TANK MIXING DO'S AND DON'TS

Many superintendents combine two or more plant health products in one spray application to save time and money. Tank mixes might include one or more of the following materials: pesticides (especially herbicides, fungicides, and insecticides), fertilizers, adjuvants, spray dyes, micronutrients, macronutrients, biostimulants, and plant growth regulators. Tank mixing reduces the number of times a sprayer must operate, thereby saving labor, reducing use of fuel, and reducing soil compaction that can occur as a result of multiple applications on the same site. In some cases, tank mixing can slow the development of pesticide resistance by using pesticides with more than one mode of action to target the pest.

Physical and Chemical Incompatibility

However, there can be many drawbacks to combining products. Some products may reduce the effectiveness of other products when applied at the same time. Equally concerning, some combinations involve products that are incompatible with each other, resulting in a sludgy mess that accumulates in the bottom of the tank or clogs hoses and nozzles. When products are physically incompatible, one material might not go into suspension in the presence of another, or the products might separate into layers, or the combination might foam excessively, or solids might clump together. When any of these things happen, the applicator may have to clean the tanks, and remove and clean all the filters, screens, and nozzles. In extreme cases, a sprayer can be ruined as a result of a bad tank mix combination.

Chemical incompatibility is not always obvious at the time of the application, but can end up having a negative effect on product uptake or surface retention by the plant. An example of a chemical incompatibility would be phytotoxicity that appears hours or days after the application. Chemical incompatibility often occurs when surfactants that have been included in the tank mix are not compatible with other products in the mix.

The Role of Water Quality in Tank Mixing

Water is the primary carrier for most liquid applications, usually accounting for more than 95% of the final volume in the tank. The pH (a measure of acidity or alkalinity), chemical composition, presence of minerals, and temperature can all affect the compatibility of products.

Your source of water can make a difference. Pond or lake water may have more turbidity (small suspended particles) in it, which can bind to some active ingredients, rendering them less effective. Well water may contain minerals from the underlying aquifer, which may in turn result in a relatively high or low pH or particularly "hard" or "soft" water. City or municipal water supplies may include additives such as chlorine to ensure safe drinking standards. Municipal systems often have a pH of 7.5 to 9.0 (in part to make it less likely that lead will dissolve out of pipes and into the water), and the pH can vary seasonally. Regardless of your source of water, you should be checking your water supply regularly (several times a year), in particular to determine the pH, the degree of hardness (a measure of the concentration of calcium and magnesium ions), and presence of particulate matter.

Concepts of Tank Mixing

This fact sheet will describe some of the concepts of tank mixing that must be considered when determining whether specific combinations "make sense" and are less likely to cause application problems. Much of the information provided here is derived from "Avoid Tank Mixing Errors", an Extension publication from Purdue University (*Avoid Tank Mixing Errors.* Purdue Pesticide Program Bulletin PPP-122. 44 pp. Purdue University Pesticides Program. (www.extension.purdue.edu/extmedia)

Understanding the Chemistry of Pesticide Formulations

A little terminology is helpful to understand the following descriptions of formulations. These terms are also important to understand when trying to determine which pesticides can be combined in a "**tank mix**" (a combination of two or more pesticides or fertilizers that are applied at the same time).

Sorption refers to the process of adhering a liquid active ingredient (AI) on to a solid surface (e.g., a dust or a granule). Adsorption occurs when there is a chemical or physical attraction between the AI and the surface of the solid. Absorption occurs when the AI enters pores on the solid.

A ***solution*** occurs when a substance (the solute) is dissolved in a liquid (the solvent). The solute can be a solid or a liquid. Once a solution forms, the solute and the solvent cannot be mechanically separated. (An everyday example is table salt that has dissolved in water.)

A ***suspension*** occurs when very fine solid particles disperse in a liquid. The solid particles do not dissolve in the liquid, and the liquid must be agitated to maintain thorough distribution (and to avoid the particles settling to the bottom of the tank).

