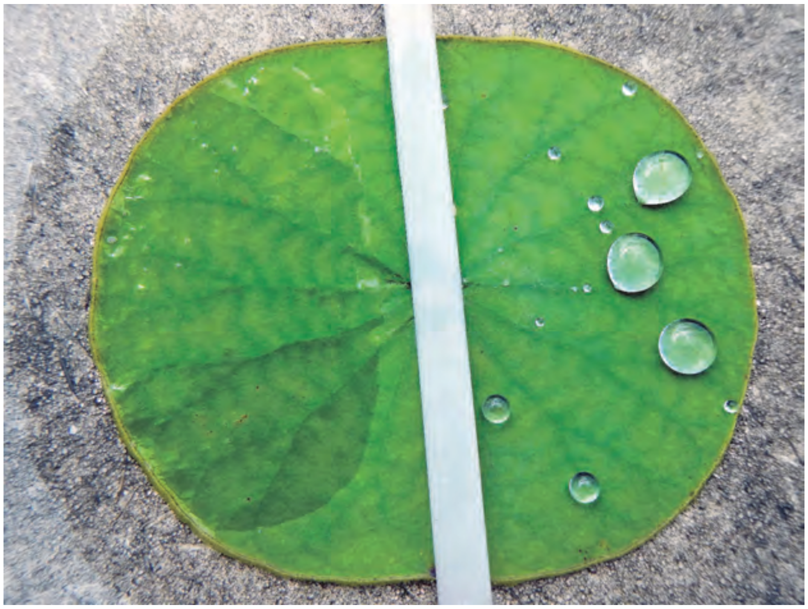
Before we talk about how different adjuvants work, we should first examine a plant leaf to understand how herbicides are absorbed into a typical emergent or terrestrial plant. This leaf cross section shows many different tissue and cell types, but of particular interest are the large veins in the middle of the leaf. These veins contain the xylem and phloem, which are specialized tissues that transport water and nutrients throughout the plant. Many herbicides (such as glyphosate) are highly effective because they are systemic, meaning they are moved in the phloem throughout the entire plant and result in total kill. But to kill the plant, these herbicides must first reach the veins in order to be transported. This is no easy task since the herbicide must land on the leaf, diffuse through the tissues, and reach the active site at a high enough concentration to be lethal. The active site is the location in the plant where herbicides interfere with enzyme production or other biochemical pathways to kill the plant. Both sides of the leaf are covered in a layer of wax called the cuticle. The cuticle is important to the leaf, since wax repels water and prevents it from "leaking" out of the leaf. Most foliar herbicides are diluted in water, so the cuticle is a formidable barrier to herbicide entry into the plant.

Activator adjuvants

As stated previously, activator adjuvants do not have herbicidal properties, but rather work with the herbicide to improve efficacy. The primary role of an activator adjuvant is to help the herbicide breach the cuticle barrier and enter the leaf. This group of adjuvants is often further divided into two broad categories: 1) wetter/spreaders, also generically called surfactants, and 2) penetrants.

Wetter/spreaders

Wetter/spreaders are often called surfactants or stickers and are likely the most common type of adjuvant used to improve herbicide performance. Members of this class, which are specially developed soaps, are quite effective while also being inexpensive. Their main function is to not interact with the herbicide per se, but to change the properties of the spray mixture in order to increase movement of the herbicide into the plant.



Why is this important? Recall that the leaf's waxy cuticle repels water. At the same time, molecules of water are attracted to each other, which causes them to form round, bead-shaped droplets (think raindrops). When no surfactant is added to a spray solution, the absorption of herbicide into the leaf is limited for two reasons. First, the round, bead-like droplet prefers to stay as a round droplet. Therefore, as the droplet contacts the leaf surface (at a high speed since it is being propelled by a pressurized sprayer), the droplet will flex and then snap back into the round shape. This "flex and snap" action will commonly cause the droplet to bounce off the leaf. Second, if the droplet is retained on the leaf, the waxy cuticle repels it and only a small part of the droplet actually contacts the leaf surface. It is through this small area of contact that the herbicide has to diffuse from the droplet into the leaf, which it does quite slowly. An additional challenge is that the droplet quickly starts to evaporate. If the droplet dries before the herbicide enters the plant, the herbicide will often turn into a crystal on the leaf (think of the white residue left behind when saltwater evaporates). If the herbicide crystallizes, the likelihood that it will ever enter the plant is extremely low. The key is to get the herbicide from the droplet into the leaf as rapidly as possible. If the droplet bounces off, is repelled by the leaf or dries too quickly, an insufficient amount of herbicide will enter the leaf and the weed will survive the treatment.

