Spray Adjuvants With Herbicides

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Spray adjuvants are substances added to spray solutions to improve pesticide use efficiency. Adjuvants modify the physical properties of the spray solution and/or increase pesticide efficacy.

Numerous spray adjuvants are available with many different trade names. The need for an adjuvant and the most effective adjuvant to use depends on the pesticide applied, crop, weed species, and environmental conditions. Decisions on adjuvant use are difficult because many different products are on the market and adjuvant terminology is often confusing. The misuse of adjuvants can increase crop injury and/or decrease weed control. Therefore, adjuvants should not be used indiscriminately.

Adjuvants can be separated into two categories depending on function: 1) spray modifiers and activators or 2) utility modifiers. Spray modifiers and activators generally improve weed control by increasing spray coverage, spray droplet retention, and herbicide absorption. Examples of spray modifiers and activators include surfactants, wetting agents, sticker-spreaders, oils, and fertilizers. Utility modifiers are used to reduce herbicide mixing, handling, or application problems. Examples of utility modifiers include emulsifiers, stabilizing agents, compatibility agents, and drift control agents.

Specific adjuvants may have several functions and can be classified as a spray modifier and activator, as well as a utility modifier, further complicating the subject.

Spray Modifiers and Activators

Surfactants are **surface active agents** that reduce the surface tension of the spray solution. Most spray adjuvants have some surfactant properties. Spray solutions without surfactants usually have a high surface tension and cohesive spray droplets. Surfactants reduce spray surface tension and reduce the repulsion between water and other materials such as pesticides or the wax on the leaf surface. Therefore, surfactants may help facilitate pesticide mixing and allow spray droplets to spread more evenly over the leaf surface (Figure 1).

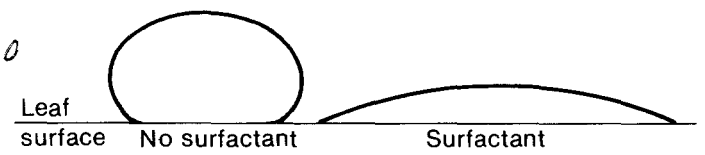

Figure 1. The influence of a surfactant on spray droplet surface tension and droplet spread over a leaf surface.

Surfactants are classified into three general types: nonionic, cationic and anionic. Nonionic surfactants are the most common type of surfactant and usually are compatible with most materials because they are not likely to react chemically with other molecules. Cationic surfactants are postively (+) charged and anionic surfactants are negatively (-) charged molecules. Cationic and anionic surfactants are not readily available and are not commonly used because of possible reactions with pesticides and water impurities in the spray solution.

Surfactants may aid in the mixing, dispersal, spreading, and wetting properties of pesticide spray solutions. Wetting agents, sticker-spreaders, emulsifiers, and compatibility agents all are surfactants. Wetting agents and sticker-spreaders are spray modifiers and activators while compatibility agents and emulsifiers function primarily as utility modifiers. However, the term surfactant often is used interchangeably with wetting agents.

Wetting agents increase the surface coverage of the spray solution on the leaf by causing the individual droplets to spread over a larger area. Increasing wettability may increase or decrease spray retention depending on the nature of the leaf surface and spray volume. Wetting agents will probably increase spray retention and pesticide activity on plants that have a smooth waxy leaf surface and are hard to wet. Retention and activity may actually be decreased on plants which are easier to wet because of spray runoff, especially with high spray volumes. Therefore, selectivity also may be altered by the addition of a wetting agent if selectivity was based on differential spray retention by the crop and weeds. A wetting agent may actually increase crop injury and decrease weed control by increasing spray retention on the crop and decreasing spray retention on the weed. Wetting agents are usually comprised of nonionic surfactants and are commonly referred to as surfactants.

Sticker-spreaders also improve surface coverage as well as help retain the pesticide on the leaf surface, even if a rain follows application. Sticker-spreaders are usually a blend of surfactants and other chemicals, such as latex. Stickers help retain the pesticide on the leaf surface because of a strong attraction to the chemical as well as the leaf surface.

Oil adjuvants are petroleum or vegetable oil-based materials which are combined with emulsifiers and added to the spray solution to increase pesticide activity. Oil adjuvants may differ in composition, emulsifier type and concentration, and effectiveness. Some oil adjuvant brands even may differ in composition from year to year.

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Terminology of oil adjuvants is confusing. Petroleum-based oils with 2 to 5 percent emulsifiers are called crop oils and generally are used at 0.5 to 1 gallon per acre. Petroleum-based oils with 5 to 20 percent emulsifiers are called crop oil concentrates and usually are applied at 1 to 2 pints per acre.

