GENERAL INFORMATION

Refer to web version of the ND Weed Control Guide at: www.ndsu.edu/weeds for additional general information:
- Field investigation of crop injury
- Herbicide + Insecticide/Fungicide/Fertilizer
- Herbicide storage temperatures

A1. PPI AND PRE HERBICIDES
Incorporation of herbicides

Good weed control with PPI and PRE herbicides depends on many factors, including rainfall after application, soil moisture, soil temperature, soil type and weed species. For these reasons, PRE herbicides applied to the soil surface sometimes fail to control weeds. Herbicides that are incorporated into the soil surface usually require less rainfall after application for effective weed control than unincorporated herbicides. A rotary hoe or harrow will activate PRE herbicides under dry conditions and control small weeds emerging through a PRE herbicide.

Many factors influence the activity and performance of soil-applied herbicides. Factors that should be considered are: rate too low for soil type, high weed pressure, weeds not listed on label, poor control in wheel tracks, cloddy soil, wet soil, amount of previous crop residue, dry weather, poor incorporation, improper setting of incorporation implement, herbicide resistant weeds, incorporation too shallow or deep, incorporation speed too slow, worn sweeps on cultivator, single pass instead of two pass incorporation, and second incorporation deeper than first. Consider these possibilities before poor weed control is attributed only to the herbicide.

Buckle, Eptam, Far-Go, Ro-Neet, Sonalan, and Treflan* require incorporation. Eptam, Far-Go, and Ro-Neet must be incorporated immediately (within minutes) after application. Treflan incorporation may be delayed up to 24 hours if applied to a cool, dry soil and if wind velocity is less than 10 mph. Sonalan incorporation may be delayed up to 48 hours. Prowl* is labeled only PPI in soybean, dry beans, and pulse crops and labeled PRE, not PPI, on corn. Dual*, Harness/Surpass*, and Outlook* may be used PRE but shallow PPI improves weed control, particularly on fine textured soils. Incorporation of Dual*, and Nortron* may be delayed several days. Incorporation of Eradicane and Eptam can be delayed up to 4 hours when applied with liquid fertilizer and the same day when impregnated on dry bulk fertilizer. Ro-Neet can be incorporated up to 4 hours after application and up to 8 hours when impregnated on dry fertilizer.

Perform a second tillage at right angles to the initial incorporation if a disk or field cultivator is used. The second incorporation will incorporate any herbicide remaining on the soil surface and provide more uniform distribution in the soil, thereby improving weed control and reducing crop injury.

A2. SOIL ORGANIC MATTER TEST

Soil-applied herbicides are adsorbed and inactivated by soil constituents in the following order: organic matter>clay>silt>sand. Adjust herbicide rates for soil type and organic matter content. Most soil-applied herbicides require higher rates to be effective in high organic matter soils, but crop safety may be marginal on low organic matter soils. Linuron activity requires low organic matter. Far-Go, Treflan* and most POST herbicides are affected only slightly by organic matter levels. Organic matter levels should be determined on each field where organic-matter-sensitive herbicides are to be used. Organic matter levels change very slowly, and testing once every 5 years should be adequate.

*Or generic equivalent.

A3. POST APPLIED HERBICIDES

Weed control from POST herbicides is influenced by rate, weed species, weed size, and climatic conditions. Labeled rates will be effective under favorable conditions and when weeds are small and actively growing. Use the highest labeled rates under adverse conditions and for well established weeds.

Sunlight inactivates some herbicides by the ultraviolet (UV) spectrum of light. Treflan* and Eptam degradation is minimal when incorporated soon after application. “Dim” herbicides (Achieve, Select*, and Poast) are highly susceptible to UV light and will degrade rapidly if left in nonmetal spray tanks for an extended period of time or if applied during mid-day. To avoid UV breakdown, apply soon after mixing and add an effective oil adjuvant which speeds absorption.

Ideal temperatures for applying most POST herbicides are between 65 and 85 F. Speed of kill may be slow when temperatures remain below 60 F. Some herbicides may injure crops if applied above 85 F or below 40 F. Avoid applying volatile herbicides under conditions where vapors and particle drift may injure susceptible crops, shelterbelt trees, or farmsteads.

Temperatures following herbicide application influence crop safety and weed control. Crops metabolize herbicides but metabolism slows during cool or cold conditions, which extends the amount of time required for plants to degrade herbicides. Rapid degradation under warm conditions allow plants to escape herbicide injury. Herbicides may be sprayed following cold night-time temperatures if day-time temperatures warm to at least 60 degrees.

Some “Fop” ACCase herbicides (fenoxaprop) are more effective during cold/cool temperatures and are much less effective when grass weeds are drought stressed. Other ACCase herbicides, such as Assure II*, Poast, and Select* control grasses best in warm weather when grasses are actively growing. ALS grass herbicides in wheat generally provide more consistent and greater grass control in warm, dry conditions compared with cool, wet conditions. Cool or cold conditions at or following application of ACCase herbicides may increase injury to wheat. Wild oat is a cool season grass but green and yellow foxtail are warm season grasses and may stop growing under cold conditions, resulting in poor control. Weeds are controlled most effectively when plants are actively growing.

Cold temperatures and freezing conditions following application of ALS herbicides, Buctril*, and metribuzin may increase crop injury with little effect on weed control. Delay applying fenoxaprop, ALS herbicides, and metribuzin until daytime temperatures exceed 60F and after active plant growth resumes.

Basagran*, Cobra, Flexstar, Liberty, Ignite, paraquat*, Reflex, and Ultra Blazer are less likely to cause crop injury when cold temperatures follow application but less weed control may result.