The addition of a wetter/spreader to the spray mixture greatly changes the spray droplet by lowering the surface tension of the water (the forces that make the water form a round bead) and provides three advantages. First, as the droplet contacts the leaf, the lower surface tension means that the droplet no longer wants to form a round bead; instead of bouncing off the leaf, the droplet flattens out and spray retention is greatly improved. Second, the flat droplet contacts much more of the leaf than a round droplet. This increased coverage allows better diffusion of the herbicide into the leaf since more surface area is exposed to the herbicide solution. Third, the addition of the surfactant slows down droplet evaporation, giving the herbicide more time to diffuse into the leaf.

One of the most common questions about wetter/spreader adjuvants is which brand is best. This is a difficult question to answer for many reasons, but in general, the best brand is the one you have successfully used for many years. Problems occur when an applicator attempts to buy the least expensive product (which often changes from year to year). The wisest strategy is to find a brand you are comfortable with and use that as much as possible. When trying a new product, start with a small amount and see if it fits your needs. The labels of many aquatic herbicides provide guidance regarding adjuvant selection; in fact, some products require the use of a particular type of adjuvant. However, don't over-spend because doubling or tripling your adjuvant expenses may not be cost effective. Another common question is what rate of wetter/spreader to use. In general, 0.25% v/v (1 quart of product per 100 gallons of spray mix) works great. There can be an advantage to increasing this to 0.5% v/v, but a rate higher than this rarely results in added benefit. Lastly, not all adjuvants are labeled for application in aquatic environments. Before applying any product to an aquatic system, check the label and make sure the product can be used in or around aquatic sites. The adjuvant label will specifically state "*Not for use in aquatic sites*" if the product cannot be used in, on or over water.

Organosilicones

Organosilicones are a distinct class of spray adjuvants. Their performance is similar to the wetter/spreaders, but organosilicones dramatically reduce (or totally remove) the surface tension forces of water. This causes the droplet to distribute itself into a very thin sheet across the leaf for maximum coverage. Organosilicones work quite well, but they are often more expensive and are not used as often as wetter/spreaders.

Penetrants

Penetrants are oil-based adjuvants and are most often crop oil concentrates and methylated seed oils. Using a water-dispersible oil adjuvant has a clear advantage over a traditional wetter/spreader. Recall that the wetter/spreader does little to improve herbicide uptake beyond ensuring that the droplet lies flat on the leaf. The herbicide must still diffuse through the cuticle to reach the cells and veins below. The waxy cuticle cannot be dissolved by water or a soapy wetter/spreader, but oil *will* soften or dissolve the cuticle. Therefore, as the spray droplet contacts the leaf surface, the oil-based adjuvant begins to dissolve these waxes. As the waxes are stripped away, the herbicide can easily penetrate the leaf and be transported to the regions where it can be most effective.

Since these adjuvants help the herbicide penetrate into the leaf, weed control is often greater with an oil-based penetrant than with a wetter/spreader. Penetrants are typically used on weeds that are larger and more difficult to control, or on species with leaves that are particularly waxy (think waterhyacinth – Section 2.11). Penetrants can also be useful if the weather has been dry, because plant cuticles may thicken to reduce drought stress. If weed control must be performed during these times, an oil-based adjuvant may be essential to help dissolve these thick leaf waxes and facilitate herbicide uptake. You should take into consideration that penetrants are usually applied at a 1% v/v (1 gallon per 100 gallons of spray mix), while wetter/spreaders are added at 0.25% v/v.

It is important to note that penetrant adjuvants are not always the best solution. For example, glyphosate does not perform as well when oil-based adjuvants are used. Conversely, other herbicides should only be used with penetrant adjuvants. It is, therefore, important to read the herbicide label so the recommended adjuvant can be used. Also, since oil-based adjuvants strip away leaf waxes, they can injure desirable plants that are not normally affected by the herbicide. For example, 2,4-D is often used to control broadleaf weeds in grass because grasses are not damaged by 2,4-D. However, if 2,4-D is applied with a high rate of an oil-based adjuvant, the penetrant oil can actually burn the desirable grass since the cuticle is eroded and the cells beneath die when exposed to the environment. The grass will recover, but the injury can be unsightly for a period of time.

Utility adjuvants

Utility adjuvants have a very different role and purpose than activator adjuvants. Activator adjuvants actively promote herbicide uptake into the plant by influencing the spray droplet, the plant cuticle or both, but utility adjuvants improve the efficiency of the spray operation. There are many types, brands and blends of utility adjuvants that have value for their specific uses, but their benefit is often situational and may not provide an advantage across all conditions. Therefore, it is important to understand what these products are designed to do so they can be used to maximum effect.

