Understanding Herbicide Adjuvants

The Function of Adjuvants

Adjuvants in herbicide formulations and spray mixtures can help improve herbicide application and performance. Herbicide labels, which MUST be read and followed, are the most important source of information for adjuvant recommendations and cover diverse use situations and tank mixtures. Adjuvant recommendations are specific for each herbicide product as researched and developed by the herbicide manufacturers. Adjuvants include spreaders, stickers, wetting agents, penetrants, stabilizing agents, compatibility agents, buffering agents, antifoam agents, and others.[1]

Adjuvants can be classified as activators and utility modifiers (or special purpose adjuvants):

- Activators, such as surfactants, crop oil concentrates (COC), and nitrogen (N) are normally used to help improve the performance of herbicides by increasing herbicide retention or penetration into leaf surfaces, improving rain fastness, or to decrease photodegradation of herbicides.[2]
- Utility modifiers, such as buffering, antifoam, and drift control agents, typically modify the characteristics of the spray solution and product compatibility.

Labels MUST be followed since use of an herbicide product in a manner inconsistent with its labeling is a violation of federal law. Each herbicide product has adjuvant requirements that are specified on the herbicide label. The label provides guidance and adjuvant options to address tank mixtures, environmental conditions, or weed species characteristics. Some herbicides, such as Roundup PowerMAX® 3 Herbicide, are formulated with sufficient adjuvants and may not require the use of additional adjuvants. Other herbicides have specific adjuvant recommendations that MUST be added to the spray mixture. Each herbicide manufacturer may have supplemental labels or fact sheets that provide additional guidance for the use of adjuvants for specific application situations, weed species, crops, or tank mixtures.

There is a diverse array of adjuvant products and brands. Therefore, the applicator must understand the composition and function of each product while considering expected environmental conditions at the time of application to properly match the adjuvant to individual herbicides or tank mixtures.

Types of Adjuvants

Adjuvants that can be used with herbicides include surfactants, oil concentrates, nitrogen fertilizers, spreader-stickers, wetting agents, and penetrants.[1,2,3]

- Non-ionic surfactants (NIS) are dispersing agents to help improve plant coverage and penetration of foliar-applied herbicides with low crop toxicity.
- Crop oil concentrates (COC) are derived from petroleum.
- Methylated seed oils (MSO) function like other oil concentrates but are derived from seed oils.[2]
- High surfactant oil concentrates (HSOC) are emulsifiable oil-based products containing 25 to 50% surfactant (wt/wt) in a minimum of 50% oil (wt/wt) which can be MSO or COC based.

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- Nitrogen fertilizer products, used at recommended rates, can act as adjuvants to help improve the performance of certain herbicides, especially under hard water conditions, drought, or in tank mixtures. Spray-grade ammonium sulfate (AMS) or urea ammonium nitrate (UAN) are common nitrogen fertilizer adjuvants. Nitrogen fertilizer solutions are generally recommended in conjunction with NIS or COC.
- Blended adjuvants contain specific combinations of special purpose and/or activator adjuvants that serve multiple functions.[2]
- The risk for crop injury may be increased with COC, MSO, and HSOC products compared to surfactants.[3]

Table 1. Adjuvant recommendations for Bayer herbicides.*

(Individual herbicide labels MUST be read and followed. The information in this table does not replace the label)

