USING ADJUVANTS TO IMPROVE CROP PROTECTION PERFORMANCE

From the introduction of 2,4-D, the first modern herbicide in the early 1940s, to the development of biotech traits in the 1990s, to the latest technology launches, agriculture has created powerful weapons to control weeds, insects and disease. However, the effectiveness of these powerful weapons still depends on several environmental and physical factors working with the chemistry. You may have heard that adjuvants can help to make these chemical, environmental and physical factors work more efficiently together in your tank mix, but if you've found yourself confused as to what an adjuvant is, what it does and how to use it properly, you aren't alone. Many questions still exist about this growing product category.

Use this guide to build your understanding of adjuvants and how to use them to increase crop protection product performance. We'll cover topics like:

- What adjuvants are
- How they are grouped
- The functions they perform
- How to select the right ones for your operation
- Tank mixing
- Retailer opportunities

What is an Adjuvant?

An adjuvant is a broad term for any substance in a spray solution used to improve pesticide activity or application characteristics. Adjuvants can perform one or several functions, including:

- Improved pesticide coverage, adherence and penetration to a pest
- Water conditioning
- Increased water droplet size
- Additional stability, solubility and compatibility of a solution
- Decreased tank mix foaming
- Field marking

Spray Adjuvants: Two Groups

While all adjuvants serve to improve crop protection performance, they do so in one of two specific ways – hence two core group names. The first group gets its name from the specific purpose the adjuvants in this group do: activate crop protection products. The second group contains a broader list of adjuvant types, but each one serves to make tank mix ingredients work better together.

Activator Adjuvants

Activator adjuvants enhance the biological activity of a specific crop protection product. For example, herbicides already have the ability to enter into and kill a weed, depending on their active ingredient formulations. When an activator adjuvant is added to the equation, it helps the herbicide to more readily enter the weed. Crop protection products applied with an activator adjuvant will have increased absorption and penetration rates, allowing for better weed, insect or disease control. This group of adjuvants includes:

- Surfactants
- Oil adjuvants
- Liquid fertilizer solutions

Special Purpose/Utility Adjuvants

Special purpose/utility adjuvants work by altering the physical characteristics of the spray solution for maximum performance. They correct issues in the tank mix that could negatively affect spray applications, so you can be confident that every droplet leaving the sprayer is providing effective weed control. This group includes:

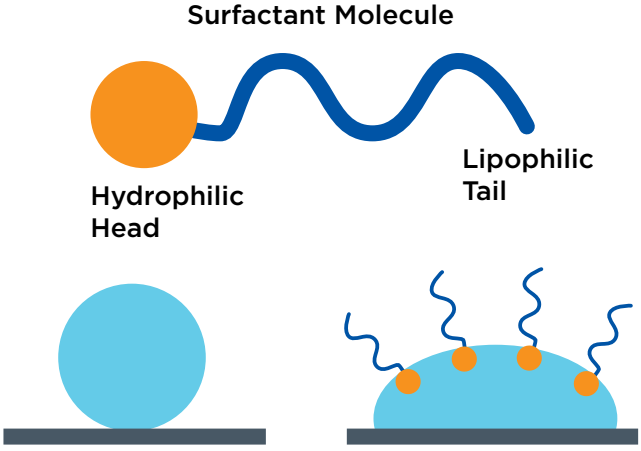
- Drift control agents
- Deposition aids
- Compatibility agents
- Water conditioners
- Other special purpose/utility adjuvants

Types of Activator Adjuvants

Surfactants (Wetter-Spreaders)

For best results, pesticides must be able to spread and adequately cover the surface of the pest –for example, the leaf of a weed. Some weeds have very waxy or hairy surfaces, making it difficult for herbicide to spread out and fully cover a leaf. Surfactants, also known as wetter-spreaders or wetting agents, help to spread solutions by reducing the surface tension between the spray solution and the target surface. This allows water droplets to spread across the weed's leaf – for example, increasing the contact area for better absorption. Surfactants are one of the most commonly recommended adjuvants on herbicide labels, especially for water-soluble and systemic herbicides.

