What you need to know about SPRAY ADJUVANTS

There are a great number of products called ‘adjuvants’ that are not regulated by the EPA or any other regulatory agencies. The purpose of this document is to describe various classes of adjuvants and when one should use them.

Adjuvants are not needed with soil-applied herbicides unless weeds have emerged and labels call for combing postemergence and soil-applied herbicides. However, adjuvants are useful with postemergence herbicides and effectiveness depends on three factors, spray droplet retention, deposition of the active ingredient, and herbicide absorption by weed foliage. Adjuvants and spray water quality influence postemgergence herbicide efficacy.

Spray adjuvants generally consist of surfactants, oils, and fertilizers. The most effective adjuvant will vary with each herbicide, and the need for an adjuvant will vary with environment, weeds, and herbicide used. Adjuvant use should follow label directions and be used with caution as they may influence crop safety and weed control. An adjuvant may increase weed control from one herbicide but not from another.

Surfactants (nonionic surfactants, NIS) are used at 1 to 4 qt/100 gallon of spray solution (0.25 to 1% v/v) regardless of spray volume. NIS rate depends on the amount of active ingredient in the formulation, plant species and herbicides used. The main function of a NIS is to increase spray droplet retention, but may, to a lesser degree, function in herbicide absorption. When a range of surfactant rates is given, the high rate is for use with low herbicide rates, drought stress and tolerant weeds, or when the surfactant contains less than 90% active ingredient. Surfactants vary widely in chemical composition and in their effect on spray droplet retention, herbicide deposition, and absorption. Nonionic surfactants are most commonly applied with glyphosate.

Silicone surfactants reduce spray droplet surface tension, which allow the liquid to run into leaf stomata (“stomatal flooding”). This entry route into plants is different than adjuvants that penetrate through the leaf cuticle. Rapid entry of spray solution into leaf stomata does not always result in improved weed control. Silicone surfactants are weed and herbicide specific like other adjuvants. I have successfully used silicone surfactants with glyphosate.

Petroleum oil concentrates generally are used at 2 pt/A or 1 gal/100 gal of spray solution depending on herbicide and adjuvant label. Oil additives increase herbicide absorption and spray retention. Oil adjuvants are petroleum (PO) or methylated vegetable or seed oils (MSO) plus an emulsifier for dispersion in water. The emulsifier, the oil class (petroleum, vegetable, etc.), and the specific type of oil in a class all influence effectiveness of an oil adjuvant. Oil adjuvants enhance POST herbicides more than NIS and are effective with all POST herbicides, except Liberty, and will antagonize glyphosate. The term crop oil concentrate (COC) designates a petroleum based oil but is misleading because the oil type in COC is petroleum and not crop vegetable oil.

MSO adjuvants greatly enhance POST herbicides much more than NIS and PO adjuvants. MSO adjuvants are more aggressive in dissolving leaf wax and cuticle resulting in faster and greater herbicide absorption. The greater herbicide enhancement from MSO adjuvants may occur more in low humidity/low rainfall environments where weeds develop a thicker cuticle. MSO adjuvants cost 2 to 3 times more than NIS and PO adjuvants. The added cost of MSO and increased risk of crop injury when used at high temperatures have deterred people from using this class of adjuvants. Using reduced herbicide rates with MSO adjuvants can enhance weed control while lowering risk of crop injury. Some herbicide labels restrict use of oil adjuvants and recommend only NIS alone or combined with nitrogen based fertilizer solutions. Follow label directions for adjuvant selection. Where labels allow use of oil additives, PO or MSO adjuvants may be used. MSOs typically are applied with UpBeet, Betamix or Nortron in sugarbeet (without glyphosate).