2,4-D, MCPA, Banvel*, Starane*, Stinger*, and glyphosate (resistant crops) have adequate crop safety and provide similar weed control across a wide range of temperatures, but weed death is slowed when cold temperatures follow application.

Dew may increase absorption and weed control by hydrating leaf cuticle but may reduce weed control if spray run-off occurs. Rainfall shortly after POST herbicide application reduces weed control because herbicide is washed off the leaves before absorption is complete (See the rainfast interval chart on the next page).

*Or generic equivalent.

Minimum Interval Between Application and Rain for Maximum POST Weed Control.

Herbicide	Time Intrvl.	Herbicide	Time Intrvl.
Acuron/Flexi	4 hr	**Milestone**	4 hr
Aim	1 hr	**Olympus**	4 hr
Alluvex	6-8 hr	**OpenSky**	4 hr
Ally*/Escort*	4 hr	**Orion**	4 hr
Armezon	1 hr	**Osprey**	4 hr
Armezon Pro	1 hr	**Panoflex**	4 hr
Assure II / Targa	1 hr	paraquat*	0.5 hr
Atrazine*	4 hr	**Permit**	4 hr
Axial Star	1 hr	**Perspective**	6-8 hr
Axial XL	0.5 hr	**Plateau**	1 hr
Basagran/bentazon*	4-8 hr	**Poast**	1 hr
Betamix*	6 hr	**PowerFlex HL**	4 hr
Beyond	1 hr	**Pursuit**	1 hr
Bromoxynil*	1 hr	**Quelex**	4 hr
Cadet	4 hr	**Raptor**	1 hr
Callisto	1 hr	**Realm Q**	4 hr
Callisto GT	6-8 hr	**Redeem**	2 hr
Capreno	1 hr	**Reflex**	2 hr
Cobra	0.5 hr	**Reglone**	0.5 hr
Curtail* / M*	6-8 hr	**Remedy**	6-8 hr
Dicamba	6-8 hr	**Require Q**	4 hr
DiFlexx/Duo	4 hr	**Resicore**	6-8 hr
Diquat*	0.5 hr	**Resolve***/**Q**	4 hr
Discover NG	0.5 hr	**Resource**	1 hr
Engenia	4 hr	**Revulin Q**	4 hr
Enlist Duo	1 hr	**Rimfire Max**	4 hr
Everest 3.0 / Sierra	1 hr	**Select***/**Max**	1 hr
Express*	4 hr	**Sharpen**	1 hr
Extreme	1 hr	**Solstice**	4 hr
Facet L	6 hr	**Spartan Charge**	1 hr
Fenoxaprop	1 hr	**Starane*/Flex**	4 hr
FirstRate	2 hr	**Starane NXT***	1 hr
Flexstar	1 hr	**Status**	4 hr
Flexstar GT 3.5	6-12 hr	**Stinger***	6-8 hr
Fusilade DX	1 hr	SU herbicides	4 hr
Glyphosate(Full adjuv.)	6-12 hr	**Supremacy**	2 hr
Glyphosate (Partial adj.)	6-12 hr	**Talinor**	1 hr
Glyphosate (No adjuv.)	6-12 hr	**Tordon 22K**	6-8 hr
GoldSky	4 hr	**Ultra Blazer**	4 hr
Halex GT	1 hr	**UpBeet**	6 hr
Harmony*	4 hr	**Varisto**	4 hr
Hornet / Stanza	2 hr	**Varro**	1 hr
Huskie / Complete	1 hr	**Weedmaster***	6-8 hr
Impact	1 hr	**WideMatch***	6 hr
Instigate	4 hr	**Wolverine Advanced**	1 hr
Laudis	1 hr	**Xtendimax/FeXapan**	4 hr
Liberty/Rely 280	4 hr	**Zidua Pro**	1 hr
Lumax EZ	4 hr		
Marvel	1 hr	2,4-D amine	4-8 hr
MCPA amine	4-6 hr	2,4-D ester	1 hr
MCPA ester	1 hr		

*Or generic equivalent

A4. GLYPHOSATE

1. Use full rates that will kill weeds. Commercial glyphosate formulations contains 3 to 5 lbs acid equivalent (4 to 6.1 lb active ingredient) per gallon. Refer to the end of section A4 for rates based on formulation. Dead weeds do not produce seed or contribute to glyphosate resistance. Reduced glyphosate rates will amplify low-level resistance in weed progeny. Lambsquarters, waterhemp, horseweed (marestail), ragweed, and kochia have low-level resistance and require at least a full or elevated glyphosate rate. A reduced glyphosate rate may cause temporary injury symptoms allowing plants to recover, resume growth, and produce seed. Progeny from recovered plants will have a higher level of resistance and require higher herbicide rates to give the same level of control than parental plants. Surviving plants will contribute seed to the seed bank possessing amplified level of resistance. Refer to General Weed Management Guidelines in Section X1 - Herbicide Resistant Weeds.

2. Apply to small, actively growing annual plants. This early timing will not coincide with the preferred timing of early bud to early flower for most perennial weeds. Usually larger and older annual plants can be more difficult to control.

3. To optimize glyphosate phytotoxicity from sequential applications, delay the second application until new growth appears (>10-14 days).

4. Delay tillage at least 1 day after treating annual weeds and 3 days after treating perennial weeds for greater weed control from increased glyphosate absorption and translocation.

5. Low water volume (gpa) will enhance glyphosate activity. Low water volume produces spray droplets with high glyphosate concentration that results in greater absorption. Low spray volume also reduces the concentration of antagonistic salts in water that can interact with glyphosate. Low gpa produces small drops which may increase risk of damaging drift.