Oils derived from sunflowers, soybeans, flax, etc., plus 2 to 20 percent emulsifiers are called vegetable oils, and usually are applied at 1 to 2 pints per acre. Vegetable oils may be more, less, or equally as effective as petroleum-based oils for use as adjuvants depending on the herbicide, crop, and weed species.

Vegetable oils can be fractioned and modified in various ways to alter their composition and effectiveness as adjuvants. Research at North Dakota State University indicates that methylated vegetable oils (Sun-It) may be more effective as adjuvants than crop oil concentrates or unmodified vegetable oils with some herbicides.

Oil adjuvants generally enhance weed control by increasing herbicide absorption into the plant. Oil adjuvants may increase spray coverage, herbicide retention, and/or act as a cosolvent with the waxes and cuticle on the leaf surface to enhance absorption into the plant.

Fertilizer and salt additives such as 28 percent liquid UAN (urea ammonium nitrate) nitrogen fertilizer, 10-34-0 fertilizer, and ammonium sulfate have improved control of some weed species with certain herbicides. The proper amount of fertilizer or salt adjuvant added to the spray solution varies with herbicide, crop, weed species, and environmental conditions. Fertilizers apparently increase weed control by increasing herbicide absorption or counteracting the effect of impurities and other pesticides in the spray solution.

Utility Modifiers

Utility modifiers are added to the spray solution to reduce problems with herbicide mixing, handling, or application. The primary function of utility modifiers is to reduce problems associated with the pesticide application rather than influence herbicide efficacy, although efficacy of postemergence herbicides also may be affected.

Emulsifiers are substances included in pesticide and oil formulations to help disperse non-water soluble materials in the spray solution as an emulsion. Many chemicals and oils are not water soluble, and therefore would not mix uniformly in water without an emulsifier. Emulsifiers help suspend non-water soluble materials in the spray solution as tiny droplets. Most pesticides and oil additives include emulsifiers in the formulation, so additional emulsifiers generally are not needed for pesticide application.

Compatibility agents are added to the spray solution to prevent physical or chemical reactions from occurring when pesticide or pesticide-fertilizer combinations are used. Compatibility agents may be beneficial to facilitate the mixing of certain pesticides or pesticide-fertilizer combinations, but will not solve all compatibility problems. A "quart jar compatibility test" with and without a compatibility agent should be conducted before adding non-labelled tank mixtures to the spray tank (refer to the NDSU Agricultural Weed Control Guide, W-253, for directions on compatibility tests).

Stability agents are substances such as antifoaming agents or buffer agents which are added to the spray solution. Antifoaming agents suppress foam formation when certain chemicals are mixed and would reduce mixing and application problems due to excess foam. Buffer agents alter the pH of the spray solution. Water pH may affect pesticide efficacy or rate of breakdown of some pesticides in the spray solution. Therefore, buffer agents might be beneficial to overcome such problems. However, information on the need for buffer agents with herbicides is limited.

Humectants are substances which reduce the rate of spray droplet evaporation. Herbicides are most readily absorbed through the leaf surface when dissolved or suspended in the liquid phase. Therefore, humectants may provide a longer period for pesticide uptake and increase total herbicide absorption. Many spray adjuvants, as well as pesticide formulations, have some humectant properties.

Drift control agents are added to the spray solution to reduce the potential for physical spray drift from the target area to a non-target site. Most drift control agents reduce

Table 1. Various Adjuvants available in North Dakota

Product name	Adjuvant type
Activator 90	90% a.i. Nonionic Surfactant-Wetting Agent
Active-It	90% a.i. Nonionic Surfactant-Wetting Agent
Activate-Plus	90% a.i. Nonionic Surfactant-Wetting Agent
Add-It	Crop Oil Concentrate
Ammonium Sulfate	Fertilizer Salt
Amway All Purpose Spray Adjuvant	24% a.i. Nonionic Surfactant-Wetting Agent
Balance	Buffer Agent-Wetting Agent
Bioveg	Vegetable Oil
Bond	Sticker-Spreader
Citowett Plus	Sticker-Spreader
Chem-Trol	Drift Control Agent
Class 17% Concentrate	Crop Oil Concentrate
Class Knock-Down Crop Oil	Crop Oil
Class EV Concentrate	Vegetable Oil
Class Spray Booster	90% a.i. Nonionic Surfactant-Wetting Agent
Compex	Compatibility Agent
COOP Spreader-Activator	90% a.i. Nonionic Surfactant
Crop Oil Plus	Crop Oil Concentrate
Dash	Activator (confidential)
Easy Mix	Compatibility Agent
Extend-It	Buffer Agent
EZ Mix	Compatibility Agent
Foam Buster	Antifoaming Agent
Herbimax	Crop Oil Concentrate
Induce	90% a.i. Nonionic Surfactant
Hi-Light	Marker Dye
LI-700	80% a.i. Nonionic Surfactant-Buffer Agent
Moract	Crop Oil Concentrate
Nalco-Trol	Drift Control Agent
Natur'l Oil	Vegetable Oil
NoFoam	Foam Retardant
Ortho X-77	80% a.i. Nonionic Surfactant-Wetting Agent
Prime-Oil	Crop Oil Concentrate
Prime-Oil II	Vegetable Oil
R-11 Spreader Activator	90% a.i. Nonionic Surfactant-Wetting Agent
R900XC Spreader Penetrator	90% a.i. Nonionic Surfactant-Wetting Agent
R-56 Spreader-Sticker	Sticker-Spreader
SCI 40	Buffer Agent
Stick-It	Sticker-Spreader
Sun-It	Methylated Vegetable Oil
Super Spread	12% a.i. Nonionic Surfactant-Wetting Agent
Surfactant WK	90% a.i. Nonionic Surfactant-Wetting Agent
Surf-Aid	80% a.i. Nonionic Surfactant-Wetting Agent
Surfel	Crop Oil Concentrate
Triton Ag-98	80% a.i. Nonionic Surfactant-Wetting Agent
Tronic	Mixed ionic Surfactant-Wetting Agent
Unite	Compatibility Agent
Veg-It	Vegetable Oil
10-34-0 fertilizer	Fertilizer
28% UAN fertilizer	Liquid Fertilizer