Surfactants are categorized by ionic charge. Non-ionic surfactants (NIS) have no ionic charge and are the most common type required on labels. Organo-silicone surfactants are a newer type of surfactant and are often called "super-spreaders" due to their ability to provide greater spreading of spray solutions. Other types include cationic surfactants (positively charged) and anionic surfactants (negatively charged), but they are rarely mentioned on labels.



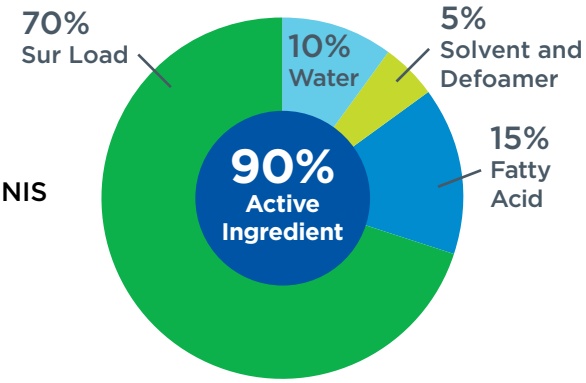
Water drop without a surfactant. Note how the droplet "stands up".

Water drop with a surfactant.

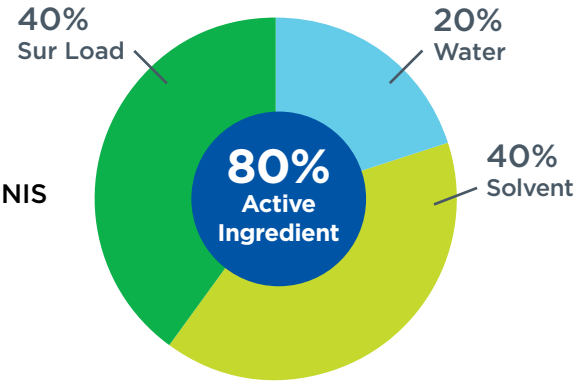
A basic surfactant molecule consists of a hydrophilic head, or water loving head, and a lipophilic, or oil loving tail. Once the hydrophilic head is inside of the water droplet, the lipophilic tail protrudes through the surface, decreasing the surface tension of the water droplet. The more molecules that are in the tank, the more surface tension is reduced.

The more surfactant load present in a product the more effective it will be at reducing surface tension. Be sure to read the label to make a distinction between the total percent of active ingredient and the actual surfactant load, as solvents also contribute to the percent of active ingredient. For example, 80-20 NIS is made up of 80% active ingredient and 20% inactive ingredient (water). However, this does not mean that the product contains an 80% surfactant load since both surfactants and solvents contribute to the active ingredient percent. As shown in the figure below, both surfactants B & C are 80-20 NIS products, however surfactant B has twice as much surfactant load as surfactant C. Always read the label carefully to see how much each load is actually contributing to the active ingredient percent.

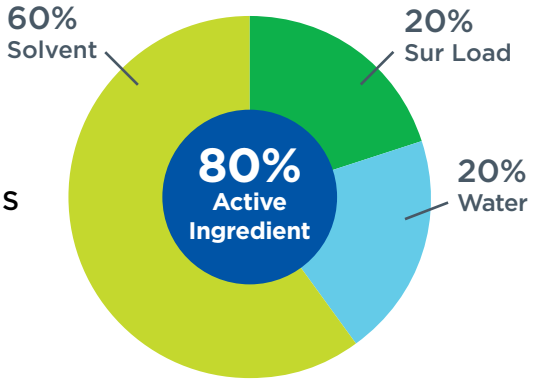
A. 90-10 NIS



B. 80-20 NIS



C. 80-20 NIS



While both Surfactants B & C are 80-20 NIS products, Surfactant B has twice as much actual surfactant (surfactant load) as surfactant C.

Oil Adjuvants

Pesticides are only effective if their active ingredients are able to penetrate into the target pest, such as an insect's tough exoskeleton. Oil adjuvants can be used to solubilize oil pesticides, improve deposition, extend drying time and increase penetration of pesticides.