6. Glyphosate is very water soluble. High water solubility causes slow absorption through waxy plant cuticles. High air humidity increases glyphosate absorption and activity by hydrating leaf cuticle. Glyphosate activity also increases when plants are growing under good soil moisture. Inversely, weed control is reduced under low humidity and when weeds are drought stressed.

7. Always add reputable surfactant (NIS) to glyphosate unless prohibited by the label. Glyphosate absorption into plant tissue is slow and generally only 20-40% in most weed species. Add NIS at 1 qt/100 gal water to full adjuvant load formulations, 1 to 2 qt/100 gal water to partial adjuvant formulations, and 2 to 4 qt/100 gal water v/v to glyphosate formulations with no adjuvant. NIS may also increase retention of spray droplets and improve control of hard-to-wet species such as lambsquarters, and most grasses. Not all surfactants are equal - use reputable adjuvants.

8. Most oil adjuvants (COC) antagonize glyphosate - See #6. Most herbicides applied with glyphosate are lipophilic (oil soluble). These include Group 1, 2, 4, 5, 14, 15, and 27 herbicides (See X1). Oil adjuvants (COC and MSO) greatly enhance oil soluble herbicides but antagonize glyphosate. NIS + AMS enhance glyphosate phytotoxicity more than other additives, are less effective with oil soluble herbicides, and will only partially overcome oil adjuvant antagonism of glyphosate. MSO based ‘high surfactant oil concentrate’ adjuvants (HSMOC-see page 128) contain a higher concentration of surfactant than COC and MSO and enhance oil soluble herbicides without decreasing glyphosate activity. Most COC/petroleum based ‘high surfactant oil concentrate’ (HSPOC) adjuvants are inferior to HSMOC adjuvants and usually do not perform differently than common COC or petroleum oil adjuvants.

A4 - GLYPHOSATE

9. Apply oil adjuvants on an area basis (i.e. pt/A) rather than a volume basis (1% v/v/1 qt / 100 gal of water). HSMOC adjuvants are commercially recommended at half the POC and MSO rate (0.5% v/v vs 1% v/v). HSMOC adjuvants applied at full rates and on an area basis (1 to 1.5 pt/A) rather than on a volume basis (0.5% v/v spray water) will provide greater herbicide enhancement and more consistent weed control. HSMOC applied on a volume basis at low gpa does not contain enough oil adjuvant to optimize glyphosate and POST herbicides.

10. Always add AMS to glyphosate. AMS enhances glyphosate absorption and translocation and deactivates antagonistic hard water salts (Na, Ca, Mg, Fe). As spray droplet water evaporates, sulfate from AMS binds with antagonistic salts and prevents binding with glyphosate. In addition, ammonium from AMS binds with glyphosate resulting in greater absorption and weed control. Nitrogen (ammonia) enhances glyphosate resulting in greater weed control in good and adverse growing conditions and even in the absence of antagonistic salts in water (See Section A6). AMS can be added at any time during spray tank loading when applying glyphosate but should be added first if applying several active ingredients in the tank with glyphosate. Allow granular AMS to dissolve before application or use a liquid formulation.

11. Glyphosate labels suggest AMS at 8.5 to 17 lb/100 gallons of water. However, analysis of water across the U.S. show 4 to 6 lbs/100 gal of AMS are adequate to overcome most hard water. Add AMS at a minimum of 1 lb/A if using greater than 12 gpa spray volume or 8.5 lb/100 gallons of water. The following equation can be used to calculate the amount of AMS needed to overcome antagonistic ions in the spray solution: *lbs AMS/100 gal = (0.002 X ppm K) + (0.005 X ppm Na) + (0.009 X ppm Ca) + (0.014 X ppm Mg) + (0.042 X ppm Fe).*
The formula does not account for cationic minerals (Ca) on leaf surfaces (lambsquarters, sunflower, velvetleaf, others) that can antagonize glyphosate. Refer to A6. Water in Montana and western ND and SD can have hardness levels of 1600 to 2500 ppm and require AMS at 17 lb/100 gal water. Determine water quality to determine minimum AMS rate. If using adjuvants called "Water Conditioning", or "AMS Replacement" adjuvants, use only those containing at least 4 lbs of AMS/100 gallons of water at their recommended rates. Data show generally less control from these AMS replacement adjuvants as compared to AMS at 8.5 lb/100 gal + NIS at 0.25% v/v.

12. Applying contact herbicides (Group 10, 14, and 22 - see X1) with glyphosate may result in antagonism and reduced weed control, especially of large weeds, winter-annual, biennial and perennial weeds. Contact herbicides cause rapid wilting and desiccation before the systemic glyphosate is absorbed reducing uptake and translocation within the plant. Contact herbicides may quickly kill small and susceptible weeds but regrowth of large weeds may be noticeable only a few days after application. Some contact herbicides that may antagonize glyphosate include: Group 10, 14, and 22. High spray water volumes may overcome some antagonism.

13. Cold weather is a stress to plants. Generally, weed control from glyphosate applied during or after cold weather may be the same as when applied in warm weather but the end result (weed control) may take longer. However, cold weather may decrease glyphosate activity on certain weeds. Ideal temperatures for applying POST herbicides are between 65 and 85 F. Speed of kill will be slower during cold weather. Use higher rates to overcome reduced control from cold temperatures before or after application. Glyphosate applied during cold weather, to large weeds, and weeds with low-level resistance will result in less weed control. AMS enhances weed control and can partially overcome reduced control of stressed plants.

Research data show wide temperature fluctuations (>15 F) 1 to 2 days before and after application are more likely to reduce weed control than consistently cool or cold temperatures. Wide temperature fluctuations can likely explain many situations where weed control is poor due to cold weather, especially with lambsquarters.