Herbicide	Adjuvant Recommendation
Alion® Herbicide	No additional adjuvant required for these herbicides. If tank-mixing, follow the adjuvant recommendations for the tank-mix partner. For Degree Xtra® Herbicide, Harness® Herbicide, Harness® Xtra Herbicide, Harness® Xtra 5.6L Herbicide, and Warrant® Herbicide: Predetermine the compatibility of these products or labeled mixtures of these products with fluid fertilizer carriers.
Axiom® DF Herbicide	
Degree Xtra® Herbicide (Restricted Use Pesticide)	
Harness® Herbicide	
Harness® Xtra Herbicide (Restricted Use Pesticide)	
Harness® Xtra 5.6L Herbicide (Restricted Use Pesticide)	
Nortron® SC Herbicide	
Ricestar® Herbicide	
Ricestar® HT Herbicide	
TripleFLEX® II Herbicide	
VARRO® Herbicide	
Warrant® Herbicide	
Wolverine® Herbicide	
Wolverine® Advanced Herbicide	
Autumn™ Super 51 WDG Herbicide	External adjuvant and a nitrogen source are required. External Adjuvant Requirement: Crop Oil Concentrate (COC), Methylated Seed Oil (MSO), or equivalent oil blend at 1% v/v (1 gallon per 100 gallons of final spray volume). Nitrogen Fertilizer Requirement: 28 or 32% Urea Ammonium Nitrate (UAN) at 1.5 to 2 qts/acre or Spray Grade Ammonium Sulfate (AMS) at 1.5 to 3.0 lb/acre.
Balance® Flexx Herbicide (Restricted Use Pesticide)	No additional adjuvant required. If tank-mixing, follow the adjuvant recommendations for the tank-mix partner. Do Not use Crop Oil Concentrate (COC), Methylated Seed Oil (MSO), or a loaded glyphosate formulation applied to emerged corn. If herbicide is to be tank mixed with liquid fertilizers or other pesticides, compatibility needs to be tested prior to mixing.
Corvus® Herbicide (Restricted Use Pesticide)	

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Capreno® Herbicide	External adjuvant and a nitrogen fertilizer source are required to achieve optimum weed control when weeds are present at time of application. The use of nonionic surfactants or refined vegetable oils will result in unacceptable or erratic weed control. External Adjuvant Requirement: Use Crop Oil Concentrate (COC) which contains at least 80% crop oil and 10% emulsifier or greater at rate of 1% v/v (1 gallon per 100 gallons of water). A high surfactant oil concentrate (HSOC) at recommended rates may substitute for the addition on COC. Methylated Seed Oil (MSO) at 0.5% v/v may be substituted for COC when plants are growing under adverse conditions such as drought stress, low humidity, etc. Nitrogen Fertilizer Requirement: Use 1.5 qt/acre of a high-quality urea ammonium nitrate (UAN) or 1.5 lb/acre or 8.5 lb/100 gallons with a minimum of 1.5 lb/acre of a spray-grade ammonium sulfate (AMS). Use UAN under conditions of low relative humidity for greater weed control. Postemergence applications should be made in water as the carrier. Sprayable fluid fertilizer as a herbicide carrier for postemergence applications in corn can typically cause corn injury up to and including tissue burn (necrosis). Sprayable fluid fertilizer as a carrier is not recommended after crop emergence unless typical fertilizer burn symptoms on the crop are acceptable.