NDSU research has shown wide difference in adjuvant enhancement of herbicides. However, in many studies, no or small differences occur depending on environmental conditions at application, growing conditions of weeds, rate of herbicide used, and size of weeds. For example, under warm, humid conditions with actively growing weeds, NIS + nitrogen fertilizer may enhance weed control to the same level as oil adjuvants. The following are conditions where MSO type additives may give greater weed control than other adjuvant types:

1. Low humidity, hot weather, lack of rain, and drought-stressed weeds or weeds not actively growing due to some stress condition.
2. Weeds larger than recommended on the label.
3. Herbicides used at reduced rates.
4. Target weeds that are somewhat tolerant to the herbicide.
5. When university data supports crop safety and improved weed control.

Most herbicides, except glyphosate and Stinger, have greater activity when applied with MSO type adjuvants.

Adjuvant applied on a volume or area basis Labels of many POST herbicides recommend oil adjuvants at 1% v/v. At water volume of 15 or 20 gpa, 1% oil adjuvant will provide a minimum adjuvant concentration (1% v/v PO in 17 gpa = 1.4 pt/A). The optimum rate of a PO is 2 pt/A. ND surveys show common spray volumes are 10 gpa or lower. PO at 1% v/v in 8.5 gpa = 0.68 pt/A and does not provide a sufficient amount of oil adjuvant. Further, aerial applications at 5 gpa will also require a higher adjuvant concentration if PO is used at 1% v/v.

Some herbicide labels contain information on adjuvant rates for different spray volumes. To ensure sufficient adjuvant concentration, add the oil adjuvant at 1% v/v but no less than 1.25 pt/A at all spray volumes. Surfactant at 0.25 to 1% v/v water is generally sufficient across spray water volumes. Hard-to-wet weeds (lambsquarters) will require a higher NIS concentration and surfactants that retain more droplets on plant foliage.

High surfactant oil concentrates (HSOC) were developed to enhance lipophilic herbicides without antagonizing glyphosate. HSOC adjuvants contain at least 50% w/w oil plus 25 to 50% w/w surfactant, are PO or MSO based, and are commercially recommended at ½ the oil adjuvant rate (area basis). Glyphosate must be applied with other herbicides to control glyphosate tolerant weeds and crops and to delay resistant weeds. Glyphosate is highly hydrophilic, is enhanced by NIS and nitrogen fertilizer surfactant type adjuvants, and is antagonized by oil adjuvants. Postemergence herbicides preferred by growers to mix with glyphosate to increase weed control are lipophilic (ethofumesagte, Betamix) and require oil adjuvants for optimum herbicide enhancement. Surfactants are less effective in enhancing lipophilic herbicides. Oil adjuvants, including PO and MSO adjuvants, may antagonize glyphosate. NDSU research has shown wide variability among PO based HSOC adjuvants with many performing no different than common PO (COC) adjuvants. However, MSO based HSOC adjuvants **(HSMOC)** enhance both glyphosate and the lipophilic herbicide. MSO based HSOC adjuvants enhance lipophilic herbicides more than PO based HSOC, MSO and PO adjuvants. Apply MSO based HSOC adjuvants at full rates on an area basis (1 to 1.5 pt/A) rather than a volume basis to provide greater herbicide enhancement and more consistent weed control.

Some water pH modifiers are used to lower (acidify) spray solution pH because many insecticides and some fungicides degrade under high water pH. Most solutions are not high or low enough in pH for important herbicide breakdown in the spray tank. Water conditioners that reduce spray solution pH (AMS replacement adjuvants) were developed from the theory that acidifying the spray solution results in greater absorption of weak-acid-type herbicides. However, low pH is not essential to optimize herbicide absorption. Many herbicides are formulated as various salts, which are absorbed more readily than the acid form. Salts in the spray water may antagonize formulated salt herbicides. In theory, acid conditions would convert the herbicide to an acid and overcome salt antagonism. However, herbicides in the acid form are less water soluble than in salt form. An acid herbicide with pH modifiers may precipitate and plug nozzles when solubility is exceeded, such as with high herbicide rates in low water volumes. Antagonism of herbicide efficacy by spray solution salts can be overcome without lowering pH by adding AMS or, for some herbicides, 28% UAN.

