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WEED CONTROL GUIDE FOR SUGARBEET

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WEED COMPETITION

Sugarbeet is a low growing crop and many weeds grow taller than sugarbeet. Weeds that become taller than the crop will cause greater yield loss than weeds that do not overtop the crop canopy so yield losses in sugarbeet due to weed competition can be large. Also, weed losses from direct competition are only part of the problems that may be caused by weeds. Weeds may also a) cause harvest problems, b) reduce the quality of the harvested product, c) produce seed that increases future weed problems, d) act as co-hosts for insects and diseases, e) increase tillage needed for weed control, and f) reduce animal and human health.

Competition research conducted in eastern North Dakota and Minnesota found that a 5% loss in extractable sucrose per acre was caused by 25 redroot pigweed plants per 100 feet of row or by 30 wild oat plants per 100 feet of row averaged over 10 experiments or 11 experiments, respectively (Figure 1).

Competition research in Colorado by Ed Schweizer found that only one kochia plant in 200 feet of row would cause a 5% loss in sugarbeet yield. Weed species differ in their competitive ability with larger, taller weeds causing more loss per plant than smaller, shorter weeds. Weeds also vary in competitive ability in different environments since one environment may favor the weed more than the crop while another environment may favor the crop more than the weed. For example, redroot pigweed at a density of three plants per meter of row caused a 44% sugarbeet yield loss in one experiment in the Red River Valley, while the same density of redroot pigweed caused only a 1% yield loss in a different experiment. The more competitive redroot pigweed emerged five days before the sugarbeet with a May 10 planting date while the less competitive redroot pigweed emerged 7 days after the sugarbeet with an April 28 planting date. Also, sugarbeet with a uniform distribution of plants will be more competitive with weeds than sugarbeet having gaps in the stand. Weeds that survive herbicide treatment generally will be less competitive than weeds not treated with herbicide. All of these observations lead to the conclusion that sugarbeet yield loss can not be accurately predicted from weed density alone.

Richard Evans conducted competition research in sugarbeet in eastern North Dakota and Minnesota as his PhD thesis research at North Dakota State University. He developed equations to predict sugarbeet yield loss from redroot pigweed and wild oat competition.

1. Predictive equation for redroot pigweed.

Extractable sucrose in kg/ha = $7255 - D(159.5) + D^2(29.2) - C(147.2) - CD(16.7) + P(206.5)$

D = redroot pigweed density in plants per meter of row.

C = Average of maximum and minimum daily soil temperatures for 7 days in centigrade taken 10 cm under grass sod.

P = Total precipitation for 7 days in cm.

All measurements should be taken during the fourth week after planting.

2. Predictive equation for wild oat.

Extractable sucrose in kg/ha = $7051 - D(412.7) + D^2(20.9) - C(129.3) + CD(5.6) + P(142.8)$

D = wild oat density in plants per meter of row.

C = Average of maximum and minimum daily soil temperatures for 7 days in centigrade taken 10 cm under grass sod.

P = Total precipitation for 7 days in cm.

The equations must be worked twice to obtain an estimate of the yield loss that would be caused by weed competition. Use the equations once assuming zero weeds and once using the actual weed population. The difference between the two yield estimates is the estimated loss from weed competition. Calculate a percentage loss and then apply this percentage to the estimated potential yield of the field in question.

Weeds should be controlled within four weeks after sugarbeet emergence in order to avoid yield loss from weed competition. These equations were developed to be used early in the growing season, i.e. four weeks after planting, to assist with weed control decisions that must be made by four weeks after sugarbeet emergence. The environmental conditions the remainder of the growing season can have a large influence on relative weed competition and predictive equations that include environmental measurements two months or more into the growing season would be more accurate. However, weed control decisions must be made early so a useful predictive equation only can utilize information available in the early part of the season. In this research, using soil temperatures and precipitation for six weeks after planting in the equations did not improve the ability to predict yield loss as compared to using soil temperatures and precipitation only from the fourth week after planting.