DiFlexx® Herbicide	To improve post emergence weed control, particularly in dry growing conditions, use one of the following: Nonionic Surfactant (NIS): 0.25% v/v or 1 qt/100 gallons Crop Oil Concentrate (COC): 1.0% v/v or 1 gal/100 gallons Methylated Seed Oil (MSO): 1.0% v/v or 1 gal/100 gallons
DiFlexx® DUO Herbicide	This herbicide is a suspension concentrate that requires the use of an external surfactant to achieve optimum weed control when applied postemergence or when applied preplant or preemergence if weeds are present. Agriculturally approved drift reducing additives may also be added. Methylated Seed Oil (MSO): 1.0% v/v or 1 gal/100 gallons Crop Oil Concentrate (COC): 1.0% v/v or 1 gal/100 gallons The MSO or COC should contain at least 80% MSO or COC and 10% emulsifier or greater. High Surfactant Oil Concentrates (HSOC) containing 25 to 50% surfactant wt/wt in a minimum of 50% oil wt/wt, may be used at recommended rates as an alternative to COC or MSO surfactants. If tank-mixing, see label for adjuvant alternatives.
Harness® MAX Herbicide	Predetermine the compatibility of this product or labeled mixtures with fluid fertilizer carriers. Preemergence Spray Adjuvants: When applying preplant or before corn is emerged, and where emerged weeds are present, the use of any agricultural adjuvant is permitted. To enhance control of emerged weeds Methylated Seed Oil (MSO) adjuvants are typically better than Crop Oil Concentrate (COC) adjuvants, which are generally better than Nonionic Surfactant (NIS) adjuvants. Urea ammonium nitrate (UAN) or ammonium sulfate (AMS) typically improves control of emerged weeds. Postemergence Spray Adjuvants: Use either NIS or COC. COC will provide more consistent weed control than NIS but may result in temporary crop injury. Nonionic Surfactant (NIS): 0.25% v/v or 1 qt/100 gallons Crop Oil Concentrate (COC): 1.0% v/v or 1 gal/100 gallons In addition to NIS or COC, a nitrogen-based adjuvant (AMS or UAN) may also be added to increase weed control consistency. The use of nitrogen-based adjuvants will increase the risk of temporary crop injury. Yellow popcorn: Use NIS for postemergence applications to minimize the risk of crop injury. DO NOT use AMS or UAN. DO NOT use MSO when applied alone or as a postemergence tank mixture with other products toe emerged field corn (all types).
Huskie® Herbicide	Spring planted cereals: When applied alone, ammonium sulfate (AMS), urea ammonium nitrate (UAN), or non-ionic surfactant (NIS) may be used, especially under challenging conditions to optimize herbicidal activity. Winter wheat and winter barley: When applied alone or under challenging conditions, spray additives such as AMS or UAN are recommended to optimize herbicidal activity. When tank-mixing, use additives according to the label for the tank-mix partner as additional additives may cause unacceptable crop response. AMS: 0.5 to 1 lb/acre (preferred N source) UAN: 1 to 2 qt/acre NIS: Use tankmix partner label recommendation or at a concentration of 0.25 to 0.5% v/v (1 to 2 qt/100 gallons of spray solution). At least 80% of the surfactant must be active NIS.