There are several different types of oil adjuvants to choose from, each containing different ingredients and compositions. Many oil adjuvants contain a surfactant, providing the penetration properties of oil and the spreading properties of a surfactant. Choosing the right oil adjuvant depends on the source of oil base required on the product label. Oil adjuvants are categorized by the oil source as shown in the chart below.

Some oil adjuvants are more abrasive than others. For example, you can think of crop oils as helping to open a door. For example, they find spots on the leaf to burn through the cuticle of the plant, so herbicide can move through. Methylated seed oils, on the other hand, are more abrasive. They burn a hole through the leaf's surface so herbicide can enter, more like breaking a door down.

Oil Concentrates (COC & VOC)

Oil concentrates are either petroleum oil-based (COC) or vegetable oil-based (VOC), with the former being more common. COC's are often used with systemic herbicides rather than contact herbicides as well as with fungicides and insecticides. Today, COC and VOC's are a blend of 80-85% oil and 15-20% emulsifier, thus allowing pesticide to mix more thoroughly in a tank mix than earlier COC's.

Methylated Seed Oils (MSO)

Methylated seed oils are made by reacting highly refined oil with ethanol or methanol to create an "esterified oil". Emulsifiers are then added to increase overall mixability and efficacy. MSO's are often used with conventional grass herbicides and many broadleaf contact herbicides. Most MSO blends primarily consist of 80-85% seed oil and 15-20% emulsifier. Compared to COCs, MSOs more aggressively penetrates the leaf cuticle, because it has a similar structure to cuticular waxes. MSOs are also better spreaders than COCs at the cost of being more injurious.

High Surfactant Oil Concentrate (HSOC)

High surfactant oil concentrates are usually made up of 50-60% oil and 40-50% emulsifier. HSOCs were created with the same idea in mind as COCs in regard to adding more emulsifier to increase the efficacy of the oil. HSOCs enhance lipophilic herbicides without antagonizing glyphosate, which allows growers to add both oil-loving and surfactant properties (such as clethodim, tembotrione or fomesafen) to a tank mix with glyphosate. The two types of HSOCs available to growers are: Crop oil concentrate based (HSCOC), which work similarly to COCs, and Methylated seed oil based (HSMOC); HSMOCs are the most active oil with the most cuticle disruption.

Liquid Fertilizer Solutions (AMS)

Nitrogen fertilizers like urea ammonium nitrate (UAN) at 28% and 32% and ammonium sulfate (AMS) can be added to a tank mix to serve multiple purposes. As an activator adjuvant, it helps to increase the absorption within the target pest, making it more effective. This unique adjuvant can also serve as a special purpose adjuvant, added to condition hard water, enhancing the physical characteristics of the spray solution as explained in the "water conditioners" section.

Name	Ingredients	
Crop Oil Concentrates (COCs)	80-85% petroleum oil	15-20% nonionic surfactant
Vegetable Oil Concentrates (VOCs)	80-85% seed oil (corn, cotton, peanut, rapeseed, sunflower, canola or soybean)	15-20% nonionic surfactant
Methylated Seed Oil (MSOs)	80-85% methylated seed oil (modified vegetable oil)	15-20% nonionic surfactant
High Surfactant Oil Concentrates (HSOC)	50% petroleum or methylated seed oil	50% surfactant
Crop Oil	95% paraffin or naphtha-based petroleum oil	5% nonionic surfactant

Drift control agents create the ideal spray droplet size for penetration. Left: Droplets that are too small will drift away. Middle: Droplets that are too large will bounce off leaves. Right: Ideal droplet size aids with placement and penetration.

Deposition aids help to keep particles in place for better penetration.

Types of Special Purpose/ Utility Adjuvants

Drift Control Agents (Drift Reduction Agents)

Drift is the unintentional, off-target application of crop protection products. Factors such as severe temperatures, high wind speeds, nozzles used and small droplet size can increase drift and decrease performance of crop protection products. Drift control agents are especially important to use near sensitive sites to prevent damage to surrounding crops and when facing less than ideal weather conditions.

Drift control agents can help to improve the precise placement of a pesticide spray by increasing the spray droplet size. Larger droplets remain on leaves longer and spread better than smaller droplets, helping with improved foliar intake. Consult the product label for information about optimal droplet size and calibration of nozzles. Drift control agents are the most common adjuvant used with crop protection products, and some new dicamba herbicides even require an approved drift reduction agent (DRA) in the tank mix.