The equations were developed using the following assumptions:

1. Weeds will be controlled within four weeks after sugarbeet emergence.

2. Sugarbeet populations are adequate and uniformly spaced.

3. The weeds are not injured by herbicides.

4. No late germinating weeds become established after weed densities are determined.

5. Weed density will be 9 plants per meter of row or less.

The equations will not provide an exact estimate of sugarbeet yield loss for all situations because many variables (such as environment for the rest of the growing season) are not included in the equations and because the listed assumptions will not be true for all fields. However, the equations will give a more accurate estimate of sugarbeet yield loss from redroot pigweed and wild oat competition than from weed density alone. Figure 1 provides yield loss data averaged over several experiments conducted in eastern North Dakota and Minnesota for reference purposes but please remember that the relative competitive ability of the weeds varied considerably from experiment to experiment.

Sugarbeet growers should and usually do consider that a) sugarbeet is a high-value crop, b) weeds can cause severe sugarbeet yield loss, c) weeds produce seeds that cause future problems and d) weeds cause losses and problems not directly related to competition. After due consideration, sugarbeet growers can not be faulted for concluding that the only good weed is a dead weed. Most sugarbeet growers are willing to spend extensive time and resources attempting to obtain total weed control. Every situation is different but often total weed control can be justified, even if the cost of control of the last few weeds may be greater than the value of the yield losses that would be caused by the weeds. This is especially true in fields with low weed seed densities where a few weeds producing seed will significantly increase future weed problems. Control of the last few weeds is harder to justify in a field with a large existing populations of weed seed although near total weed control is needed in order to significantly reduce the levels of weed seed in the soil.

THE WEED CONTROL SUGGESTIONS are based on Federal label clearances and on information obtained from Agricultural Experiment Stations and the Research Report of the North Central Weed Science Society. CAUTION: The weed control suggestions in this guide are based on the assumption that all herbicides mentioned in this guide have and will continue to have a registered label with the Environmental Protection Agency. Herbicide labels should be checked for registered uses on sugarbeet prior to application. Portions of this section are taken from the North Dakota State University Agricultural Weed Control Guide, Circular W-253 so some non-sugarbeet herbicides are included in the text.

USE CHEMICALS ONLY AS RECOMMENDED ON THE LABEL.

RATES ARE BASED on broadcast application and are expressed as active ingredient or acid equivalent, and as the amount of commercial product. Commercial formulations of the same herbicide may vary in amount of active ingredient. For example, Eptam is available in a liquid formulation which has seven pounds of active ingredient per gallon or in a granular formulation which has 20% active ingredient. A desired application rate of 2 lb/A would require 2.3 pints/A of the liquid formulation or 10 lb/A of the granules.

RAINFALL shortly after application often reduces weed control from post-emergence applications because the herbicide is washed off the leaves before absorption is complete. Herbicides vary in rate of absorption and in ease of being washed from leaves and therefore vary in response to rainfall. The amount and intensity of rainfall also influence the washing of herbicides from leaves. The approximate time between application and rainfall needed for maximum weed control from several herbicides follows: Assure II--1 hour; Betamix*--6 hours; Betanex*--6 hours; Progress*--6 hours; Roundup--6 hours; Prism/Select --1 hour; Stinger*--6 hours; Poast--1 hour; UpBeet--6 hours.
*Or generic equivalent

SPRAY AND VAPOR DRIFT

Movement of herbicides off target is a problem in North Dakota each year as herbicides move from target fields into nontarget areas containing crops or other plant species susceptible to the herbicide. Spray drift and injury to plants are affected by several factors.

a) Wind velocity and direction: To minimize spray drift injury, wind direction should be away from susceptible plants during herbicide application. The wind velocity should be less than 10 miles per hour. However, drift can occur even with lower wind velocities, especially when air is vertically stable. Normally, air near the soil surface is warmer than higher air. Warm air rises and cold air sinks which causes vertical mixing of air and dissipation of spray droplets. Vertically stable air (temperature inversion) occurs when air near the soil surface is cooler or similar in temperature to higher air. Small spray droplets can be suspended in stable air, move laterally in a light wind, and impact plants two miles or more downwind. Herbicide application should be avoided when vertically stable air conditions occur. These conditions can be identified by observing smoke bombs or dust from a gravel road. Fog also would indicate vertically stable air.