drift potential by increasing the viscosity of the spray solution and causing larger spray droplets which are less subject to offsite movement by the wind.

Table 1 provides information on the composition and primary function of many of the products sold as adjuvants in North Dakota. The list may not include all of the adjuvants available in North Dakota, and the use of commercial names is not an endorsement of these products.

Adjuvant Use

Adjuvants may be beneficial to improve herbicide selectivity and weed control but can also increase crop injury, decrease weed control, or decrease selectivity. Some herbicides require adjuvants all the time, other herbicides may need adjuvants only part of the time, and adjuvants should not be used with other herbicides. Therefore, detailed information is essential to determine proper adjuvant usage for each pesticide. The best source of information for adjuvant use is the herbicide label. The label will indicate if, when, what type, and what rate of adjuvant should be used with that product. However, the label may not indicate a specific adjuvant to use.

Herbicide activity may differ depending on which particular adjuvant is used. No uniform tests are conducted to evaluate the many different adjuvants with all herbicides, so the user has to rely on personal experience and any other reliable source of information. Weed control and crop response to various herbicide adjuvant combinations are presented in Table 2.

Environmental conditions and stage of plant growth can influence pesticide efficacy and the need for an adjuvant. Postemergence herbicides must be absorbed through the cuticle and waxes that cover the plant foliage before exerting an effect on the weed. The cuticle and waxes on the leaf surface are defense mechanisms of the plant to prevent drying out and for protection against insects and diseases. However, the cuticle and wax layers, as well as leaf pubescence or hairs, also are barriers to pesticide absorption into the plant. Plants develop thicker cuticles and wax layers as they mature or when exposed to environmental stress such as dry conditions for an extended period. Thick cuticle and wax layers prevent herbicide absorption and thus the plants are more tolerant to herbicide treatment. Surfactants, fertilizer, and oil adjuvants often improve control of older weeds or weeds growing under stress by increasing pesticide absorption into the plant. On the other hand, additives also may increase absorption by crops and cause excessive crop injury.

Temperature and humidity at treatment also can influence herbicide and adjuvant activity. Herbicide absorption generally is greater with high than low humidity. Some herbicides such as Hoelon and Carbyne are more active at low temperatures while most herbicides are more active at high temperatures. An adjuvant may be beneficial to improve weed control if the herbicide is applied when conditions are not favorable for activity. However, an adjuvant could increase crop injury if the herbicide is applied when conditions are favorable for activity. Most herbicide labels outline the temperature and conditions when adjuvants should and should not be used.

Experimental data indicates that adjuvants do not improve the effectiveness of soil-applied herbicides, although utility modifiers may be useful for application. Utility modifiers such as compatibility agents may be useful for tank mixtures of soil-applied herbicides or if applied with liquid fertilizer as a carrier.

Spray adjuvants should be used only if recommended on the herbicide label or where experience or research has proven acceptability and effectiveness. The addition of adjuvants to dicamba (Banvel), 2,4-D, or bromoxynil (Buctril), for example, often causes increased crop injury. The nonlabelled use of an adjuvant could exempt the pesticide company from liability for nonperformance of a product.

Table 2. Influence of various adjuvants on herbicide efficacy.