Deposition Aids (Stickers)

Deposition aids, or stickers, are often used to increase the ability of water-soluble pesticide particles to stick to a plant's surface, reducing evaporation for a waterproof coating. This stickiness helps to keep the particles in place through rain and irrigation, while preventing degradation from UV rays. Deposition aids are one of the most used adjuvants on the market, and many include a surfactant for better coverage and stickiness on a target surface.

Compatibility Agents

When aid is needed to stabilize and disperse formulations, compatibility agents are used. They ensure tank mix ingredients work together physically and chemically. By reducing clumps and uneven distribution in the tank, they prevent clogging of pumps and hoses, which can cause application problems and expensive cleanup and repairs.

Water Conditioners

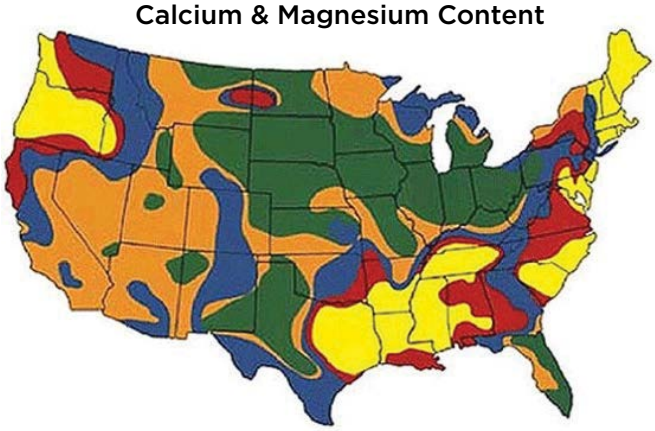
Water is an essential and working part of any spray solution. The molecular, chemical and physical properties of water used in a tank mix can change the effectiveness of the solution. Before starting a tank mix, water should be tested to see if any properties need to be altered for maximum spray application effectiveness.

Conditioning Agents

Hard water tends to be an issue in tank mixes because it contains ions like magnesium (Mg+), calcium (Ca+), iron (Fe+), sodium (Na+), potassium (K+) and other impurities that bind to and deactivate active ingredients in pesticides, rendering them useless. This is especially a problem for those living in the Corn Belt with extremely hard water, especially when tank mixes contain 2,4-D, glyphosate and other herbicides since hard water ions can replace pesticide ions in solution.

A water conditioner, or water-softening agent, often used with surfactants, will bind to molecules in hard water ions to maintain the effectiveness of the crop protection products used.

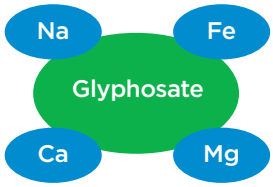
Hard Water based on Calcium & Magnesium Content



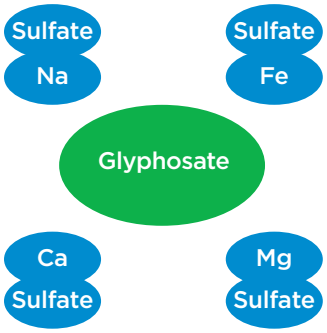
gpg = grains per gallon

Over 14 gpg	Extremely Hard
10 to 14 gpg	Very Hard
7 to 10 gpg	Hard
3 to 7 gpg	Moderately Hard
Less than 3	Slightly Hard

Extremely hard water can be found in much of the corn belt due to calcium and magnesium content in the water.



Without a water conditioner, calcium, sodium, iron and magnesium ions are tied up with the glyphosate, rendering the glyphosate useless.



When adding a water conditioning agent such as AMS, the sulfate in ammonium sulfate ties up hard water ions, allowing the glyphosate to be free, attaching to a nitrogen, creating glyphosate N, and easily taken up by the plants.