*Or generic equivalent

b) Distance between nozzle and target (boom height): droplets should be released as close to the target as possible while maintaining uniform spray coverage. Less distance means less time to fall and therefore less potential for drift to occur.

c) Herbicide formulation: All herbicides can drift as spray droplets but some herbicides are sufficiently volatile to cause plant injury from vapor or fume drift. Herbicide volatility and consequent risk of damage to susceptible plants increases with increasing temperature. The so-called high volatile esters of 2,4-D or MCPA may produce damaging vapors at temperatures as low 40 F while low volatile esters may produce damaging vapors between 70 to 90 F. Amine formulations are essentially non-volatile even at high temperatures. Temperature on the soil surface often is several degrees warmer than air temperature. Thus an applied low volatile ester could be exposed to temperatures high enough to cause damaging vapor formation even when the air temperature is below 70 F. Dicamba (Banvel) also is volatile and can drift as droplets or vapor. Herbicide vapor drifts further and over a longer time than spray droplets. A wind blowing away from susceptible plants during application will prevent damage from droplet drift but a later wind shift towards the susceptible plants could move damaging vapors to the plants. Thus, to minimize the risk of drift injury, herbicides such as 2,4-D esters, MCPA esters, and dicamba with high potential to form damaging vapors should not be used near susceptible plants.

d) Drift control: Spray drift can be reduced by increasing droplet size since a wind will move large droplets less than small droplets. Droplet size can be increased by reducing spray pressure, increasing nozzle orifice size, special drift reduction nozzles, adjuvants that increase spray viscosity, and rearward nozzle orientation on aircraft.

e) Shields around spray nozzles or spray booms will partially protect spray droplets from wind and reduce spray drift. Small plastic cones that fit around individual nozzles reduce drift by approximately 25 to 50% and spray shields which enclose the entire boom reduce drift by approximately 50 to 85%. Spray shields give a greater reduction in drift when winds are low and droplets are relatively large. Therefore, spray shields should not be used as a substitute for other drift control techniques but should be used as a supplement to all other applicable methods of drift reduction.

f) Injury from herbicide drift: Damaging drift from other crops into sugarbeet is primarily a problem with 2,4-D, MCPA, Banvel, Clarity, Assert, Express, Glyphosate brands, Gramoxone Extra, Harmony, Harmony Extra, Liberty, Pinnacle, Pursuit, Raptor and Tordon in North Dakota and Minnesota. Other herbicides may drift but generally do not cause significant damage or are not used commonly near sugarbeet. The primary risk of damaging drift from sugarbeet to other crops with postemergence grass control herbicide drift into small grains or corn and with

UpBeet drift into small grains, corn and peas. All herbicides may drift and cause significant damage to susceptible nontarget plants, so caution must be observed with all herbicide applications.

FIELD INVESTIGATION OF CROP INJURY

Keep an open mind and investigate all possible causes and sources of the observed problem when assessing crop injury. Do not accept, without question, statements of involved persons about the cause and the source of the problem. The truth often is not obvious. Crop injury can have many causes other than herbicides and symptomology does not always provide definitive answers.

The Plant Diagnostic Laboratory at North Dakota State University will accept samples and provide an opinion on the cause of the problem. In most situations, opinions on the cause of plant injury will be based on injury symptoms.

Be aware that analysis of plant tissues or soil by a private testing laboratory may not provide a definitive answer to the cause of the problem. Each herbicide must be tested individually so testing can be very expensive if numerous herbicides are the possible cause of the problem. A positive detection of a herbicide can be useful but the detected herbicide may not have caused the symptoms. A negative test for a herbicide does not prove that the herbicide did not cause the problem since the herbicide may cause injury at levels less than the detection limit or the herbicide may have been degraded before the samples were taken.

The pattern of crop injury in a field will help identify the source of the injury. A sprayer skip in a field will be valuable in diagnosing a herbicide problem, especially if the applicator remembers the reason and the time that the skip occurred. The history of herbicide use on the field for the past 2 to 5 years should be considered. Uniform damage over the field would suggest herbicide carryover or injury from a direct application rather than drift.