14. Excessive dew on plant foliage at application may reduce weed control by diluting the glyphosate concentration in spray droplets and negate the effect of low spray volume at application. Glyphosate absorption in plants is slow which partially explains the 6 to 12 hour rainfast period. Allow a 6 to 12 hour rainfast period for all glyphosate formulations regardless of label statements. Research has consistently shown increased glyphosate activity in humid conditions when leaf cuticles are hydrated. Dew on leaves will hydrate leaf cuticles and facilitate absorption.

15. Glyphosate is not deactivated by sunlight. However, time of day application studies show that activity of glyphosate is greatest when applied in full sunlight after 10:00 am and before 6:00 pm.

16. Use drift management techniques. Glyphosate is a non-selective, non-residual, translocated, foliar herbicide. Glyphosate can cause severe injury or death of plants intercepting even a small amount of active ingredient in down-wind spray droplet drift. Several drift reducing nozzles (example, Turbo Tee-Jet) can reduce drift without reducing phytotoxicity. Do not use 'thickener' drift reducing adjuvants that negatively alter the spray pattern and reduce herbicide activity.

17. Glyphosate is not volatile and does not produce fumes or vapor after application. Off-target movement of glyphosate from wind or during temperature inversions is in the form of droplets or particle drift, not volatility.

18. Tolerant plants escape phytotoxicity by metabolizing herbicides, except glyphosate. Plant metabolism slows during cool or cold conditions extending the amount of time required to degrade most herbicides. Plants do not metabolize glyphosate and absorbed glyphosate will remain in the plant until warm temperatures cause plants to resume translocation of glyphosate to growing points via the phloem.

19. Glyphosate can be applied in the fall after several frosts and will result in excellent control of annual, biennial, and perennial weeds. However, plant tissue must be green or purple and leaves firmly attached to the stem to absorb and translocate the herbicide. Do not apply glyphosate to desiccated plant tissue from low freezing temperatures. Fall application to new plant growth is required for optimum herbicide activity.

20. Glyphosate is deactivated by strong adsorption to soil (including dust) and organic matter. Slow absorption allows glyphosate on the plant leaf surface to be inactivated by dust present either on the leaf surface or transported by wind. This applies also to using slough or river water for spraying. The addition of NIS or AMS will not overcome inactivation. Placing nozzles before or after wheels may reduce inactivation from dust. Applying glyphosate perpendicular to the previous application or shifting the sprayer to one side of the previous path may also reduce inactivation by dust.

21. Do not apply glyphosate brands formulated with surfactant (partial or full adjuvant formulations) to bodies of water because surfactant components are toxic to fish and aquatic life. Only no-adjuvant formulations, such as Aquamaster, Rodeo, and some 4 lb ae/gal formulations of glyphosate can be applied to water. An approved NIS surfactant at 1 gal/100 gal water must be added to no-adjuvant glyphosate formulations for adequate weed control. Refer to the Adjuvant Section, on page 128 for a list of NIS adjuvants registered for use in water.

22. Glyphosate has been reported to inhibit manganese (Mn) uptake in plants from soil. Glyphosate is a strong nutrient chelator and can immobilize micronutrients through enzyme inhibition and reduce micronutrient efficiency. These responses have only been seen in micronutrient deficient soils and can be managed by applying micronutrients as warranted by soil test analysis and fertilizer recommendation.

23. Glyphosate does not require low spray solution pH. Generally, efficacy of glyphosate is equal across normal water pH used for herbicide application. A theory has been promoted that at low spray solution pH, glyphosate and other weakly acidic herbicides would be more lipophillic (nonpolar) and more readily absorbed across nonpolar plant cuticles. Some adjuvants for glyphosate formulations lower pH but glyphosate is soluble at low pH and maintains efficacy. Adding acidifiers with the purpose of lowering the pH of spray solutions containing glyphosate is unjustified. Most AMS replacement adjuvants (see Adjuvant Compendium on page 128-130) used at 2 qt/100 gal water reduce spray solution pH which may prevent some binding of glyphosate with antagonistic minerals in spray water. However, they do not contain sulfate to bind with cationic minerals and do not contain ammonia which binds with glyphosate and is required for glyphosate optimization. "Acidic AMS Replacement" adjuvants (see page 129) contain AMADS or monocarbamide dihydrogen sulfate (urea + sulfuric acid), can reduce spray solution pH to ~2 to reduce cation antagonism, and can optimize glyphosate similar to AMS but only when applied at a minimum of 2 qt/100 gal water. Refer to #1 on page 131 - "Understanding a water quality analysis report" for additional information on spray solution pH.

24. Potassium (K) salt formulations of glyphosate may negatively interact with dma (dimethyl amine) salt formulations of 2,4-D in the spray tank resulting in precipitation. Conditions that increase the risk of precipitation are application in low gpa, using cold water, and using high herbicide rates. This is an example of two dissimilar salts causing physical incompatibility and possibility of reduced weed control. Another example of negative herbicide salt interaction is grass antagonism from tank-mixing glyphosate-ipa (isopropyl amine) and 2,4-D-dma (dimethyl amine). Landmaster BW, a mixture glyphosate-ipa and 2,4-D-ipa avoided this antagonism by containing the same salt (ipa) for both herbicides.