Acidifiers and Buffering Agents

For water where low pH (acidity) or high pH (alkalinity) is detected, an acidifier or buffering agent may be considered. Some crop protection products like herbicides perform best in slightly acidic water with a pH of 4.0-6.5. If water is alkaline, an acidifier adjuvant can lower the pH. Adding a buffering agent, or buffer, can then stabilize the solution at an acceptable pH level for maximum performance.

Other Special Purpose/Utility Adjuvants

While 80% of adjuvants fall into five categories, surfactants or deposition aids (50%) and oils, foliar nutrients and compatibility agents (30%), there are several smaller categories of adjuvants as shown in figure below.

Type of Adjuvant	Use
Colorants	Alter the color of spray solution to visually aid in placement
Defoaming/ Anti-foaming Agents	Reduce or eliminate foam caused by a surfactant or agitation
Humectants	Slow evaporation for greater absorption; often used during high temperatures, low humidity and low spray volume situations
Foam Markers	Produce foam to leave a mark where product is applied to avoid skips or overlapping areas
Suspension Agents	Extend the amount of time a pesticide will remain in suspension once agitation has stopped
Tank Cleaners	Clean spray equipment by degrading or deactivating active ingredients

Multifunctional Adjuvants

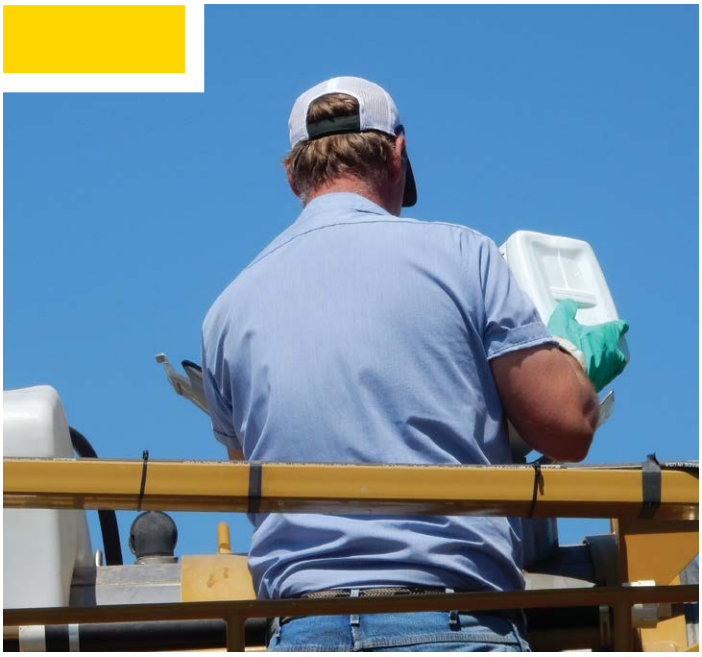
While some adjuvants only perform one function, multifunctional adjuvants can be used to perform several functions simultaneously, according to product label needs. Multifunctional adjuvants offer added convenience and can help avoid specific compatibility issues, which can be costly and time-consuming.

Selecting the Right Adjuvant

Adjuvants are extensively tested and formulated to work just right to enhance crop protection products. Selection of an adjuvant, whether single or multifunctional, should always be based on agronomically sound information and customer needs evaluation, including the site to be sprayed, the target pest and equipment to be used. Retailers should work with their CHS Agronomy representative to find the right formulation based on their operation's needs, and growers should work with their local agronomist for more information about the adjuvants selected for their fields.

Tank Mixing

Combining adjuvants and pesticides at the right rate, in the correct order, ensures maximum efficacy. Before tank mixing, always read and follow label directions to ensure rates and ingredients are added in the correct order, and perform a jar test to ensure compatibility, solubility and stability of ingredients. Any changes to mixing order, rate, agitation, water volume, pressure of the sprayer and other environmental conditions can decrease performance.



Mixing Order and Rates

The effectiveness of a tank mix is dependent on how well the products work together. The amount and order of ingredients is extremely important. If mixed out of order or at the wrong rate, products can clump and gel instead of remaining in the solution, reducing performance and causing costly cleanup from clogged equipment. Always consult the label for the amount and order to add products to ensure physical compatibility, proper solubility and pH. While most labels should list specific mixing sequences, if instructions are not provided, a simple mnemonic can be used to remember proper tank mix order: A.P.P.L.E.S.