Drift is nearly always worse near the source of the drift with damage becoming less as the distance becomes greater. Lessening of injury with distance may not be evident shortly after the drift has occurred but the differences should become more visible with time since the recovery of the damaged plants will be more rapid and more complete as the distance from the drift source increases. Crop injury that is associated with one or two sprayer tank loads would suggest sprayer contamination or a mistake in mixing where the wrong herbicide or too much of the correct herbicide was put in a spray tank. An aerial photograph often is very useful in identifying patterns of crop injury in a field.

The family of the herbicide that caused the injury often can be identified by the injury symptoms and the species which are not injured. Look in the affected field, in surrounding fields and between fields. The approximate date of injury can sometimes be determined by observing or learning the date that the injury first became evident. The size of plants when affected by a growth regulator herbicide can sometimes be determined by the height of the stem where malformed leaves first occur. Plants that are affected as soon as they emerge usually are being damaged by a herbicide in the soil rather than drift. Dates that injury occurred can be related to dates of herbicide application on and around the damaged field.

The direction of the source of herbicide drift can sometimes be determined by finding “drift shadows” by trees, buildings, or elevated roads. Anything that intercepts or deflects spray droplets can cause an area of undamaged plants on the downwind side of the object. The shape and direction of the “drift shadow” often will identify the direction of the drift source. The damage from spray drift sometimes moves at an angle across nearby fields with a rather distinct line between damaged and undamaged plants at the edge of the line. Placing tall stakes at the edge of this line through the damaged field will often form a line that points at the edge of the field that was the source of the spray drift. Spray droplets move with the wind. Spray droplets will only move down wind so the wind direction during application will often indicate which potential drift sources are possible and which are not possible. Some herbicides like 2, 4-D ester, MCPA ester and Banvel are volatile and a wind shift after application may cause vapor drift in a different direction than the drift of spray droplets. Spray droplets only move in the direction that the wind is moving.

Some sources of unintended herbicide exposure are very difficult to identify. For example, drift or an accidental and unreported spraying of a long residual herbicide on a tolerant crop would have no effect that year but the residual in the soil the next year could damage a susceptible crop. Another example is soil movement due to wind or water erosion which causes a damaging level of herbicide to move with soil.

An obvious question is whether to destroy or keep the damaged field. A general rule of thumb is that damage from drift is not a bad as the initial appearance would suggest and a decision should not be made within one week of the drift. With growth regulator herbicides, about 10 days is needed before surviving plants will begin to produce new leaves. Evaluation of the level of injury from growth regulator herbicides should not be attempted prior to 10 days after exposure. With ALS inhibitor herbicides and glyphosate, the less damaged plants begin to visibly recover and separate themselves from plants with more injury about two weeks after exposure. Rapid conclusions can lead to bad decisions with spray drift.

Everyone involved will want to know how much yield loss will be caused by the herbicide damage. Accurate visual estimation of yield loss from a non-lethal exposure to herbicide is not possible. Some means of collecting meaningful yield comparisons is essential in obtaining an accurate estimate of yield loss. When part of a field is injured and part is not injured, yield in the uninjured portion of the field can be compared to yield in the injured portion. Hand harvesting at several places, harvesters with yield monitors or harvesting and weighing yield from strips through the field all could be used. Usually, splitting the field into six or eight strips or pieces is better than comparing one half of the field to the other half of the field.

Obtaining accurate yield data is very difficult when the entire field is damaged. Comparisons to nearby fields can be done but variability among fields is great. Use of the average yield of several nearby fields also could be considered.

SPRAYER CLEANOUT

Crop injury may occur from a contaminated sprayer. The risk of damage is greatest when spraying crops highly susceptible to the previous herbicide and when the previous herbicide is very active in small amounts. Rinsing with water is not adequate to remove all herbicides. Some herbicides have remained tightly adsorbed in sprayers through water rinsing and even through several tank-loads of other herbicides. Then when a tank-load of solution including an oil adjuvant or nitrogen solution was put in the sprayer, the herbicide was desorbed, moved into the spray solution, and damaged susceptible crops. Highly active herbicides that have been difficult to wash from sprayers and have caused crop injury include dicamba (Banvel) and the ALS inhibitor herbicides (Harmony Extra, Express, Pinnacle, Pursuit, Ally, Accent, Amber, Beacon and other related herbicides).