Partial List of Registered Glyphosate Products in ND:

Trade Name	Manufacturer	Glyphosate salt	lb ae/gal	lb ai/gal	Adjuvant Load*
Abundit Edge	Dupont	K	4.5	5.5	Full
Accord	Dow	ipa	4	5.4	None
AquaNeat	Nufarm	ipa	4	5.4	None
Buccaneer	Tenkoz	ipa	3	4	Partial
Buccaneer Plus	Tenkoz	ipa	3	4	Full
Buccaneer 5	Tenkoz	ipa	3.7	5	Partial
Buccanr 5 Extra	Tenkoz	ipa	4	5.4	Partial
Cornerstn 5 Plus	Winfield Sol.	ipa	4	5.5	Full
Credit / 41	NuFarm	ipa	3	4	Partial
Credit / 41 Extra	NuFarm	ipa	3	4	Full
Credit Xtreme	NuFarm	ipa & K	2.5 + 2	5.83	Full
Duramax	Dow	dma	4	5.07	Full
Durango DMA	Dow	dma	4	5.07	Full
Extra Credit 5	NuFarm	ipa	3.7	5	Partial
Glyphogan	MANA	ipa	3	4	Partial
Gly Star 5 Extra	Albaugh	ipa	4	5.4	Full
Gly Star Gold	Albaugh	ipa	3	4	Full
Gly Star Original	Albaugh	ipa	3	4	Partial
Gly Star Plus	Albaugh	ipa	3	4	Full
Helosate Plus/Ad	Helm Agro	ipa	3	4	Full
Helosate 75SG	Helm Agro	-	68.9%	75.7%	Partial
Honcho K6	Monsanto	ipa	4.5	5.5	Partial
Imitator DA	Drexel	di-ammon	3	3.6	Full
Imitator Plus	Drexel	ipa	3	4	Full
Mad Dog	Loveland	ipa	3	4	Partial
Mad Dog Plus	Loveland	ipa	3	4	Full
Mad Dog 5.4	Loveland	ipa	4	5.4	Partial
Makaze	Loveland	ipa	3	4	Full
Rodeo	Dow	ipa	4	5.4	None
RT 3	Monsanto	K	4.5	5.5	Full
RU PowerMax	Monsanto	K	4.5	5.5	Full
RU/Private labels	Various	ipa	3	4	Partial
RU WeatherMax	Monsanto	K	4.5	5.5	Full
Showdown	Helena	ipa + NH_4	2.7 + 0.3	3.64	Full

*Unless prohibited add NIS to commercial glyphosate formulations as follows:
Full adjuvant load = add NIS at 1 qt/100 gal water.
Partial adjuvant load = add NIS at 1 to 2 qt/100 gal water.
No adjuvant load = add NIS at 2 to 4 qt/100 gal water.

Table. Actual glyphosate product rates based on acid equivalent (ae) and active ingredient (ai) formulation concentrations - Refer to page 4 for more information.

lb ae		lb ai		0.75 ae	1.125 ae	1.5 ae	2.25 ae	3 ae
				---------------------- fl oz/A ----------------------				
3	=	4	=	32	48	64	96	128
3.75	=	5	=	25.6	38.4	51.2	76.8	102.4
4	=	5.4	=	24	36	48	72	96
4.17	=	5.1	=	23	34.5	46	69	92.1
4.5	=	5.5	=	21.3	32	42.6	64	85
4.72	=	6.3	=	20.3	30.5	40.7	61	81.4
5	=	6.1	=	19.2	28.8	38.4	57.6	76.8

A5. SPRAY ADJUVANTS

Spray adjuvants generally consist of surfactants, oils and fertilizers.

Surfactants (nonionic surfactants = NIS) are used at 0.25 to 1% v/v (1 to 8 pt/100 gal of spray solution) 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 retention, but at a lesser degree, may increase 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 retention, deposition, and herbicide 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 aid in absorption through the leaf cuticle. Rapid entry of spray solution into leaf stomata from use of silicone surfactants often does not result in improved weed control. Silicone surfactants are weed and herbicide specific just like other adjuvants.

Oils generally are used at 1 to 2 pt/A or at 1% v/v (1 gal/100 gal of spray solution) depending on herbicide and oil. 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 Roundup. The term crop oil concentrate (COC) is used to designate a petroleum oil concentrate but is misleading because the oil type in COC is petroleum and not a 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 reduced herbicide rates.

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 gallons per acre (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. State 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, in aerial applications at 5 GPA, PO at 1% v/v will not provide sufficient adjuvant. For example, Pursuit and Raptor labels require oil adjuvants to be added at 1.25% v/v or 1.25 gal/100 gal water for aerial application at 5 GPA.

Some herbicide labels contain information on adjuvant rates for different spray volumes. To insure sufficient adjuvant concentration, add 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 sufficient across all water volumes.

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 usually applied 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 adjuvants. However, MSO based HSOC adjuvants enhance both glyphosate and the lipophilic herbicide. MSO based HSOC adjuvants can enhance lipophilic herbicides more than PO based HSOC, MSO and PO adjuvants.

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. A theory has long been postulated that acidifying the spray solution results in greater absorption of weak-acid-type herbicides. pH-reducing adjuvants (water conditioners/AMS-replacement) were developed under this belief. However, low pH is not essential to optimize herbicide absorption.

Many herbicides are formulated as various salts, which are absorbed as readily as the acid. 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 130) 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 and can prevent herbicide antagonism with 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 the same level of herbicide enhancement as AMS.

A6. SPRAY CARRIER WATER QUALITY

Minerals, clay, and organic matter in spray carrier water can reduce the effectiveness of herbicides. Clay inactivates paraquat, diquat, 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 (Group 1, 2, 4, 6, 9, 10, 14, 19, and 27). Cations antagonize weak acid herbicides by binding form salts (e.g. glyphosate-Ca) that are not readily absorbed by plants. The antagonism is related to the salt concentration.

ND water often contains a combination of sodium, calcium, magnesium, and iron and these cations generally are additive in the antagonism of herbicides. Water in ND, SD, and MT is often high in sodium bicarbonate which does not normally occur in other areas of the U.S. Calcium levels above 150 ppm and sodium bicarbonate levels above 300 ppm in spray water can reduce weed control in all situations. Water with 1600 ppm sodium bicarbonate can occur in ND, but total hardness levels can exceed 2,500 ppm.