The A.P.P.L.E.S. method provides a roadmap for the order chemicals should be added to a tank mix. The A.P.P.L.E.S. method starts by adding hard-to-mix chemicals to water, followed by the addition of easier-to-mix chemicals, with true solutions added last.

A	**Agitate**
P	**Powder solubles: dry fertilizers, soluble granulars (SG) and soluble P**
P	**Powders dry: dry flowables (DF), water disposable granulars (WDG), wettable powders (WP)**
L	**Liquid flowables and suspension (ASC, F, ME, SC, SE)**
E	**Emulsifiable concentrates (oils): (EC, EW, OD)**
S	**Solutions: (S, SL)**

As published in the North Dakota Weed Control Guide, when using the A.P.P.L.E.S. method, each ingredient must be mixed uniformly in solution before adding the next one. For example, a soluble powder must be completely dissolved before adding the next component. Adjuvants are added to the tank mix in the same sequence as pesticides in the same group. For example, ammonium sulfate (AMS), a water conditioner adjuvant, is a soluble powder; an oil adjuvants are emulsifiable concentrates; and most surfactants are solutions. Within each group, always add the pesticide before the adjuvant. For example, add a soluble-powder pesticide before a soluble-powder adjuvant like AMS.

Agitation

Without proper agitation, bigger and smaller particles won't fully dissolve into solution, known as "falling out". The tank mix may appear separated with particles lining the tank or floating in solution rather than evenly mixed. Agitation is also important to prevent the solution from becoming stagnant. Tank mixes should be applied as soon as possible once fully mixed to prevent the tank mix from continuing to react and potentially separating.

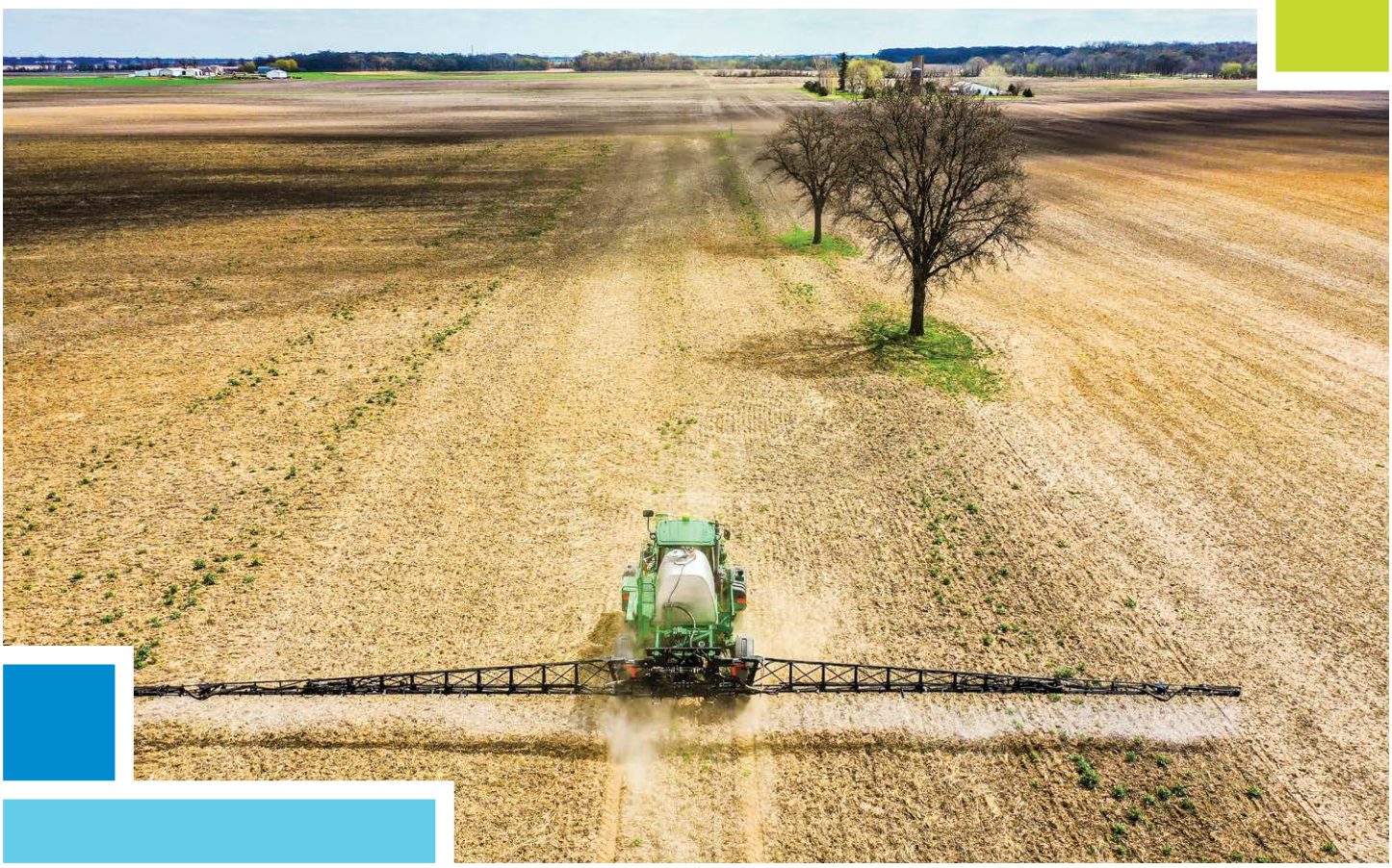
Improper tank mix solution showing settling, caking and undissolved pesticide due to inadequate water and agitation.