Herbicides which are difficult to remove from sprayers are thought to be attaching to residues remaining from spray solutions that deposit in a sprayer. The herbicide must be desorbed from the residue or the residue removed in a cleaning process so the herbicide can be removed from the sprayer. Sprayer cleanout procedures are given on many herbicide labels and the procedure on the label should be followed for specific herbicides. The following procedure is given as an illustration of a thorough sprayer cleanup procedure that would be effective for most herbicides.

Step 1. Drain tank and thoroughly rinse interior surfaces of tank with clean water. Spray rinse water through the spray boom. Sufficient rinse water should be used for 5 minutes or more of spraying through the boom.

Step 2. Fill the sprayer tank with clean water and add a cleaning solution (many labels provide recommended cleaning solutions). Fill the boom, hoses, and nozzles and allow the agitator to operate for 15 minutes.

Step 3. Allow the sprayer to sit for 8 hours while full of cleaning solution. The cleaning solution should stay in the sprayer for 8 hours so that the herbicide can be fully desorbed from the residues inside the sprayer.

Step 4. Spray the cleaning solution out through the booms.

Step 5. Remove nozzles, screens, and filters and clean thoroughly. Rinse the sprayer to remove cleaning solution and spray rinsate through the booms.

Common types of cleaning solutions are chlorine bleach, ammonia, and commercially formulated tank cleaners. Chlorine lowers the pH of the solution which speeds the degradation of some herbicides. Ammonia increases the pH of the solution which increases the solubility of some herbicides. Commercially formulated tank cleaners generally raise pH and act as detergents to assist in removal of herbicides.

Read the herbicide label for recommended tank cleaning solutions and procedures. **WARNING: Never mix chlorine bleach and ammonia as a dangerous and irritating gas will be released.**

Sprayers should be cleaned as soon as possible after use to prevent the deposit of dried spray residues. If a sprayer will remain empty over night without cleaning, fill the tank with water to prevent dried spray deposits from forming. A sprayer kept clean is essential to prevention of damage from herbicide contamination.

GROUNDWATER CONTAMINATION

Groundwater contamination with pesticides is a growing public concern. Pesticides can contaminate groundwater by movement from small areas contaminated through factors such as spills, rinsing spray cans, rinsing tanks, and back-siphoning, (point source) or by movement of pesticides used according to their label on relatively large land areas (non-point source).

Point source contamination probably accounts for most groundwater contamination problems and can be minimized by using the following precautions:

1. Mix pesticides away from wells and other water sources maintaining at least a 150-ft buffer between water source and sprayer.

2. Prevent back-siphoning into the well by using an anti- backflow check valve, or maintaining an air gap between the end of the fill hose and the surface water level in the sprayer.

3. Triple rinse pesticide containers and add the rinsate to the spray tank.

4. Minimize extra spray solution by mixing only the quantity of spray required. Apply extra spray solution to fallow land or to a labeled crop following label recommendations.

5. Properly seal active and abandoned wells.

Non-point source groundwater contamination occurs over a broad area as a result of labeled pesticide uses. Groundwater contamination can occur as the chemical is leached by water through the soil profile. The potential for non-point source pollution of groundwater with a herbicide depends on soil type, irrigation or precipitation, depth of groundwater, herbicide application rate and frequency, and herbicide mobility. Non-point pollution of groundwater can be minimized by using the following practices:

1. Select herbicides with short residual and limited mobility in soil.

2. Properly calibrate sprayers to prevent application of excessive rates of herbicide.

3. Apply herbicides only when necessary and follow all herbicide label recommendations and guidelines.

4. Use good agronomic practices that minimize weed competition and maximize herbicide performance such as crop rotation, herbicide rotation, timely cultivation, and cover crops.

5. Use band application rather than broadcast application to reduce the amount of pesticide used per acre.

6. Do not apply herbicides near open water.

7. Avoid use of persistent and/or mobile herbicides on soil with a shallow water table.

WEED RESISTANCE TO HERBICIDES

Herbicide resistance (R) occurs with repeated use of a specific herbicide for control of weed species that contain some plants in the population with a resistant gene. The resistant type will increase with each use of the herbicide because the gene pool in the field will shift from susceptible to resistant. This shift is permanent assuming that the resistant type plants are equally "fit" in the cropping environment. Use of one herbicide from a group with one mode of action may give resistance to other herbicides with the same mode of action. However, weed specificity for resistance is known for different herbicides within a mode of action group. For example, wild oat resistant to Hoelon is often but not always controlled by other herbicides with similar chemistry and by Poast or Select of different chemistry, but all with the same mode of action.