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 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 especially in those that accumulate salts on or in leaf tissue (lambsquarters, velvetleaf, and sunflower).

AMS enhances phytotoxicity and overcomes salt antagonism for weak-acid herbicides formulated as a salt (listed above). 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 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. 28% UAN does not contain sulfate and does not condition water by precipitating cationscalcium 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 more than 4 lb/100 gal may be required to fully optimize herbicides. Use at least 1 lb/A of AMS when spray volume is more than 12 gpa. The amount of AMS needed to overcome antagonistic ions can be determined as follows: Lbs AMS/100 gal = (0.002 X ppm K) + (0.005 X ppm Na) + (0.009 X ppm Ca) + (0.014 X ppm Mg) + (0.042 X ppm Fe). This does not account for antagonistic minerals on or in the leaf tissue in species like lambsquarters, sunflower, and velvetleaf which may require additional AMS.

Commercial liquid solutions of AMS contain ~3.4 lbs of AMS per gallon. For 8.5 lbs of AMS/100 gallons of water add 2.5 gallons of liquid AMS solution. Generally, 4 gal of 28% UAN/100 gal of spray is adequate. AMS or 28% UAN does not preclude the need for an oil adjuvant with lipophilic herbicides. AMS and 28% UAN enhance herbicide control of most weeds even without antagonistic salts. Nitrogen fertilizer/surfactant blends may enhance weed control of most herbicides formulated as a salt.

The analysis may report salt levels in ppm or grains. To convert from grains to ppm, multiply by 17 (Example: 10 grains calcium X 17 = 170 ppm calcium). AMS at 2% (17 lb/100 gallons water) will overcome antagonism from the highest calcium and/or sodium concentrations in water. However, AMS at 4 lb/100 gal is adequate for most water sources. Iron is the most antagonistic to many herbicides but not abundant in water.

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 also called AMS replacement adjuvants. Pesticide applicators prefer the convenience of low use rate water conditioners, but performance is not equal to AMS. Glyphosate plus commercial water conditioner products that included AMS at the equivalent rate of 2.5% v/v can give similar control to 8.5 lbs/100 gal AMS. Commercial water conditioners that do not provide an equivalent amount of AMS 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 have been made to enhance herbicide activity, and negate the effects 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. Generally, AAR adjuvants applied with glyphosate in 1000 ppm hard water (Ca and Mg) gave similar weed control as when applied in distilled water supporting the theory of non-binding herbicide molecules when pH is below the pKa of the herbicide.

Low spray volumes (5 to 10 gpa) have been equally or more effective than higher spray volumes for many herbicides. Low spray volume increases efficacy of most systemic POST herbicides because it reduces the ratio of antagonistic cations to herbicide molecules in the spray solution. Low spray volumes also increases efficacy because of higher herbicide concentration in the spray deposit (NDSU Pile Theory). Contact herbicides (Group 6, 10, 14, and 22) 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 most POST herbicides. Limited research is available about efficacy based on droplet size although will become important as regulation requires larger droplet size to mitigate drift from small droplets.

A7. SPRAY AND VAPOR DRIFT
Risk of off-target herbicide movement and injury to non-target plants depends on the susceptibility of the plant to the applied herbicide. 2,4-D, MCPA, dicamba, glyphosate, and ALS herbicides have the greatest potential for damaging non-target plants.

Wind velocity and direction: Apply when wind direction is away from susceptible plants, during low wind speed, and in the absence of temperature inversions.

Boom height: Adjust boom as close to the target as possible while maintaining uniform spray coverage. Choose nozzles with a wide angle as opposed to narrow angle nozzles.

Spray shields: Cones around nozzles reduce drift by 25 to 50% and spray shields that enclose the entire boom reduce drift by 50 to 85%. Spray shields should not be used as a substitute for other drift control techniques but as a supplement to drift reduction.

Drift control: Reduce drift by increasing droplet size, reducing spray pressure, using drift reduction nozzles, adding drift reducing additives that do not increase spray viscosity, and orienting nozzles rearward on aircraft.

Drift-reducing nozzles: Sprayer nozzles designed to reduce spray drift increase spray droplet size and reduce the number of small droplets (fines). Two primary types of drift-reducing nozzles have pre-orifice and air-induction (venturi) designs.

Herbicide formulation: Some herbicides have been formulated to reduce drift. Amine formulated herbicides are less volatile than ester formulations. 2,4-D is formulated as an acid, ester, and various amine salt (e.g. dimethyl amine (dma)). 2,4-D has been formulated as a choline salt for use in Enlist soybean and is the least volatile formulation. Likewise, dicamba has been formulated as a dma salt (Banvel) and a comparatively less volatile diglycol amine (dga) salt (Clarity). Dicamba has been formulated as a bis(3-aminopropyl)methylamine (bapma) salt for use in RU Xtend soybean and is the least volatile formulation.

2,4-D resistant (Enlist) soybean and dicamba resistant (RU Xtend) soybean have been developed with Best Management Practices (BMP) to reduce risk of off-target movement. These include course to ultra coarse droplet size, buffer zones to susceptible plants, low volatile herbicide formulations, low boom height, and wind speed between 3 and 10 mph. Use only low volatile herbicide formulations that have been registered on each crop technology. Soybean is approximately 100 times more susceptible to dicamba than 2,4-D. Off-target movement as well as proper tank clean-out are important factors to consider for soybean safety.