Water Volume

Water plays a critical role in the effectiveness of a tank mix. Having enough water in the tank before adding other products can make the difference between an effective solution with well mixed ingredients and a solution where ingredients gum up and become ineffective. Starting with half a tank of water is recommended for best results.

Jar Testing

During a jar test, proportionately smaller amounts of tank mix ingredients are mixed in a clear quart jar to ensure compatibility before a full solution is created. When performing a jar test, always wear personal protective equipment (PPE), and follow the mixing order as prescribed on the label. It's also important to remember that a jar test will only show the physical compatibility of a tank mix. It will not provide information about how an ingredient may inactivate another or cause toxicity. For questions about incompatibility, retailers should talk to their CHS Agronomy representative.



CHS Agronomy Tank Mix Partners

CHS Agronomy develops and offers a full range of single and multifunctional adjuvants, from drift inhibitors and buffers to compatibility agents, deposition aids and surfactants to enhance herbicide, fungicide and insecticide technologies on the market. CHS Agronomy representatives can provide recommendations to fit a specific operation, application type and situation. Recommended adjuvants for use with dicamba, glyphosate and 2,4-D herbicides, are shown below.

LAST CHANCE™ PRO

Adjuvant Type:

- Nonionic surfactant
- Water conditioner
- Deposition aid

Compatible Herbicides:
Glyphosate and glufosinate

VERASURE™

Adjuvant Type:

- Volatility reduction agent
- Drift reduction agent
- Water conditioner
- Surfactant

