NebGuide

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Research-Based Information That You Can Use

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Testing Pesticide Mixtures for Compatibility

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This NebGuide describes the use of jar tests to avoid pesticide tank-mixing errors that may impact pest management, the environment, and human health.

Understanding how to tank mix pesticides is helpful for efficiently and sustainably managing pests. Tank mixing allows applicators to control multiple pests at once while making fewer trips through agricultural fields, which reduces soil compaction and saves fuel, labor, and equipment mileage. When used appropriately, tank mixing is also a valuable tool for preventing or slowing the development of pesticide-resistant pest populations. However, many things can go wrong when tank mixing pesticides. The best way to avoid these problems is to perform a jar test with the pesticides and adjuvants you wish to use before mixing an entire spray load.

Chemical Interactions

Chemical compounds are created by molecular bonds between different elements. Table salt, or sodium chloride (NaCl), is an example of a simple chemical compound. Table salt is composed of a sodium (Na) atom and a chlorine (Cl) atom fused together by an ionic bond. Everything in the universe is made up of one or more chemical compounds, including the human body. When compounds encounter each other, interactions can occur that alter their chemical makeup or produce entirely different compounds. Pesticides are no exception.

Tank mixing is the deliberate combination of complex chemical compounds, and the potential for unwanted interactions always exists. Some interactions are "visible," such as solidification, fizzing, foaming, clotting, settling, heat production, heat loss, combustion, or explosion. Some interactions may not be visible, but they may still impact pesticide effectiveness.

It is important to watch for visible interactions AND check for nonvisible interactions when tank mixing.

Physical incompatibility. When tank mix partners are unable to remain uniformly mixed in a spray tank, even with moderate agitation, 'physical incompatibility' results.

An example of physical incompatibility is the combination of 28% nitrogen (N) with 2,4-D herbicide. A 28% N solution is compatible with 2,4-D ester, but not with 2,4-D amine. If a 28% N solution is combined with 2,4-D amine, the mix thickens to an unusable mayonnaise-like consistency.

Use a jar test to determine if a tank mix will behave in a way that could clog equipment or otherwise impact its ability to be applied.

Chemical incompatibility. When tank mix partners alter each other's pesticidal effectiveness (efficacy), 'chemical incompatibility' results.

A tank mix that does not have a visible interaction may still have a non-visible one. When pesticides are combined, there can be a range of impacts on their efficacy (Table 1). This change is often not observable until a test application is made. An 'additive interaction' is when two chemicals are combined and neither interferes with the efficacy of the other. An 'antagonistic interaction' is when one chemical reduces the efficacy of another, such as when the herbicides atrazine and glyphosate are mixed. 'Synergism' occurs when a chemical's efficacy is increased by another chemical, whether or not the second chemical has any efficacy on its own. When a non-pesticidal chemical (e.g., an adjuvant) synergizes with a pesticide, it is also sometimes called 'potentiation.' Synergism can be a cause for concern because supercharged pesticidal activity creates the potential for harm to non-target organisms, such as humans, pollinators, or crops.

Chemical interaction type	Efficacy of Chemical A	Efficacy of Chemical B	Combined efficacy of A & B
Additive	15%	35%	50%
Antagonism	35%	25%	15%
Synergism (potentiation)	10%	10%	100%
	0%	20%	50%

Table 1. Types of chemical interactions and their impact on pesticidal effectiveness. Note that the percentages listed are generic and for illustrative purposes only.

To determine if a desired tank mix will produce an unwanted chemical interaction, mix a small tank load and apply it to a small area of the application site. This will help identify any non-visible interactions and determine if the tank mix may cause damage to any organisms that are not the intended target.

Basics of Tank Mixing

Applicators may benefit from using pesticide tank mixes. However, a variety of factors can influence the viability of mixtures. Success requires close attention to pesticide label directions, the properties of each tank mix material, and the order in which materials are added to the mix. Practices such as suitable tank agitation, prompt use of spray loads after mixing, and thorough cleaning of application equipment also aid tank-mixing success.

Label directions. The first step in making a tank mix is always to read each pesticide product label. A product's labeling may list approved and/or prohibited tank mix partners; some product labels forbid mixing with anything that isn't explicitly approved, while others instruct the applicator to perform a jar test with such combinations. Labels may list specific application rates for tank mixes; these must be followed when present. If a product requires the addition of an adjuvant to be effective, its label will say so. Labels may also identify carrier properties (e.g., water pH) required for optimal pesticide performance. If label instructions are at odds with any guidance in this NebGuide, always follow the label.