Do not use AMS with any formulation of dicamba. Ammonium significantly increases the volatility of dicamba and reduces the effect of low-volatile DGA and BAPMA formulations of dicamba.

A proportion of the spray volume will be deposited on the soil surface. Unabsorbed dicamba on plant tissue or on the soil surface can volatilize as temperatures increases and after dew or small rain events solubilize dicamba crystals. Multiple volatilization events can occur several days and weeks after application.

Refer to the following web sites for additional information:
http://www.ag.ndsu.edu/smallgrains/presentations/2013-best-of-the-best-in-wheat-and-soybean/robinson

http://www.ag.ndsu.edu/publications/landing-pages/crops/air-temperature-inversions-ae-1705

A8. SPRAYER CLEANOUT
Herbicides may adsorb to the spray tank, hoses, nozzles, screens, and filters requiring thorough cleaning. Adsorbed herbicide may remain tightly adsorbed in sprayers through water rinsing and even through several tank-loads of other herbicides. Through subsequent sprayer applications including an oil adjuvant, nitrogen solution, or basic pH blend adjuvant may cause the herbicide to desorb, disperse into the spray solution, and damage susceptible crops. Highly active herbicide residues that persist in sprayers and cause crop injury include dicamba and ALS herbicides. Herbicides attached to all tank and sprayer components must be desorbed and the residue removed in a cleaning process. Sprayer cleanout procedures are given on herbicide labels and should be followed. The following procedure illustrating a thorough sprayer cleanup procedure is effective for most herbicides:

Step 1. Drain tank and rinse tank with clean water. Spray rinse water through the spray boom for at least 5 minutes.
Step 2. Fill the sprayer tank with clean water and label identified cleaning solution. Agitate for 15 minutes.
Step 3. Allow solution to set for 8 hours.
Step 4. Spray the cleaning solution through the booms.
Step 5. Clean nozzles, screens, and filters. Rinse the sprayer to with water and spray rinsate through the booms.

Common types of cleaning solutions are chlorine bleach (lowers pH), ammonia (increases pH), and commercially formulated tank cleaners. Never mix chlorine bleach and ammonia as a dangerous gas will be released. Read herbicide label for recommended tank cleaning solutions and procedures.

SPRAYER CLEANING SOLUTIONS FOR HERBICIDES:
Water: Extreme, Glyphosate, Lightning, Raptor, SG formulations.
Bleach: Laudis.
Ammonia or commercial tank cleaner + water:
2,4-D, Assure II, Basagran*, Bromoxynil*, Cadet, Callisto, Cobra, Dicamba, Extreme, FirstRate, Fusilade DX, Gramoxone*, Harmony DF*, Harness*, Hornet, Metolachlor*, Metsulfuron*, Paraquat*, Permit, Prowl*, Pursuit, Python, Raptor, Reflex, Rimsulfuron*, Resource, Select*, Stinger*, Surpass*, Targa*, Thifensulfuron, Tribenuron*, Treflan*, Ultra Blazer, and Valor.
Detergent or commercial tank cleaner + water:
Aim, Atrazine*, Clarity*, Flexstar, Liberty 280, Metribuzin*, Poast, and Status.

A9. MIXING INSTRUCTIONS:
Some herbicide labels list a specific mixing sequence. Formulation codes follow the categories in parenthesis. In absence of specific directions follow adding pesticide formulations to a tank partially filled with water follows the **A.P.P.L.E.S.** method:
Agitate
Powders soluble (dry fertilizers, SG, SP)
Powders dry (DF, WDG, WP)
Liquid flowables and suspensions (ASC, F, ME, SC, SE)
Emulsifiable concentrates (EC, EW, OD)
Solutions (S, SL)
Each ingredient must be uniformly mixed before adding the next component, e.g., a soluble powder must be completely dissolved before adding the next component. Adjuvants are added in the same sequence as pesticides, e.g., ammonium sulfate is a soluble powder, oil adjuvants are emulsifiable concentrates; and most surfactants are solutions. Within each group, usually add the pesticide before the adjuvant, e.g., a soluble-powder pesticide before ammonium sulfate.

A10. WICK APPLICATION

Weed control programs may leave tall weeds that are above the crop canopy. The crop may be beyond the stage of POST herbicide timing with no effective chemical options. Wick application with glyphosate at a 25 to 50% solution will control most annual weeds and suppress perennial weeds. Wick applicators are commercially available or instructions for building a wick applicator can be found on the web.

Add NIS at 0.5 to 1% to all glyphosate mixtures. Position the applicator above the crop canopy. Keep absorbate material moist but not saturated to dripping. Travel at a speed to sufficient to moisten weed foliage and avoid spatter. Drops from the wick or dislodged from weeds "whipping" back from the application bar will cause crop death or severe injury. Quackgrass, kochia, redroot pigweed, and soybean can exude glyphosate through roots, and kill susceptible plants/crops through root exchange. Wick application in non-crop and cover crops may control many species. Tall broadleaf and grass weeds can be controlled leaving low canopy turnip, radishes and other broadleaf cover crop species. Use only registered glyphosate formulations.

A11. BACKPACK SPRAYER CALIBRATION

No-Math Version:

Step 1. Mark a calibration plot 18.5 foot wide X 18.5 feet long.
Step 2. Spray the plot uniformly with water while recording the number of seconds required to spray the plot.
Step 3. Spray into a bucket for the same number of seconds.
Step 4. Measure the collected volume of water in fluid ounces.
Step 5. The number of ounces collected equals the number of gallons per acre the sprayer is delivering.

Hand-held Sprayers:

Spray coverage should be uniform and the foliage of target plants should be wet but not to the amount of spray solution run-off.
Hand-held sprayers should be calibrated by:
1) spraying a known area using water following a standard, reproducible procedure
2) measuring the amount of water applied
3) calculating gallons per acre (gpa).