Defoamers

Wetter/spreader adjuvants are commonly added to improve herbicide performance. These adjuvants are soaps, so foaming is common when the tank is refilled. A small amount of defoamer added prior to tank filling can prevent bubble formation and greatly improve the efficiency of the application. Consider the photo shown at left; though a foam-forming adjuvant was used in both beakers, defoamer was only added to the container on the right. Adding defoamer after a large quantity of bubbles has formed requires much more product and time to clear the tank for refilling. It is important to be proactive and add defoamer to the spray tank before adding soapy adjuvants.

Water conditioners

All natural waters contain dissolved minerals, including iron, magnesium, calcium and aluminum, and these minerals can change the properties of water. For example, the amount or type of minerals in water is what makes water from one region of the country taste different from another. The mineral content of water used in a spray tank can affect application because the minerals listed above are all positively charged, while many commonly used herbicides are negatively charged. When these negatively charged herbicides and positively charged minerals are dissolved in a spray tank together, they naturally attract each other like magnets.

This causes problems because herbicides are highly specific and work by binding to exact places on exact enzymes within the plant. Also, they diffuse through plant cuticles in a specific manner. When a herbicide is bound to a mineral such as calcium or a magnesium complex, it may be unable to enter the plant and work properly. If many herbicide molecules are bound to and deactivated by mineral complexes, they will lose their herbicidal activity and the application will be less effective.

Water conditioners were developed to minimize the impact of dissolved minerals on herbicides. One of the most common conditioners is ammonium sulfate [$(NH_4)_2SO_4$]. Ammonium sulfate and other water conditioners bind to minerals that are dissolved in the water, which makes the minerals unavailable to bind to the herbicide and prevents the herbicide from being deactivated. If mineral content is high (especially with aluminum, iron, calcium and magnesium, which are often considered to be most detrimental), it might be useful to add a water conditioner to the tank prior to adding the herbicide.

If all water contains dissolved minerals, do all applications require water conditioners? Not necessarily; it depends on how high the mineral concentration is in the mix water and how many herbicide molecules could be deactivated. In general, the higher the mineral concentration in the water, the greater the likelihood of herbicide deactivation, and the more likely the need to use a conditioner.

Things to consider:

- The addition of a water conditioner may not always be needed because not all aquatic herbicides are affected by water hardness, so consult the label. If herbicide efficacy is lower than expected, send a water sample to a lab for analysis. If the results say your water is "hard" or "extremely hard", consider adding a water conditioner.
- If you are using a dry ammonium sulfate product, be sure to use "spray grade". If not, you may have difficulty getting the product to fully dissolve in water. Spray grade or liquid ammonium sulfate products avoid this problem.
- Add the water conditioner to the tank before the herbicide. Fill the tank 25% full, add the water conditioner, fill to 50%, add the herbicide and fill to 100%.
- Always check the herbicide label before adding a water conditioner. Some labels specifically state that NO ammonium sulfate may be used in the application. Remember, the label is the law.

pH buffers

It can also be important to know the pH of the water used in a tank mix. pH is measured on a scale of 0 to 14 and describes water as acidic (pH 0 to 6.9) or alkaline (pH 7.1 to 14). We often think water is neutral (pH 7), but that is rarely the case. For example, if you live in an area with limestone in the soil, your water pH may be 8.0 or higher. Water pH is important because acidic or alkaline water can react with herbicide molecules, which can affect efficacy. The majority of herbicides we currently use are classified as "weak acids" and they perform better in an environment that is slightly acidic – ideally, water with a pH of 4.5 to 6.5. Therefore, mixing a weakly acid herbicide in alkaline water with a pH of 8 could cause the herbicide to begin to degrade and become less effective.

Does this mean that spray water must always be acidified? Not necessarily. Although herbicide breakdown in the tank can occur if the water pH isn't correct, this may never be an issue if you mix and spray quickly. Regardless, read the product label to determine whether acidification of tank water is necessary. Some labels recommend that herbicides be diluted with water that has a pH of 6 to 8, while others recommend water with a pH of 4 to 7. If water pH is in the recommended range, no action may be required. However, pH testing can be very useful if you are attempting to optimize your spray program.

Spray dyes

Spot-spray applications can be a highly efficient, selective and cost effective way to manage sporadic populations of unwanted plants. However, these plants are often randomly distributed across a landscape, which complicates spot-spraying. Invariably, some patches will be treated twice, while others are missed entirely. If you plan to perform spot-spray treatments, a non-toxic dye can be added to the spray mix to ensure that each and every weed is treated once. A spray dye is a colorant that stains the weeds that have been sprayed. This gives the applicator an immediate visual cue that a particular weed has been sprayed, or missed. Many different brands and colors of spray dye are currently available, but blue is the most common. The color fades and is gone within 1 to 5 days after spraying.