Weed plants with a wide genetic diversity develop resistance rapidly, especially for herbicides with one site of action. Kochia developed resistance rapidly in North Dakota to SU herbicides because of kochia diversity and the SU single site of action. Kochia plants vary in resistance to various SUs, but in general kochia plants rapidly develop resistance to the individual SU herbicides. Imidazolinone (Imi) herbicides are in the same action group (ALS inhibitors) as SUs, but weeds do not necessarily have cross resistance. For example, nightshade spp exhibit natural tolerance to SUs, but only recently developed resistance to Imi herbicides. Tables that follow list herbicides within various mode of action groups as a guide for possible cross resistance.

Types of Resistance

Altered site of action - ALS inhibitors and other herbicides act on one specific site in a plant selecting for resistant plants in diverse plant species. Herbicides that affect one enzyme in a plant usually are prone to altered site of action resistance.

Altered herbicide metabolism - Plants prevent herbicide toxicity by rapid degradation. Corn degrades atrazine by this mechanism. This type of resistance is more complex than altered site of action type resistance because it involves several plant processes. Plants with altered metabolism resistance can degrade several unrelated herbicides of different modes of action through multiple genes controlling metabolic processes.

Plants having altered site of action resistance are often not affected by herbicide concentration, but plants having altered metabolism resistance are affected by herbicide rate. As rate increases, the plant eventually reaches a point where it cannot degrade the herbicide faster than the herbicide is absorbed.

Cross and Multiple Resistance

A plant with a single resistance mechanism that enables survival when treated with different chemicals is cross resistant to those chemicals. Resistance that develops to one sulfonylurea (SU) often confers cross resistance to others. The same is generally true with imidazolinones. In some cases, resistance that develops to a SU confers cross resistance to imidazolinones.

A plant with two or more resistance mechanisms that survives treatment with different chemicals has multiple resistance. Kochia may be resistant to SUs and atrazine. Different resistance mechanisms are involved; therefore, a kochia plant that withstands treatment with SUs and atrazine has multiple resistance.

Herbicide resistant weed species in ND:
1. Green foxtail to the DNA herbicides.
2. Wild oat to ACCase inhibitor herbicides.
3. Wild oat to ALS (Assert) herbicides.
4. Wild oat resistant to Avenge
5. Wild oat resistant to Far-Go
6. Kochia to ALS herbicides.
7. Kochia to 2,4-D and dicamba.
8. Kochia to atrazine
9. Redroot pigweed to IMI herbicides.

10. Waterhemp to ALS herbicides.
11. Wild mustard to ALS herbicides.
12. Eastern black nightshade to imidazolinone herbicides.
13. Marshelder resistance to ALS herbicides (not documented)
14. C. ragweed resistance to ALS herbicides (not documented)

Trifluralin (DNA) resistant green foxtail is found in areas of ND where trifluralin is used consecutively in small grain crops, row crops, and fallow. Continuous small grains, small grain/fallow, or small grain/sunflower rotations allows continuous DNA use. Also, trifluralin is usually applied at high rates in sunflower and residue may partially control green foxtail in the small grain crop planted the next year. Continuous use of and residue from high DNA rates increase selection pressure for DNA resistant green foxtail.

ACCase resistant wild oat is found within ND and MN. Hoelon and fenoxaprop (Puma, Dakota, Tiller, and Cheyenne) resistance has been documented in nearly every county in ND. Resistance to Achieve and Discover has also been documented. Resistance has varied from complete resistance to recovery from near death and all possible responses in between. Wild oat resistance to Assure II and Poast has been documented in the RRV of ND and MN. Wild oat resistance to Select has not been documented in ND or MN.

Assert (ALS) resistant wild oat has been documented in MN and eastern ND. Wild oat biotypes resistant to Assert may or may not be resistant to one or more of the other grass-killing ALS inhibiting herbicides.