Material properties. The characteristics of each tank mix component influence the overall performance of the spray load.

Carrier—The carrier (usually water, or sometimes liquid fertilizer) constitutes most of a spray load's total volume. Before it can carry pesticides to the target site during application, the carrier must adequately dissolve and/or suspend them in the tank for uniform coverage at full labeled rates. The pH, mineral content (hardness), and temperature of carrier water influence its ability to do this (Table 2).

Carrier water characteristic	Potential effects
pH	Some common pesticides break down in alkaline conditions (pH higher than 7), leaving less chemical available to control the pest. Others dissolve more easily and perform better in high-pH conditions.
Hardness/softness (mineral content)	Some products bind to the minerals in hard water, leaving less chemical available to control the pest.
Temperature	The colder the water, the longer it takes for soluble products to dissolve properly.

Table 2. Effects of carrier water on pesticides.

Because most pesticides are formulated to perform best in water, substituting liquid fertilizer as the carrier complicates the task of tank mixing by increasing the likelihood of unwanted interactions. Some pesticide labels explicitly state that a product is compatible or incompatible with fertilizers. Always heed this guidance. See the *Guide for Weed, Disease, and Insect Management in Nebraska* (EC130) for a table of fertilizer compatibility with common herbicides.

Pesticide products—Commercially available pesticide products are complex chemical formulations. Both the active and inert ingredients influence how a product mixes into a spray load. For example, the inert ingredients in water-dispersible granules are designed to break the granules into tiny particles when they contact water. This distributes the active ingredient evenly throughout the tank. However, if the granules first encounter an oil-based tank-mix partner, they will not "disperse," leading to diminished pest control and potentially clogged or damaged equipment. This is an example of why pesticide mixing order is so critical.

Some liquid pesticide formulations separate into layers while sitting in their containers. Shake liquid product containers before use to ensure products are added to the tank as formulated.

Adjuvants—The term 'adjuvant' encompasses a wide variety of spray additives used either to improve the performance of a pesticide or alter the characteristics of a spray load. Adjuvants can make or break a tank mix. A pesticide label may require or recommend the use of an adjuvant when the product is to be applied on certain labeled sites, with certain tank-mix partners, or by certain application methods. Some products may require the use of an adjuvant for all applications. On the other hand, a pesticide label may prohibit the use of an adjuvant, either entirely or for certain use patterns. When tank mixing two or more pesticides, be sure the products' adjuvant requirements/recommendations do not conflict.

Products containing more than one type of adjuvant are common in the marketplace. For example, a spreader-sticker product contains surfactants for both spreading spray droplets across a target surface and helping the spray stick tightly to the surface. Crop oils contain an emulsifier, which allows them to be incorporated into water-based mixtures. Pay close attention to what you are buying, and contact the adjuvant manufacturer if you have questions about a product. The *Compendium of Herbicide Adjuvants*, published by Purdue Extension and Southern Illinois University, is also a valuable resource.

Fig. 1. A single adjuvant product can serve several purposes. (Nebraska Pesticide Safety Education Program file photo)

Micronutrients—Metallic micronutrients such as copper, iron, manganese, and zinc require special consideration when combined with tank mix partners. If a chelating agent (e.g., EDTA) is not present in the tank, either as part of the micronutrient product formulation or as an adjuvant, micronutrients may not remain in solution. Furthermore, non-chelated micronutrients are not readily absorbed by plants, whether soil- or foliar-applied, which renders them useless. Read the product label and consult with the manufacturer to determine if micronutrient products require the use of an adjuvant.

Mixing order. The order in which tank mix components are added to the spray tank greatly influences the success or failure of the mixture. In general, correct mixing order is determined by product formulation (Table 3). However, always check each product label for specific instructions on tank mixing and mixing order; as mentioned previously, label directions ultimately supersede any guidance given in this NebGuide.

Order	Formulation	Type
1	Water-Soluble Packet/Bag (WSP/WSB)	Dry
2	Wettable powder (WP)	Dry
3	Dust (D), Dry Flowable (DF), or Water-Dispersible Granule (WDG)	Dry
4	Liquid (L) or Flowable (F)	Liquid
5	Emulsifiable Concentrate (EC)	Liquid
6	Microencapsulated (M)	Dry
7	Surfactants or Oils	Liquid

Table 3. Pesticide mixing order by formulation type.