Drift reducers

Herbicides are a powerful and useful tool to manage unwanted plants while preserving and encouraging growth of desirable species. However, a constant concern is damage to desirable plants that occurs when the herbicide spray drifts, or is blown outside the treatment area. Therefore, care should be taken to avoid or minimize herbicide drift. Sprayers work by pressurizing the herbicide solution and forcing it through a hose to a spray nozzle. When the liquid solution strikes the specially designed nozzle, it fragments (or shears) into individual droplets. For example, note the small, drifting droplets being formed during the high-pressure herbicide treatment shown here. Nozzle type and sprayer pressure affect droplet formation and work together to form large or small droplets. Small droplets are of the greatest concern because they are easily moved by wind currents. One way to manage the proportion of small droplets formed is to include a drift-reducing agent in the herbicide mixture, which will “thicken” the spray solution. Thicker liquids resist shearing into small droplets, so fewer small droplets are formed and the risk of drift is reduced.

Though drift reducers can be quite effective, other techniques should also be employed to manage drift.

1. Spray at the lowest pressure possible. As pressure in the sprayer increases, more small droplets are formed.
2. Avoid spraying in high wind. The higher the wind speed, the more likely droplets will drift. Also, high wind can carry small droplets exceptionally long distances.
3. Avoid spraying into the air when possible. It is often necessary to spray into the air when undesirable trees must be managed. However, spraying in this manner increases the likelihood that droplets will drift.
4. Pay close attention to your surroundings. If valuable or highly sensitive plants are nearby (for example, gardens), closely examine what and where you are spraying and evaluate the likelihood of drift occurring.

5. Although most herbicide drift issues arise from physical movement of spray droplets, some herbicides can turn into a gas and drift as a vapor, particularly on very hot days. This is most common with herbicides such as 2,4-D and triclopyr. Products that are especially prone to drift will provide this information on the label, along with guidelines and requirements to reduce the occurrence of drift.

Summary

Adjuvants are not herbicides and do not directly control unwanted plants, but they work with herbicides to greatly improve efficacy and productivity of herbicide applications. With that in mind, here are a few things to keep in mind when considering the use of an adjuvant:

- Before making an application, ensure that the target weed will be adequately controlled by the selected herbicide. Read the herbicide label and note the appropriate plant size and application timing for the target weed. If the wrong herbicide is chosen or applied in an inappropriate manner, the addition of an adjuvant will rarely improve control.

- Be aware that some adjuvants are blends of several products. For example, it is possible to buy products that adjust pH and act as a wetter/spreader. Before you purchase a blend, make sure all of the components are necessary for the application. Using a blended product is not likely to decrease herbicidal activity, but it can result in an unnecessary increase in cost.

- Some manufacturers suggest that a particular adjuvant is so effective that the application rate of the herbicide can be reduced. Caution should be exercised before reducing a recommended herbicide use rate. Herbicide labels are written after a great amount of data is collected over several years at many locations, so recommended label rates and application methods are time proven. Expecting an adjuvant to do the work of a herbicide can result in reduced efficacy, and more often than not, an applicator is better off following the herbicide label recommendations.

- It has been suggested that the addition of common dish soap or fuel oils (such as diesel) to the spray tank may be equally effective as proper spray adjuvants. This is simply not true. Spray adjuvants have been specifically formulated to enhance herbicide performance without significantly damaging the plant. Adding soaps or fuel oils can disrupt leaf tissue, result in significant foaming and increase expenses, while potentially decreasing herbicide activity. An adjuvant that is specifically designed for the particular application should always be used instead of common household products.

Adjuvant technology has improved dramatically over the past 50 years and many of these products are highly reliable and effective. However, reading all product labels is essential to ensure that all treatment components are used for maximum effectiveness in order to improve the efficacy of any weed management program.

Photo and illustration credits:

Page 185: Cross section of a leaf on a typical terrestrial or emergent plant. Modified from an image by Ninghui Shi; used with permission
Page 186: Water on a lotus (*Nelumbo lutea*) leaf with (left) and without (right) a surfactant; Lyn Gettys, University of Florida
Page 187: Beakers with and without defoamer; Jason Ferrell, University of Florida
Page 189 upper: Using a dye while spot-spraying; Thomas D. Brock, University of Wisconsin-Madison
Page 189 lower: Spray drift from a high-pressure herbicide treatment performed at a distance from the target; Ken Langeland, University of Florida