ALS resistant kochia can be found across ND and developed originally in northern, western, and southwestern regions where Glean and SU herbicides were used extensively. Wide spread use of SUs in small grains, Pursuit in soybean and dry beans, Accent in corn, and UpBeet in sugarbeet have caused ALS resistant kochia to increase in the eastern ND.

Plant growth regulator (PGR) resistant kochia was discovered in a survey conducted in 1993. Resistance was evaluated primarily against dicamba. Some kochia types were found resistant up to 0.5 pt/A of dicamba. Even though some plants survived, they were reduced in growth and may not compete well with vigorous growing crops. Generally, all kochia biotypes tested were tolerant to 2,4-D and MCPA.

IMI resistant redroot pigweed has been documented at one location in Cass county. Continued use of Pursuit and Raptor selected for this resistant biotype.

ALS resistant waterhemp has been documented in the RRV of ND and MN. Waterhemp commonly infests the midwest and plains states. Continued use of Accent in corn, Pursuit and Raptor in soybean and dry bean and SUs in small grains have selected for this resistant biotype.

ALS resistant wild mustard has been documented in the RRV of MN and ND. This is the first documented case of wild mustard resistance to ALS herbicides in the U.S. Continued use of Accent in corn, Pursuit and Raptor in soybean and dry bean and SUs in small grains have selected for this resistant biotype.

ALS resistant eastern black nightshade has been documented in the RRV of ND/MN and in WI. This is the first documented case of eastern black nightshade resistance to ALS herbicides in the U.S. Continued use of Pursuit and Raptor in soybean and dry bean have selected for the resistant biotype.

Other weeds that have developed resistance to herbicides in other areas of the nation are listed below. This shows that resistance to these weed species could also occur in ND:

ALS Mode of action:
Green foxtail, yellow foxtail, giant foxtail, sunflower, common cocklebur, and giant ragweed.
ACCase Mode of Action:
Green foxtail and giant foxtail.
Growth regulator mode of action:
Wild mustard
Triazines:
Kochia

Genetically engineered crops resistant to glyphosate and Liberty are now available. Glyphosate and Liberty can be used to control weeds resistant to all other herbicides. However, heavy selection pressure from these herbicides may cause resistant biotypes to occur. Weeds expressing some natural tolerance to glyphosate are quackgrass, wild buckwheat, nutsedge, nightshade, smartweed, kochia, dandelion, horseweed (marestail), common mallow, and velvetleaf. Weeds expressing some natural tolerance to Liberty include lambsquarters and yellow nutsedge.

For a comprehensive list of resistant weeds in North Dakota, U.S., and world see web site: www.weedscience.com

STRATEGIES TO MINIMIZE HERBICIDE RESISTANT WEEDS
The following strategies should be effective in reducing problems with herbicide tolerant and resistant weed biotypes, but no single strategy is likely to be totally effective.
General Guidelines:
1. Scout fields regularly and identify weeds that escape herbicide treatment. Monitor changes in weed populations and restrict spread of potentially resistant weeds that match the field history and herbicide pattern.

2. Rotate herbicides with different modes of action in consecutive years.

3. Apply herbicides in tank-mix, prepackage or sequential mixtures that include multiple modes of action. Two or more herbicides in the tank-mix must have substantial activity against potentially resistant weeds. Most commercial premixes do not contain herbicides that target the same weed species.

4. Rotate crops, particularly those with different life cycles, e.g., winter annual crops (winter wheat), perennial crops (alfalfa), summer annual (spring wheat, corn or beans). Do not use herbicides with the same mode of action in the different crops unless other effective control practices are also included.

Method 1. Continued Herbicide Use - This approach allows for the use of the preferred treatment, but will require earlier close monitoring for resistance.

The best resistance management strategy is early identification of resistant plants and then complete control (eradication) by whatever means while the infestation is small. Identification can be best accomplished with highly effective herbicide rates so that uncontrolled plants are obvious for early eradication. Elimination of the resistant plants will allow for continuous use of the herbicide.

Weed resistance to herbicides cannot be prevented, but can be delayed. Herbicide and tillage rotations will only delay resistance by the length of time that the selection pressure for a given herbicide is removed by an alternative control method. The gene pool does not revert back in absence of the original selection, except if the resistant plants are poorly fit. Fitness has not been greatly different for resistant and susceptible biotypes and should not be relied on resistant management.