Agitation. Most pesticides require some degree of tank agitation to be dissolved or suspended evenly throughout the tank. Agitation becomes even more important when combining multiple products in the same tank. Too much agitation can destabilize emulsions or cause unwanted foam to form; too little agitation allows suspended particles to settle out of a mixture, resulting in a nonuniform spray load and increasing the risk of clogged equipment. Patience is key: allow plenty of time for each tank-mix partner to integrate itself into the mixture before adding the next, especially if the carrier water is cold.

Prompt use. Once a spray load is ready, use it as soon as possible. The chances of unwanted settling or other complications increase the longer a mixture waits to be applied. If delays are unavoidable, maintain adequate agitation until the application can be made. In addition, fertilizer-based tank mixes can experience changes in pH if allowed to sit for long periods of time.

Clean equipment. Thoroughly clean application equipment between applications to remove leftover pesticide residue from tanks, booms, pumps, nozzles, and screens. This is especially critical when the product(s) to be applied is/are different than what was applied previously, because residue from a previous application may interact with the next spray load in unpredictable ways. For more information on cleaning equipment, see Cleaning Pesticide Application Equipment (NebGuide G1770).

How to Conduct a Jar Test

The goal of a jar test is to determine the viability of a tank mix by simulating a real spray load as closely as possible, on a tiny scale. This means that the proportions of pesticides, carrier water, and adjuvants must be the same in the jar as they would be in a full-size spray tank. Additionally, the carrier water used for a jar test should come from the same source you would use when filling your spray tank; this enables you to observe any negative effects on the mix caused by the carrier water and correct for these effects.

Commercial test kits are available that contain 100-mL test bottles ("jars") and 1-mL pipettes for conducting jar tests. These kits simplify the process of determining the right proportions of each tank mix component by equating 1 mL of test mix to 1 gallon of full-scale mix. The Nebraska Extension Pesticide Safety Education Program (PSEP) has developed a Jar Test Proportions Calculator with Microsoft Excel that further simplifies the use of these kits by automatically calculating the amount of each product needed for a 100-mL test bottle. This tool is available for free download (see Additional Applicator Resources). The PSEP office can provide kit recommendations, and you can also make your own kit with graduated eyedroppers and jars marked off at 100 mL.

Jar Test Supply Checklist

- ☐ Carrier water
- ☐ Pesticide products and their labels
- ☐ Adjuvant products and their labels
- ☐ Personal protective equipment (PPE)
- ☐ Small jar or bottle
- ☐ Measuring cups/pipettes (liquid products)
- ☐ Scale (dry products)

A general process for conducting a jar test follows:

1. Determine which pesticide products you wish to apply together. Read all label directions and make note of any tank-mixing requirements, recommendations, or compatibility information. If a pesticide requires the use of an adjuvant, be sure to have it on hand.
2. Prepare for the jar test by determining the mixing order and how much of each tank mix component you will need. You can do this using the Excel calculator tool mentioned previously; you'll simply need to know your intended spray volume per acre, each product's application rate, and each product's formulation type. A short tutorial on how to use this tool is also available (see Additional Applicator Resources at the end of this publication).
3. Put on all PPE required for mixers/loaders by the product labels. When dealing with multiple labels, follow the label with the most stringent PPE requirements.
4. Shake all liquid pesticide containers to ensure they haven't settled into layers.
5. Add carrier to the test jar/bottle until it is 1/3- to 1/2-full.
6. Add the first pesticide product or adjuvant to the test bottle according to label directions and/or the mixing order in Table 2. Adjuvant mixing order can vary by product, so it is critical to read the adjuvant label for its recommendation.
7. Agitate the test bottle and allow the first product time to dissolve or suspend in the carrier. This will take longer if the carrier water is cold. Room temperature is best. Do not heat carrier water.
8. Add the next pesticide product or adjuvant to the test bottle. Agitate and allow the product time to dissolve or suspend in the mixture.
9. Repeat Step 8 until all desired tank-mix partners are incorporated into the mixture.
10. Add the remaining carrier (i.e., water) to the test bottle to reach a total volume of 100 mL. Agitate.
11. Allow the mixture to sit for about 30 minutes.
12. Check the mixture for physical incompatibilities. If none are visible, continue to Step 13. If physical incompatibility is observed, begin the process over again. Consider adding a compatibility agent to the next mixture. If physical incompatibility persists in the follow-up mixture, you may need to replace one or more of the pesticides with a different product.
13. Apply the mixture to a small test plot at the application site to identify any non-visible chemical incompatibilities.