An ***emulsion*** is a mixture that occurs when one liquid is dispersed (as small droplets) in another liquid. Each liquid retains its original identity. Several pesticides are formulated as "emulsifiable concentrates", where the AI is dissolved in an oil-based solvent and then added to water in the spray tank.

Pointers for Success

1. **Read the label**

   A lot of information about combinations of plant health products can be found on the label. **Remember, the label is the law** – follow the instructions when preparing an application. Often there is a section that makes specific recommendations regarding tank mixes – kinds of products that are likely to be compatible, as well as products that are known to be problematic. For example, a label might say, "Do not combine with a specific kind of fertilizer."

2. **Check the containers**

   Some formulations are liquids that contain active ingredients that can separate into layers. It is very important to shake those containers thoroughly and make sure the active ingredient has been dispersed throughout the container, before adding the contents to the sprayer.

3. **Test the combination first**

Any time you make an application with a combination of products that you have not tried before, you should test that combination for compatibility before mixing the products in the tank. (See a description of a **"jar test"** at the end of this fact sheet.) And even though you may have used a certain combination last year, the pesticide formulator may have changed the inert ingredients in the product, and those products may react differently, resulting in incompatibility issues that did not occur with the "old" formulation.

4. Add the contents in the right order.
Most products that are added to water for application form a solution, suspension, or emulsion in water. In most cases, the products should be added based on these characteristics. (See **"proper order")** later in this fact sheet.

5. Make sure there is enough water in the tank before adding products and provide adequate agitation throughout the mixing process.
Problems can occur if you have only 25 to 35% of the spray volume in the tank when you begin to add products. Each of these products needs to be able to dissolve, form a suspension, or form an emulsion in the water. If there is not enough water, that can't happen. Be sure to fill the sprayer to 50 to 75% of the intended final volume before beginning to add products to the tank.

6. Be patient when adding products to the tank.
Most plant health care products take time to dissolve, suspend, or disperse in water. You should always provide agitation during the mixing process, especially after each product is added, and before adding another material. If you add products to the tank without allowing enough time for each material to become distributed in the water, you can interfere with the dispersion and mixing of the products, and you may experience a physical compatibility that can cause considerable damage to the tank.

7. Agitate properly.
You should agitate tank mixtures throughout the mixing process as well as during the application. Failure to do so will result in some products, such as water dispersible granules, wettable powders, and suspension concentrates, setting out over time. However, it is possible to provide agitation that is too aggressive, which can lead to foaming or can cause surfactants on the surface of solid active ingredients to separate, destabilizing the tank mixture. Be sure to read the label for more guidance.

8. Recognize that temperature matters.
Water temperature can influence the rate at which products dissolve, disperse, form emulsions, and flow. In general, dry formulations and liquid flowables take more time to disperse when the water temperature is lower than 45° F. When mixing products in cold water, allow at least three to five minutes for each product to dissolve or disperse before adding the next product. Some people prepare a slurry of the product in warmer water and add the slurry to the tank. This can speed the dispersal process. Cold water can also slow the rate at which water-soluble packets dissolve. If the packages do not dissolve completely, the plasticized residue can clog nozzles and pump intakes.

9. **Measure the pH of the solution throughout the mixing process, and be sure to measure the pH of the final spray solution.**

pH measures the degree of acidity (pH < 7) or alkalinity (pH >7). Some plant health care products are subject to more rapid breakdown when pH is above or below a certain value. For example, trichlorfon (a curative insecticide) begins to break down in the tank in less than an hour if the pH of the water is above 7.5. Measure the pH of your water supply before you begin mixing. If the pH is unusually high or low, you may need to refine the order in which you add products – or you may need to add a buffer or other product to manipulate the pH. Also measure the pH of the final spray solution to make sure it is in the pH range specified by the product label. There are products available that can be added to adjust the pH either higher or lower, but be very careful. Some acidifiers, in particular, can lower the pH too much if just a little bit too much is added to the tank – and this can cause some active ingredients to precipitate out of solution.