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Huskie® Complete Herbicide (Restricted Use Pesticide)	For optimal weed control, ammonium sulfate (AMS) or urea ammonium nitrate (UAN) may be added: AMS: 0.5 to 1.0 lb/acre UAN: 1 pt/acre to 1 qt/acre
Huskie® FX Herbicide	Spring planted cereals: When applied alone, ammonium sulfate (AMS), urea ammonium nitrate (UAN), or non-ionic surfactant (NIS) may be used, especially under challenging conditions to optimize herbicidal activity. AMS: 0.5 to 1.0 lb/acre UAN: 1 to 2 qt/acre NIS: 0.25 to 0.5% v/v (1 to 2 qt/100 gallons of spray solution); at least 80% of the surfactant must be active NIS. Winter wheat: Addition of spray additives to a spray tank with Huskie® FX Herbicide will be dictated by the requirements of any tank-mix partner. If Huskie® FX Herbicide is applied in a tank mixture with other herbicides or pesticides, spray additives could cause unacceptable crop response; therefore, additives are not recommended unless specifically directed by tank-mix partner label.
Laudis® Herbicide	Requires external surfactant and nitrogen fertilizer source to achieve optimum weed control. Methylated Seed Oil (MSO) based products are preferred, particularly when used alone or tank-mixed with atrazine. MSO: 1% v/v (1 gal MSO/100 gallons water) High Surfactant Oil Concentrates (HSOC) may be used as an alternative to MSO surfactants. Non-ionic surfactant (NIS) or refined vegetable oils will result in unacceptable or erratic weed control. Fertilizer: ammonium sulfate (AMS) (1.5 lb/acre or 8.5 lb/100 gal) or urea ammonium nitrate (UAN) (1.5 qt/acre). Use UAN under conditions of low relative humidity for greater weed control.
Luxxur® A Herbicide + Luxxur® B Herbicide	After Luxxur® A Herbicide is completely dissolved, add the required amount of Luxxur® B Herbicide. For optimal weed control, add 0.5 to 1.0 lb/acre ammonium sulfate (AMS) or 0.25% to 0.5% v/v (1 to 2 qt/100 gallons of spray solution) non-ionic surfactant (NIS); at least 80% of the surfactant must be active NIS.
Olympus® 70% Water Dispersible Granular Herbicide	Non-ionic surfactant (NIS) is required at 0.25% to 0.5% v/v (1 to 2 qt/100 gallons of spray solution); at least 80% of the surfactant must be active NIS. In spray solutions containing liquid nitrogen, an NIS at a maximum of 0.25% v/v (1 qt/100 gallons of spray solution) is required. If using 100% urea ammonium nitrate (UAN) solutions as a carrier, reduce NIS rate to 0.125% v/v (0.5 qt/100 gallons of spray solution).
Osprey® Herbicide	Must include a non-ionic surfactant (NIS) plus ammonium nitrogen (urea ammonium nitrate (UAN) or ammonium sulfate (AMS)) fertilizer or a methylated seed oil (MSO) or a “basic blend” (BBA) type adjuvant. NIS: 0.5% v/v (2 qt/100 gallons of spray solution); at least 80% of the surfactant must be active NIS. UAN: 1 to 2 qt/acre (transient leaf burn may occur) AMS: 1.5 to 3 lb/acre MSO: 1.3 to 1.5 pt/acre (crop response may be increased compared to NIS plus ammonium nitrogen fertilizer); if using MSO, do not use ammonium nitrogen. BBA (pre-mix of NIS or MSO and a nitrogen source): 1% v/v or 0.8 to 1.6 pt/acre depending on per acre water carrier volume. When BBA is used, UAN or AMS fertilizer is not recommended.
Rimfire® Max Herbicide	Must include methylated seed oil (MSO), basic blend (BBA), non-ionic surfactant (NIS) plus ammonium nitrate (UAN) or ammonium sulfate (AMS). MSO: 1.3 to 1.5 pt/acre; must contain at least 80% MSO and 10% emulsifier or greater. If MSO used, UAN or AMS is not recommended as the potential for crop response may be increased. BBA: 1 to 1.25% v/v; at least 0.8 pt/acre. If BBA used, UAN or AMS is not recommended. NIS plus UAN or AMS: NIS at 0.25 to 0.5% v/v (1 to 2 qt/100 gallons of spray solution); UAN at 1 to 2 qt/acre or AMS at 1.5 to 3 lb/acre.