Final Considerations

1. Pest management is a key part of sustainable agricultural production. Many producers practice integrated pest management (IPM), which is a continual process of pest identification, prevention, monitoring, control, and evaluation. During this process, producers use multiple pest-management strategies such as sanitation and biological, cultural, mechanical, or chemical control methods to reduce or prevent pest species from becoming economic liabilities (Figure 1). Chemical control can be highly effective but should never be the first or only method of pest management. The pesticides in use should always be examined for their toxicity, use sites, effectiveness against the pest, and application method.

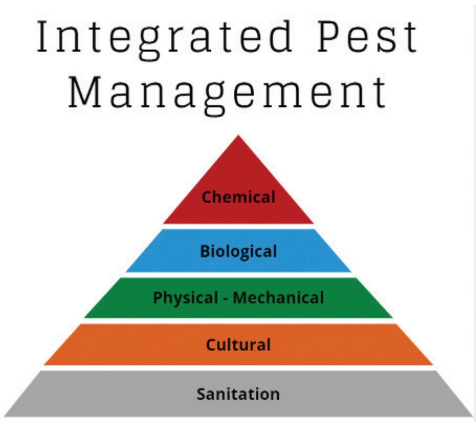

Fig. 2. IPM involves a myriad of prevention and control techniques. Start with the bottom of the triangle to prevent a pest's presence. Rely on the bottom four technique types to prevent a pest's presence and control it non-chemically. Chemical control, at the top, should be used as sparingly as possible.

2. Understanding how to complete a pesticide jar test is an important part of safely and effectively managing pests. It can help to manage resistant populations by allowing for the use of two pesticides with different modes or sites of action. It is important to understand, however, that there are several different mechanisms of resistance that can develop in a pest population. While resistance mechanisms vary somewhat among the different agricultural pest types (i.e., weeds, insects, diseases), all these pests can become resistant to pesticides by (1) modifying the site that a pesticide targets, such as an enzyme, or (2) becoming better at metabolizing the pesticide. If you believe you are dealing with a pest population with metabolic resistance to pesticides, contact your county extension office. A specialist can help you strategize how best to manage the population.

> Resistance: A **change in the sensitivity of a pest population** to a pesticide, resulting in the failure of a correct application of the pesticide to control the pest

3. Chemical interactions can have unpredictable effects on human health, both acutely and chronically. As with all pesticide handling activities, the best way to protect your health when tank mixing pesticides is to wear all label-required PPE.

4. Even if two products have been successfully tank mixed in the past, it is important to reread their labels before each application. The name of a product may stay the same, but its formulation (e.g., inert ingredients) can change without notice. As a result, labeled application rates, methods of application, active ingredient concentration, and tank mixing requirements can change, too. Consider jar testing products again if their batch numbers differ from previous containers. The more often you can consider safety in your operations, the better. The goal should be to do the job well, and only do it once.

If tank mixing seems suited to your needs, communicate with your county extension office (see Additional Applicator Resources) and work with a qualified agronomist or crop advisor to select suitable tank mix partners and plan an effective application.

Additional Applicator Resources

Nebraska Extension Pesticide Safety Education Program (PSEP) (https://pested.unl.edu)

Jar Testing Pesticides, YouTube video by Nebraska Extension PSEP (https://youtu.be/XoXCEa1GO6s)

Jar Test Proportions Calculator, *in* Math for Pesticide Applicators, Nebraska Extension PSEP (https://pested.unl.edu/math)

How to Use the Jar Test Proportion Calculator, YouTube video by Nebraska Extension PSEP (https://youtu.be/QAVByJ9Xl8Y)

Compendium of Herbicide Adjuvants (PPP-115), Purdue Extension and Southern Illinois University (https://ppp.purdue.edu/wp-content/uploads/2016/11/PPP-115.pdf)

Guide for Weed, Disease, and Insect Management in Nebraska (EC130), Nebraska Extension

Nebraska Department of Agriculture Pesticide Program (https://nda.nebraska.gov/pesticide)

Nebraska Extension's Expertise and Personnel Directory (https://epd.unl.edu/)

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