Proper Order to Mix Products

There are several different industry guidelines describing the order in which different products should be added to the tank. Most of them depend on the chemical characteristics of the active ingredient in water – does it form a suspension, a solution, or an emulsion? For more information on pesticide formulations, see the fact sheet, "Pesticide Formulations". Suggestions for the **proper order** in which products should be added to a tank are provided at the end of this fact sheet.

WALE principle

The "WALE" principle is the most traditional approach. As noted above, adequate agitation should be provided throughout the mixing process. The WALE approach calls for adding products in the following order:

- **Wettable products** (water soluble bags, water dispersible granules (WDGs), dry flowables (DFs), wettable powders (WPs)
- **Agitate**
- **Liquids other than oil-based emulsions** (flowable suspensions, liquid solutions, suspended concentrates)
- **Emulsions** (emulsifiable concentrates)

SASE principle

The SASE system is a newer variation regarding mixing order. Like the WALE approach, agitation must be maintained through the mixing process. The SASE approach adds products in the following order:

- **Suspensions** (water soluble bags, water dispersible granules WDGs), dry flowables (DFs), wettable powders (WPs), flowable suspension (F), suspended concentrates (SC)
- **Agitate**
- **Solutions** (things that dissolve in water, such as soluble powders, some fertilizers)
- **Emulsions** (oil-based emulsions, such as emulsifiable concentrates and micro-encapsulated formulations)

More details on proper order of mixing are available in the Purdue bulletin, *Avoiding tank mixing errors*. That publication expands the discussion to include the order in which ammonium sulfate and other fertilizers, compatibility agents, anti-foamers, and other adjuvants should be added to the tank.

How to Conduct a Jar Test to Screen for Compatibility Problems

Any time you plan to use a "new" combination of products in a tank mix – whether a new formulation, a new product, or materials you have not used in combination before, you should conduct a simple "jar test". This consists of filling a small glass jar with water, and adding each ingredient in the proper mixing order as described above (WALE or SASE).

1. Add 1 pint of water that will be used to fill the sprayer (be sure to use the same water source) in a clean 1-quart glass jar.
2. Add the ingredients in the proper mixing order (WALE or SASE) in an amount that reflects the application rate on the label. **Each time you add a product, agitate the jar** by shaking it or stirring it carefully.
3. Many labels provide the application rate in terms of amount of product per 100 gallons (e.g., 1 quart of product per 100 gallons for a liquid product or 1 pound per 100 gallons for a dry product). Use the guidelines below to determine how much of the product to put into the jar:
    a. For insoluble dry products, add 1 level tablespoon for each pound per 100 gallons specified on the label.
    b. For soluble dry products, add 1 level teaspoon for each pound per 100 gallons specified on the label.
    c. For liquid products, add 1 level teaspoon for each pint per 100 gallons specified on the label.
    d. Add the emulsifiable concentrates last.
    e. If the label gives a range of application rates, use the rate you intend to use in your tank mix. When in doubt, conduct the jar test using the higher rate on the label.
4. Once you have added all the products, let it "sit" – shake it or stir it occasionally to simulate agitation in the tank. You need to let the combination remain long enough for any incompatibilities to occur – at least the same amount of time it would take you to finish the application with the sprayer.
5. Physical incompatibilities are often indicated by the jar test (e.g., curdling, formation of gels, formation of sludge, settling of particles to the bottom).
6. Chemical incompatibilities are less obvious in a jar test or during an application, and often show up after the fact. Examples include phytotoxicity or a decrease in the effectiveness of one or more of the products in the combination. So conducting a jar test will not necessarily protect you from chemical incompatibilities.

Final Thoughts

If you pay attention to the details, tank mixing can save you time, money, and wear and tear on the equipment. If you don't pay attention to the details, you may end up with a thick sludge at the bottom of the tank (or worse), and the products may not perform as well as you had expected.

Reference:

Fred Whitford, Melissa Olds, Raymond Cloyd, Bryan Young, Doug Linscott, Jason Deveau, Jim Reiss, Aaron Patton, Bill Johnson, Tim Overley, and Kevin Leigh Smith. September 2018. *Avoid Tank Mixing Errors.* Purdue Pesticide Program Bulletin PPP-122. 44 pp.