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Roundup PowerMAX® Herbicide Roundup PowerMAX® 3 Herbicide	Surfactants not always required; however, may be added. Additional surfactant can increase performance at water carrier volumes above 30 gallons/acre or at application rates below 16 fl oz/acre. Non-ionic (NIS) surfactants may be used. Do not reduce herbicide rates if using a surfactant. Use a surfactant concentration of 0.25 to 0.5% v/v (1 to 2 qt/100 gallons of spray solution) when adding surfactant that contains at least 70% active ingredient, or a 1% surfactant concentration (4 qt/100 gallons of spray solution) when adding surfactant that contains less than 70% active ingredient. DO NOT add buffering agents or pH adjusting agents to the spray solution when Roundup PowerMAX® Herbicide is the only pesticide product being applied. DO NOT add additional surfactant or additives containing surfactant to this product for preharvest application to cotton or any postemergence (in-crop) application to Roundup Ready® cotton and Roundup Ready Flex® cotton. Ammonium sulfate (AMS) at a rate of 1 to 2% dry AMS by weight (8.5 to 17 lb/100 gallons of water) or equivalent rate of liquid AMS could increase the performance of this product on annual and perennial weeds, particularly under hard water conditions, drought conditions, or tank-mixed with certain residual herbicides. Ensure dry AMS is completely dissolved in the spray tank before adding herbicides.
Roundup WeatherMAX® Herbicide	Do not add surfactants, additives containing surfactants, buffering agents or PH adjusting agents to the spray solution when Roundup WeatherMAX® Herbicide is the only pesticide being applied unless otherwise directed. Ammonium sulfate (AMS) at a rate of 1 to 2% dry AMS by weight (8.5 to 17 lb/100 gallons of water) or equivalent rate of liquid AMS could increase the performance of this product on annual and perennial weeds, particularly under hard water conditions, drought conditions, or tank-mixed with certain residual herbicides. Ensure dry AMS is completely dissolved in the spray tank before adding herbicides.
RT 3® Herbicide	Extra surfactant is generally not recommended. Ammonium sulfate (AMS) at a rate of 1 to 2% dry AMS by weight (8.5 to 17 lb/100 gallons of water) or equivalent rate of liquid AMS could increase the performance of this product on annual and perennial weeds, particularly under hard water conditions, drought conditions, or tank-mixed with certain residual herbicides. Ensure dry AMS is completely dissolved in the spray tank before adding herbicides.
TriVolt™ Herbicide (Restricted Use Pesticide)	Early **postemergence** applications **MUST** be made with water as the carrier. Sprayable fluid fertilizer as a herbicide carrier for early postemergence applications in corn can typically cause corn injury up to and including tissue burn (necrosis). For **preplant/preemergence** burndown applications: when weeds are present at the time of treatment and prior to corn emergence, a tank mixture of TriVolt™ Herbicide (+/- DiFlexx® Herbicide – dicamba, EPA# 264-1173) with crop oil concentrate (COC) or methylated seed oil (MSO) is advised for burndown of labeled weeds 6 inches or less in height. When mixing with liquid nitrogen fertilizer or certain glyphosate formulations, substitute a non-ionic surfactant (NIS) for oil concentrates. **DO NOT** use COC or MSO with TriVolt™ Herbicide applied to emerged field corn. If TriVolt™ Herbicide is to be tank mixed with liquid fertilizers or other pesticides, compatibility needs to be tested prior to mixing.
Warrant® Ultra Herbicide	No adjuvants are needed unless Warrant® Ultra Herbicide is being used to burndown emerged weeds. For postemergence applications add one of the following except in tank mix with products prohibiting spray additives: 1) Nonionic surfactant (NIS): Use a NIS containing at least 75% surface active agent at 0.25 to 0.5% v/v (1 to 2 qt/100 gallons) of the finished spray volume. 2) Crop oil concentrate (COC): Use a nonphytotoxic COC containing 15 to 20% approved emulsifier, at 0.5 to 1% v/v (0.5 to 1 gal/100 gallons) of the finished spray volume. COC can improve weed control but may reduce crop tolerance. 3) Methylated seed oil (MSO): Use a nonphytotoxic MSO containing 60% MSO. Poor performance may result from the use of MSO products containing less than 60% MSO. MSO can improve seed control but may reduce crop tolerance. Note: Reduced postemergence weed control for glyphosate may result from tank mixtures with Warrant® Ultra Herbicide and oil-based adjuvants.
Wolverine® PowerPak Herbicide	Spray additives such as ammonium sulfate (AMS) and urea ammonium nitrate (UAN) may be used, especially under challenging conditions to optimize activity on susceptible broadleaf weeds. AMS (preferred nitrogen source): 0.5 to 1 lb/acre. UAN: 1 to 2 qt/acre.