For example, 0.75 gallon on 500 sq ft is the same as 65 gallons per acre: 43,560 sq ft per acre / 500 sq ft x 0.75 gallon = 65 gpa.
The desired rate in lb/A or pt/A can be used to calculate the amount of herbicide to add to the spray solution.
If 3 pt/A is desired: 3 pt/A / 65 gpa = 0.046 pt or 0.73 fl oz or 1.5 tbsp/gal of spray solution (16 fl oz = 1 pt, 2 Tbsp = 1 fl oz).

Assume a spray volume of 50 to 70 gpa when calibration is not performed and spray does not run off plant leaves. Actual volume applied can vary with the type of sprayer, spray pressure, and technique of the applicator, so calibration is strongly encouraged.

Some herbicide labels specify a percent solution for use in hand-held sprayers. The following chart provides mixing instructions to obtain solutions of varying percent concentrations on a volume/volume basis:

Desired solution volume	% concentration of herbicide				
	0.5	1.0	1.5	2.0	5.0
gallons	Amount of herbicide to add, fl oz				
1	0.6	1.3	1.9	2.6	6.4
2	1.3	2.6	3.8	5.2	12.8
5	3.2	6.4	9.6	12.8	32.0
10	6.4	12.8	19.2	25.6	64.0
100	64.0	128.0	192.0	256.0	640.0

1 pt = 16 fl oz	16 Tbls = 1 cup
1 Tbls = 3 tsp	1 fl oz = 30 mls
1 Tbls = 15 ml	1 fl oz = 2 Tbls

A12. CALCULATING HERBICIDE MIXTURES

Boom Spraying:
Mix to calibrated rate of gallons/A output of spray unit being used.

For handgun & backpack applications:
For 50 gpa application rate unless otherwise calibrated.
2 qt/A rate=1.28 fl oz x # of gal water= fl oz of herbicide for mixture
Example: For a 3 gallon backpack: 1.28 x 3 = 3.84

1 pt/A rate=0.32 fl oz x # of gal water= fl oz of herbicide for mixture
Example: For a 3 gallon backpack: 0.32 x 3 = 1 fl oz herbicide

1 qt/A rate=0.64 fl oz x # of gal water= fl oz of herbicide for mixture
Example: For a 3 gallon backpack: 0.64 x 3 = 2 fl oz herbicide

2,4-D
1 qt/A rate = 0.64 fl oz/gal water; 2 qt/A rate = 1.28 fl oz/gal water
3 gallon backpack: 2 fl oz (1 qt/A rate) / 4 fl oz (2 qt/A rate)
15 gallon sprayer: 9.5 fl oz (1 qt/A rate) / 19 fl oz (2 qt/A rate)
Pro-rate herbicide rate for different spray volumes.

Curtail (clopyralid + 2,4-D) or **Redeem/Garlon** (triclopyr)
2 qt/A rate = 1.28 fl oz/gal water
3 gallon backpack: 4 fl oz
15 gallon sprayer: 19 fl oz
Pro-rate herbicide rate for different spray volumes.

Banvel or Clarity (dicamba)
1 pt/A rate = 0.32 fl oz/gal water, 1qt/A rate = 0.64 fl oz/gal water
3 gallon backpack: 1 fl oz (1 pt/A rate) / 2 fl oz (1 qt/A rate)
15 gallon sprayer: 5 fl oz (1 pt/A rate) / 10 oz (1 qt/A rate)
Pro-rate herbicide rate for different spray volumes.

Milestone (aminopyralid)
4 to 6 fl oz/A rate = 0.12 fl oz/gal water
3 gallon backpack: 0.36 fl oz
15 gallon sprayer: 1.8 fl oz
Pro-rate herbicide rate for different spray volumes.

Escort (metsulfuron) or **Telar** (chlorsulfuron)
2 to 3 oz DF/A = 0.33 oz DF/gal water
3 gallon backpack: 1 oz DF + 0.5% v/v NIS
10 gallon sprayer: 3.2 oz DF + 0.5% v/v NIS
Pro-rate herbicide rate for different spray volumes.

TORDON 22K (picloram)
1 qt/A rate = 0.64 fl oz/gal water, 2 qt/A rate = 1.25 fl oz/gal water
3 gallon backpack: 2 fl oz (1 qt/A rate): 4 fl oz (2 qt/A rate)
15 gallon sprayer: 9.5 fl oz (1 qt/A rate): 19 fl oz (2 qt/A rate)
Pro-rate herbicide rate for different spray volumes.

TORDON 22K + 2,4-D
1 pt/A Tordon 22K + 1 qt/A 2,4-D = 0.33 fl oz + 0.67 fl oz/gal water
3 gallon backpack: 2 fl oz 2,4-D + 1 fl oz Tordon 22K
15 gallon sprayer: 10 fl oz 2,4-D + 5 fl oz Tordon 22k
Pro-rate herbicide rate for different spray volumes.

Clarity/Banvel (dicamba) **+ 2,4-D**
1 pt/A dicamba + 1 qt/A 2,4-D = 0.33 fl oz + 0.67 fl oz/gal water
3 gallon backpack: 1 fl oz dicamba + 2 fl oz 2,4-D
15 gallon sprayer: 5 fl oz dicamba + 9.5 fl oz 2,4-D
Pro-rate herbicide rate for different spray volumes.

Adjuvants and Rates
Apply adjuvants 1 to 2 pt/50 gal water if recommended.
For product names and types refer to page 126.
3 gallon backpack: 1 fl oz
10 gallon sprayer: 3.2 fl oz
Pro-rate adjuvants for different spray volumes.