A5. SPRAY ADJUVANTS

Questions about adjuvant selection are common. In most states, adjuvants are not regulated by the EPA or any other regulatory agency allowing an unlimited number of adjuvant products. Adjuvants are composed of a wide range of ingredients which may or may not contribute to herbicide phytotoxicity. Results vary when comparing specific adjuvants, even within a class of adjuvants. POST herbicide effectiveness depends on spray droplet retention, deposition of the active ingredient, and herbicide absorption by weed foliage. Adjuvants and spray water quality (Paragraph A6) influence POST herbicide efficacy. Adjuvants are not needed with PRE herbicides unless weeds have emerged and labels include POST application.

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. To compare adjuvants and determine adjuvant enhancement, herbicide rates should be used at marginal weed control levels. Effective adjuvants will enhance herbicides at reduced rates and provide consistent results under adverse conditions. However, use of below labeled rates exempts herbicide manufacturers from liability for nonperformance.

Surfactants (nonionic surfactants = NIS) are used at 1 to 4 qt/100 gal 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.

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.

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.

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 paraquat, have greater activity when applied with MSO type adjuvants.

Oil 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 an 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 (Select*, Banvel*, Laudis, others) 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 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.

Fertilizers - See Section A6 - Spray Carrier Water Quality.

*Or generic equivalent.

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 - see page 134) 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.

Acidic AMS replacement (AAR) adjuvants (see page 134) contain adjuvants including monocarbamide dihydrogensulfate (urea and sulfuric acid) and some adjuvants in this class are similar to NIS + AMS in enhancing glyphosate and other weak-acid herbicides. The sulfuric acid forms sulfate when reacting with water which can condition water and prevent herbicide antagonism from salts in water. The conversion of urea to ammonium is slow but the ammonium formed can partially enhance herbicides. AAR adjuvants must be applied at 1% v/v or greater to achieve a similar level of herbicide enhancement as AMS.

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). The solubility of herbicides in other chemical families increase with high pH: Achieve (1-Dim), florasulam (2-TPS), Everest (2-SACT), Sharpen (14), and diflufenzopyr (19), Callisto and Laudis (27-triketone), and pyrasulfatole and Impact (27-pyrazolone) (see page 104-105 for numbers representing herbicide mode of action).

Some herbicides degrade rapidly in high pH spray solution. Cobra (diphenylether), Resource and Valor (N-phenylphthalimide), and Sharpen (pH 9) 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.

Commercial adjuvants differ in effectiveness with herbicides. Data from the table below are from experiments conducted at 6 NDSU R&E Centers in ND from 1992 through 1995 and repeated in 2005 and 2006 comparing commercial adjuvants with Roundup. In 1993-95, Roundup was applied at 1 to 1.5 oz ae/A to 16 grass and broadleaf weed species. In 2005-06 Roundup was applied at 1 to 4 oz ae/A to 26 grass and broadleaf weed species (272 averages). Higher rates were used in western ND because of low activity in low humidity.

Commercial adjuvant effect on glyphosate phytotoxicity[a,b].

	Rate	Grass		Broadleaf	
Adjuvants	% v/v	93-95	05-06	93-95	05-06
	% control				
Surfactants					
None	0.5	49	68	31	42
R-11	0.5	74	90	51	66
APSA 80	0.5	74	87	50	62
Wet-Sol 99	0.5	--	86	--	61
Premier 90	0.5	--	81	--	58
Purity 100	0.5	--	82	--	56
Preference	0.5	67	79	38	58
Liberate	0.5	--	76	--	51
X-77	0.5	66	70	40	52
Spray Booster S	0.5	64	--	41	--
Activator 90	0.5	64	69	41	50
LI-700	0.5	48	66	42	41
Silwet L-77	0.25	46	--	40	--
AMS	8.5 lb/100 gal	--	86	--	68
Surfactant + AMS Fertilizer					
Class Act	2/2.5	90	94	75	76
R-11 + AMS	0.5+8.5 lb/100	--	93	--	76
R-11 + Bronc Max	0.5 + 0.5	--	92	--	73
Surfate	1	89	93	75	74
Dispatch	2	85	--	69	--
R-11+Cayuse	0.5 + 0.5	82	--	66	--
AMS Replacement / Water Conditioning Agent					
N-Tense	0.5	--	90	--	67
Alliance + Pref.	1.25 + 0.5	--	89	--	68
Citron + Pref.	2.2 lb/A + 0.5	--	84	--	66
Quest + Pref.	0.5 + 0.5	--	83	--	62
Choice + Liberate	0.5 + 0.5	--	81	--	60
Herbolyte		--	79	--	55

Pref = Preference.

Conclusions from the study:
1. Not all adjuvants are created equal.
2. Small numerical differences in data is significant as data was averaged across 68 means making outlying values to have less affect in changing the mean.
3. Most adjuvants enhanced glyphosate but some did not enhance glyphosate more than no adjuvant added.
4. The better adjuvants in 93-95 are the same as 05-06.
5. Data is arranged in numerically descending order showing similar enhancement in both 93-95 data and 05-06 data.
6. Adjuvants are non-regulated. Changes in individual adjuvant formulations may have occurred since 1995. However, this data shows relatively little change in herbicides enhancement of glyphosate over time.
7. The 05-06 data is approximately 15 to 20 points higher probably due to higher glyphosate rates used in 05-06.
8. Surfactant + AMS fertilizer adjuvants as a group were more effective than the surfactants or AMS Replacment / Water Conditioning Agent adjuvants.
9. The results are averaged over various locations and may not represent adjuvant effectiveness for all situations.

10. Adjuvants differ in effectiveness and users should compare several products for their specific conditions or select an effective adjuvant from the list.