Basic pH blend adjuvants are blends of nonionic surfactant, fertilizer, and basic pH enhancer and are used at 1% v/v regardless of spray volume. Data indicate basic blend adjuvants at 1% v/v from 5 to 20 GPA will provide adequate adjuvant enhancement for similar weed control. Basic pH blend adjuvants are surfactant based, increase spray solution pH, and contain nitrogen fertilizer to enhance herbicide activity. They contain a surfactant to aid in spray retention, spray deposition, and herbicide absorption, and a buffer to increase water pH. Basic pH blends adjuvants increase water pH to near pH 9 which increases water solubility of some herbicides and increases herbicide phytotoxicity. Within the sulfonylurea chemistry the magnitude of solubility from high spray solution pH can increase from 40 fold (Harmony GT*) to 3,670 fold (UpBeet).

Some herbicides degrade rapidly in high pH spray solution. Cobra, Resource, Valor, and Sharpen degrade within a few minutes in high pH water but are stable for several days at low pH. Optimum use of pH adjusting adjuvants requires some knowledge of herbicide chemistry or experience. Research has shown that basic pH blend adjuvants may enhance weed control similar to MSO adjuvants and can be used in situations where oil adjuvants are restricted.

SPRAY CARRIER WATER QUALITY

Minerals, clay, and organic matter in spray carrier water can reduce the effectiveness of herbicides. Clay inactivates paraquat and glyphosate. Organic matter inactivates herbicides. Hard water cations or micronutrients such calcium, magnesium, manganese, sodium, and iron reduce efficacy of all weak-acid herbicides. Cations antagonize glyphosate efficacy by complexing with glyphosate to form salts (e.g. glyphosate-Ca) that are not readily absorbed by plants. Antagonistic minerals can inactivate the activity of most POST herbicides, including glyphosate, growth regulators (not esters), ACCase inhibitors, ALS inhibitors, HPPD inhibitors, and Liberty. The antagonism is related to the salt concentration. At low salt levels, loss in weed control may not be noticeable under normal environmental conditions but will occur when weed control is marginal because of drought or partially susceptible weeds. The precise salt concentration in water that causes a visible loss in weed control is difficult to establish because weed control is influenced by other factors.

Ammonium nitrogen increases effectiveness of most weak-acid herbicides formulated as a salt. Fertilizers should always be used with herbicides unless prohibited by label. Ammonium ions greatly enhance herbicide absorption and phytotoxicity even in the absence of antagonistic salts in the spray carrier. However, enhancement of glyphosate and most other POST herbicides from ammonium is most pronounced when spray water contains large quantities of antagonistic cations. Herbicide enhancement by nitrogen compounds appears in most weed species but is most pronounced in species like volunteer corn and species that accumulate antagonistic salts on or in leaf tissue (lambsquarters, velvetleaf, and sunflower).

Ammonium sulfate (AMS) enhances phytotoxicity and overcomes salt antagonism for weak-acid herbicides formulated as a salt including glyphosate, growth regulators (not esters), ACCase inhibitors, ALS inhibitors, HPPD inhibitors, and Liberty. The antagonism may be overcome by increasing the glyphosate concentration relative to the cation content or by adding AMS and some water conditioners to the spray solution. Effective water conditioners include EDTA, citric acid, AMS, and some acidic AMS replacements. Of these, AMS has been the most widely adopted. When added to a spray solution, the ammonium (NH_4^+) ion complexes with the glyphosate molecule and reduces glyphosate interaction with the hard-water cations. The sulfate (SO_4^{2-}) ion complexes with the hard-water cations (e.g. calcium sulfate), causing the salt to precipitate from solution. This combined effect increases absorption and efficacy. Natural sulfate in water can be disregarded but can reduce antagonism if the sulfate concentration is at least three times the calcium concentration.

Antagonism of glyphosate by calcium in a spray solution was overcome by sulfuric but not nitric acid, indicating that the sulfate ion was important, but not the acid hydrogen ion. The importance of the sulfate ion explains the effectiveness of ammonium sulfate, and not 28% UAN, in overcoming calcium antagonism of glyphosate.