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XtendiMax® Herbicide with VaporGrip® Technology (Restricted Use Pesticide)	MUST be used with VaporGrip® Xtra Agent (or an equivalent volatility reduction adjuvant (VRA)). The inclusion of a drift reduction adjuvant (DRA) is also required in the tank mix, unless otherwise indicated on www.XtendiMaxApplicationRequirements.com. Only tank mix products that have been tested and found to not adversely affect the offsite movement potential of XtendiMax® herbicide with VaporGrip® Technology may be tank mixed with XtendiMax® herbicide with VaporGrip® Technology. For approved tank-mix products (including VRAs and DRAs), nozzles, and other important label information, visit XtendiMaxApplicationRequirements.com no more than 7 days before applying XtendiMax® herbicide with VaporGrip® Technology. DO NOT tank mix with ammonium sulfate (AMS).
*If not stated, assume ammonium sulfate (AMS) and urea ammonium nitrate (UAN) are spray-grade quality, non-ionic surfactant at 80% concentration, methylated seed oil (MSO) at least 80% MSO and 10% emulsifier. For additional information, contact your local Bayer representative.	

Sources:

[1] Jordan, T., Johnson, B., and Nice, G. 2011. Adjuvants used with herbicides: Factors to consider. Pest & Crop. Issue 25. Purdue University. https://extension.entm.purdue.edu/pestcrop/2011/issue25/index.html#adjuvant/.

[2] Curran, W.S. and Lingenfelter, D.D. 2009. Adjuvants for enhancing herbicide performance. Agronomy Facts 37. Penn State Extension. https://extension.psu.edu/adjuvants-for-enhancing-herbicide-performance/.

[3] Swoboda, R. (Hartzler, R., Iowa State University) 2013. Relearning to accept herbicide injury to crops. WallacesFarmer. https://www.farmprogress.com/story-relearning-accept-herbicide-injury-crops-9-95965/.

Hartzler, B. 2001. Role of spray adjuvants with postemergence herbicides. Integrated Crop Management. Iowa State University. https://crops.extension.iastate.edu/encyclopedia/role-spray-adjuvants-postemergence-herbicides/.

Legal Statement

XtendiMax® herbicide with VaporGrip® Technology is part of the Roundup Ready® Xtend Crop System, is a restricted use pesticide and must be used with VaporGrip® Xtra Agent (or an equivalent volatility reduction adjuvant). For approved tank-mix products (including VRAs and DRAs), nozzles and other important label information visit XtendiMaxApplicationRequirements.com. Applicators must check XtendiMaxApplicationRequirements.com no more than 7 days before application of this product for additional labeling, including state restrictions. Where applicable, users must comply with additional requirements found on this website.

ALWAYS READ AND FOLLOW PESTICIDE LABEL DIRECTIONS. Roundup Technology® includes glyphosate-based herbicide technologies.

Performance may vary, from location to location and from year to year, as local growing, soil and weather conditions may vary. Growers should evaluate data from multiple locations and years whenever possible and should consider the impacts of these conditions on the grower's fields.

Balance® Flexx, Corvus®, Degree Xtra®, Harness® Xtra, Huskie® Complete, TriVolt™ and XtendiMax® are restricted use pesticides. Not all products are registered for use in all states and may be subject to use restrictions. The distribution, sale, or use of an unregistered pesticide is a violation of federal and/or state law and is strictly prohibited. Check with your local dealer or representative for the product registration status in your state. Tank mixtures: The applicable labeling for each product must be in the possession of the user at the time of application. Follow applicable use instructions, including application rates, precautions and restrictions of each product used in the tank mixture. Not all tank mix product formulations have been tested for compatibility or performance other than specifically listed by brand name. Always predetermine the compatibility of tank mixtures by mixing small proportional quantities in advance. Degree® is a registered trademark of Monsanto Technology LLC. Alion®, Autumn™, Axiom®, Balance®, Bayer, Bayer Cross, Capreno®, Corvus®, Degree Xtra®, DiFlexx®, Harness®, Huskie®, Laudis® , Luxxur®, Nortron®, Olympus®, Osprey®, Ricestar®, Rimfire®, Roundup PowerMAX®, Roundup Ready®, Roundup Technology®, Roundup WeatherMAX®, RT 3®, TripleFLEX®, TriVolt™, VaporGrip®, Varro®, Warrant®, Wolverine® and XtendiMax® are trademarks of Bayer Group. All other trademarks are the property of their respective owners. For additional product information call toll-free 1-866-99-BAYER (1-866-992-2937) or visit our website at www.BayerCropScience.us. Bayer CropScience LP, 800 North Lindbergh Boulevard, St. Louis, MO 63167. ©2022 Bayer Group. All rights reserved. 1026_48301

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