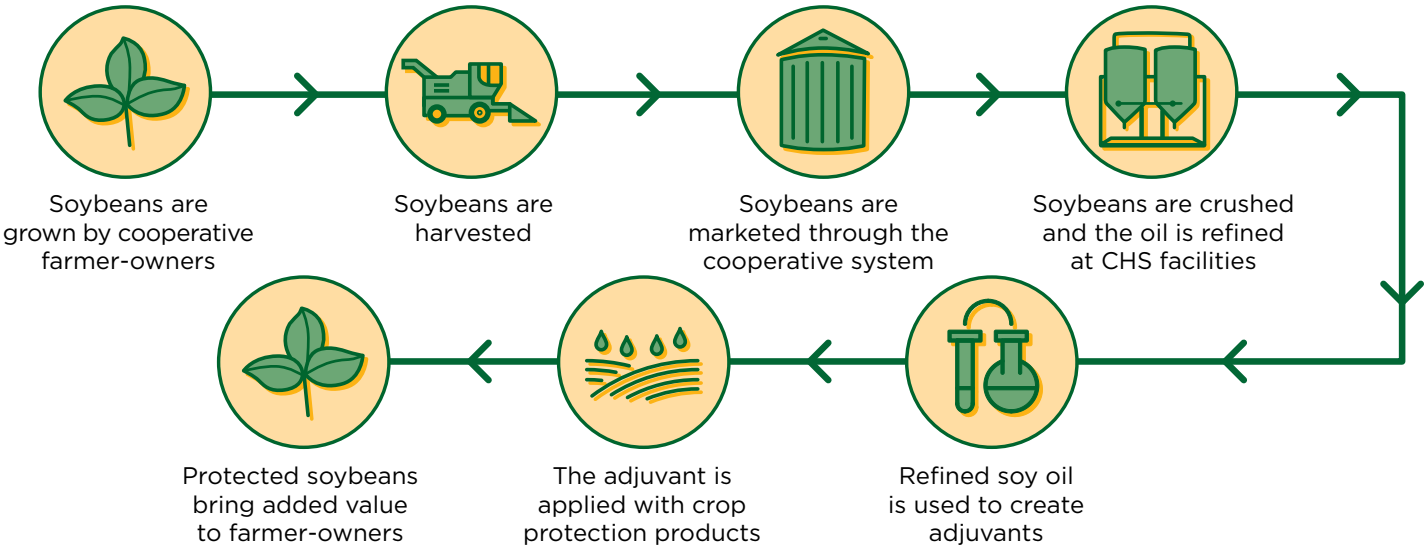
Compatible Herbicides:
Dicamba herbicides like XtendiMax® with VaporGrip® Technology and Engenia®

*Always read and follow label directions.

Soy-Enhanced Adjuvants

Our exclusive family of soy-enhanced adjuvants includes soybean oil refined by CHS from soybeans grown by CHS farmer-owners. This refined oil offers superior performance and handling characteristics versus traditional oil emulsion formulas. But, most importantly, using CHS refined soybean oil is another step taken to add value for our farmer-owners and the crops they produce. Learn more about four of these soy-enhanced adjuvants at the bottom of the page.

Soy-Enhanced



High surfactant oil concentrate

Advatrol™ is a highly concentrated blend of emulsifiers and methylated seed oil. The product is designed for use with a broad range of herbicides where a high surfactant oil concentrate adjuvant is recommended or allowed. High surfactant oil concentrates allow lower use rates than standard oil adjuvants. Advatrol increases contact activity and penetration of the spray, while also providing uniform coverage on leaf surfaces.

High-load crop oil concentrate

Covrex® offers a superior blend of highly refined soybean oil and nonionic surfactants to provide increased penetration and uniform coverage on a leaf surface. Designed for use with a broad range of pesticides and made with soybean oil grown by CHS farmer-owners, this crop oil concentrate provides greater value with enhanced performance, storage stability and mixing at a half-the-use rate of standard crop oil.

Deposition aid ▪ Drift control agent

Petrichor® is an industry-leading NPE-free oil emulsion deposition and drift reduction agent specifically designed to suppress off-target drift and increase contact activity and penetration of spray applications. Its low 3 oz/acre use rate is equivalent to the industry standard of 4 oz and because it's made with highly refined soybean oil, it offers enhanced performance, storage stability and mixing.

High surfactant oil concentrate ▪ Water conditioning agent ▪ Deposition aid

Tapran™ is a multi-functional, high-efficacy adjuvant that helps activate herbicides for better performance against tough-to-control weeds, including later season weeds. Its unique formulation includes tallow amine which acts as an emulsifier and surfactant to help herbicides spread over the leaf for better absorption.

Retailer & Grower Opportunities

Now more than ever, it's important for retailers to stay engaged with their CHS Agronomy representative to stay up to date on the latest adjuvant technology in order to select the best adjuvants for their operation and profitability. It's also important for growers to talk with their agronomist about how adjuvants are vetted, selected and used to enhance crop protection products applied on their operation.

To learn more about adjuvants, visit InTheFurrow.com, and for a listing of available tank mix solutions, visit chsagronomy.com

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Get more resources like this directly to your inbox.

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Always read and follow label directions.

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