	Adjuvant					
Herbicide*	None	X-77	Crop Oil Concentrate	Vegetable Oil	Methylated Vegetable Oil	Ammonium Sulfate
	(% grass control)					
Poast	50	64	84	79	89	
Fusilade	71	79	83	76	79	
Whip	48	53	64	49	61	
Assure	64	83	90	54	84	
Hoelon	51	58	60	61	60	
	(%)					
Blazer/Tackle						
Soybean Injury	2	5	8		10	6
Weed Control	79	85	90		92	90
Basagran						
Soybean Injury	0	0	3	0	0	2
Weed Control	47	50	70	57	72	72
Cobra						
Soybean Injury	0	12	19	6	15	13
Weed Control	84	85	88	60	63	87
Bladex						
Corn Injury	5		17	8		
Foxtail Control	67		98	95		

Source: NDSU Weed Control Research Summaries
* Comparisons among herbicides not valid.

Table 3 presents information on the recommended use of adjuvants with selected herbicides.

Adjuvant Rates

Adjuvants are applied either on a volume per acre or percent of spray volume basis. Oil and fertilizer adjuvants usually are added on a volume per acre basis, for example 1 pint, quart, or gallon per acre, regardless of spray volume per acre. Therefore, the quantity to add to the spray tank depends on the number of acres to be treated.

Most surfactants and utility modifiers are added on a percent spray volume (% v/v) basis and the quantity to add depends on the total volume of spray solution. Surfactants often are added at 0.12 to 1% v/v, which is equal to 1 pint to 1 gallon per 100 gallons of spray solution.

Surfactants are formulated and sold with various percentages of active ingredient. The percent active ingredient of surfactants also may affect the rates to be used and effectiveness. When a range of surfactant rates is recommended, the high rate generally is for use with low rates of the herbicide, drought stress, tolerant waxy weeds, or when the surfactant contains a low percentage active ingredient (less than 50 percent).

The rate of adjuvant to be applied should be stated on the herbicide or adjuvant label. The herbicide label is the best source of information for adjuvant use and rate, while the adjuvant label would provide a guide for use when the adjuvant rate is not indicated on the herbicide label. Recommended adjuvant use rates with commonly used herbicides in North Dakota are presented in Table 3.

Table 3. Recommended adjuvant use with various herbicides.

Herbicide*	Adjuvant*	Rate	Comments
Ally	Nonionic surfactant	0.12 to 0.5% v/v	Always needed. Adjuvant rate depends on surfactant and tank-mix herbicides.
Assure	Crop oil concentrate Nonionic surfactant	1% v/v 0.25% v/v	Adjuvant always needed
Atrazine	Oil concentrate	1 qt/A	Early postemergence in corn
Basagran	Oil concentrate	1 qt/A	Improves weed control and injury potential, especially at high temp.
	28% N fertilizer	1 gal/A	Velvetleaf control Do not add both oil concentrate and 28% N
Bladex WP, DF	Vegetable oil Nonionic surfactant	1 qt/A 0.25% v/v	Increases injury potential
Blazer	Nonionic surfactant	0.12% v/v	Injury potential increases at high temperatures
	Crop oil concentrate	1 qt/A	Used in some tank mixes Greater injury potential than with surfactant
	28% UAN fertilizer	2-4 qt/A	Velvetleaf control
Carbyne	28% UAN fertilizer	1 gallon/A	Improves control under stressed conditions
Cobra	Crop oil concentrate	0.25-1 pt/A	Increases injury potential especially at high temperatures
Fusilade 2000	Oil concentrate	1% v/v	Crop oil concentrate has performed better than surfactant in North Dakota
Glean	Nonionic surfactant	0.12-0.50% v/v	All postemergence treatments. Adjuvant rate depends on surfactant and tank-mix herbicides.
Harmony	Nonionic surfactant	0.12-0.50% v/v	Always needed. Adjuvant rate depends on surfactant and tank-mix herbicides.
Hoelon	Oil concentrate	1-2 pt/A	Improves control under hot dry conditions Do not use on barley or flax
Paraquat (Gramoxone Super, Cyclone)	Nonionic surfactant	0.06-0.25% v/v	Always needed
Poast	Oil concentrate	1 qt/A	Adjuvant required
	Dash	1 qt/A	Has been more effective than oil concentrate
	Modified Veg. Oil	1 qt/A	Has been more effective than oil concentrate
	Ammonium sulfate	2.5 lb/A	Used in combination with oil adjuvants to improve consistency of control
	28% N fertilizer	1 gal/A	
Roundup	Nonionic surfactant	0.5-1% v/v	Required at lower use rates
	Ammonium sulfate	17 lb/100 gal.	Use in combination with surfactant to improve consistency of control, especially quackgrass
Tackle	Nonionic surfactant	0.25% v/v	Injury potential increases at high temperatures
	Oil concentrate	0.25% v/v	Injury potential greater than with surfactant
Whip	Crop oil concentrate	1 qt/A	Always needed

* The use of commercial names is not intended as an endorsement of these products.

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