AMS is recommended at 8.5 to 17 lb/100 gal spray volume (1 to 2%) on most glyphosate labels. However, AMS at 4 lb/100 gal (0.5%) is adequate to overcome most salt antagonism but 8.5 lbs/100 gal is generally required to fully optimize herbicides. AMS at 0.5% has adequately overcome antagonism of glyphosate from 300 ppm calcium. Use at least 1 lb/A of AMS when spray volume is more than 12 gpa. AMS may contain contaminants that may not dissolve resulting in plugged nozzles. Use spray grade AMS to prevent nozzle plugging. Commercial liquid solutions of AMS are available and contain approximately 3.4 lbs of AMS/gallon. For 8.5 lbs of AMS/100 gallons of water add 2.5 gallons of liquid AMS solution.

28% UAN fertilizer is effective in enhancing weed control and overcoming mineral antagonism of most POST herbicides, but not calcium antagonism of glyphosate. Sodium bicarbonate antagonism of Poast is overcome by 28% UAN and AMS. AMS or 28% UAN does not preclude the need for an oil adjuvant with lipophilic herbicides. Generally, 4 gal of 28% UAN/100 gal of spray has been adequate. AMS and 28% UAN enhance herbicide control of most weeds even in water without antagonistic salts. Nitrogen fertilizer/surfactant blends may enhance weed control of most herbicides formulated as a salt.

Water conditioner adjuvants are liquid for user preference, applied at low use rates, may contain no or very little AMS, may lower spray solution, and are advertised to replace AMS, and thus are called AMS replacement adjuvants. Pesticide applicators prefer the convenience of low use rate water conditioners, but performance has been inconsistent. Glyphosate plus commercial water conditioner products that included AMS at the equivalent rate of 1% w/w can give similar control to 1% w/w (8.5 lbs/100 gal) AMS. Commercial water conditioners that do not provide an equivalent amount of AMS give less control than glyphosate with 1% or 2% w/w AMS and are often no better than glyphosate alone.

Acidic AMS replacement (AAR) adjuvants have been developed for use with glyphosate and other weak acid herbicides. Claims are made to enhance activity, negate affects of antagonistic salts in spray water and the antagonism from micronutrient solutions added for crop health. Most adjuvants in this class contain monocarbamide dihydrogen sulfate or AMADS (urea plus sulfuric acid) which lowers spray solution pH to 1.4 to 3. The low pH is below the pKa of postemergence herbicides causing most herbicide molecules to be in the acid state which results in fewer molecules binding to positively charged salts.

Some water conditioner adjuvants and acidic AMS replacement adjuvants (AAR) are marketed to modify spray water pH, but low pH is not required for herbicide efficacy. The type of acid or components of buffering agents and the specific herbicide all need to be considered before using pH-modifying agents. Several commercial AAR adjuvants applied with glyphosate in distilled water were tested and ranked as follows: surfactant + AMS > AMS > NIS = AAR. A commercial AAR adjuvant composed primarily of sulfuric acid was much less phytotoxic than most AAR adjuvants which support the concept and use of ammonia to enhance weak acid herbicides.

Low spray volumes (5 to 10 gpa) have been equally or more effective than higher spray volumes for many herbicides. Low spray volume originally was considered important to glyphosate efficacy because it would reduce the ratio of glyphosate and antagonistic cations in the spray solution. However, low spray volumes have enhanced glyphosate efficacy because of higher glyphosate concentration in the spray deposit. Greater efficacy from higher concentrated droplets has been shown with many other herbicides but is logical that the highly concentrated droplets with low volume would be positive for translocated herbicides. Contact herbicides (Betamix) require higher spray volume for adequate and thorough coverage to enhance control.

Low spray volumes usually imply use of low-volume nozzles that produce small droplets which can increase off-target movement. However, drift-reducing nozzles have been developed that produce large droplets at low volume. In low spray volumes, larger droplets produced by drift-reducing nozzles have been equally effective as small droplets with several translocating herbicides. However, coarse or larger droplets may be less phytotoxic than fine and medium size droplets for Poast, Laudis or 2,4-D.