There are two options relative to resistance management, one is to use the desired herbicide until resistance occurs and then change to an alternative, and the other is to rotate control methods to delay the on-set of resistance.

Herbicide Classification and Mode of Action for Resistant Weed Management

Mechanism of Action	Common Name	Herbicide Tradename	Premix Tradenames
ACC-ase Inhibitors (1)	clodinafop-P	Discover/Horizon	
	diclofop	Hoelon	
	fenoxaprop-P	Puma	Cheyenne, Dakota, Fusion, Tiller
“Fops”	fluazifop-P	Fusilade DX	Fusion
	quizalofop	Assure II	

Mechanism of Action	Common Name	Herbicide Tradename	Premix Tradenames
"Dims"	clethodim	Select/Prism	
	sethoxydim	Poast	Rezult
	tralkoxydim	Achieve	
ALS Enzyme Inhibitors (2)	imazamethabenz	Assert	
	imazamox	Raptor	
	imazapic	Plateau	
	imazapyr	Arsenal	Lightning, Sahara
Imidazolinones	imazaquin	Scepter	Backdraft, Detail, Squadron, Steel, Tri-Scept
	imazethapyr	Pursuit	Extreme, Lightning, Pursuit Plus, Resolve, Steel
Sulfonylureas	chlorimuron	Classic	Canopy XL, Reliance STS, Synchrony STS
	chlorsulfuron	Glean/Telar	Finesse
	ethametsulfuron	Muster	
	halosulfuron	Permit	
	metsulfuron	Ally/Escort	Canvas, Finesse
	nicosulfuron	Accent	Accent Gold, Basis, Basis Gold, Celebrity Plus
	oxasulfuron	Expert	
	primisulfuron	Beacon	Exceed, NorthStar, Spirit
	prosulfuron	Peak	Exceed, Spirit
	rimsulfuron	Matrix	Accent Gold, Basis Gold
	sulfometuron	Oust	
	sulfosulfuron	Maverick	
	thifensulfuron	Harmony GT, Pinnacle	Basis, Canvas, Cheyenne, Harmony Extra, Reliance, Synchrony
	triasulfuron	Amber	
	tribenuron	Express	Rave
	triflusulfuron	UpBeet	Canvas, Cheyenne, Harmony Extra
Triazolopyrimides	chloransulam	FirstRate	FrontRow
	diclosulam	StrongArm	
	flumetsulam	Python (Broadstrike)	Accent Gold, Broadstrike+Dual, Broadstrike+Treflan, FrontRow, Hornet, Scorpion III
Mechanism of Action	**Common Name**	**Herbicide Tradename**	**Premix Tradenames**
Sulfonylamino-carbonyltriazolinone	flucarbazone MKH 6561	Everest	
Root Inhibitors (DNA) (3)	benefin	Balan	Team
	ethalfluralin	Sonalan	
	oryzalin	Surflan	Rout
	pendimethalin	Prowl/Pendimax/others	Pursuit Plus, Squadron, Steel
	trifluralin	Trifluralin/Treflan/others	Broadstrike+Treflan, Buckle, Freedom, Passport, Salute, Tri-Scept
Growth Regulators (4)	2,4-D	2,4-D/others	Campaign, Crossbow, Curtail, Landmaster BW, Scorpion III, Shotgun, Starane Plus Salvo, Tiller, Weedmaster
Phenoxys	2,4-DB	Butyrac	
	MCPA	MCPA/others	Bronate, Cheyenne, Curtail M, Dakota, Starane Plus Sword, Tiller
Benzoic acids	dicamba	Banvel/Clarity/Sterling	Celebrity Plus, Distinct, Fallow Master, Marksman, NorthStar, OpTill, Rave, Resolve, Spirit, Weedmaster
Pyridines	clopyralid	Stinger/Reclaim/Transline	Accent Gold, Curtail, Curtail M, Hornet, Scorpion III
	fluroxypyr	Starane	
	picloram	Tordon 22K	
			Starane + Salvo, Starane + Sword
Quinolines	quinclorac	Paramount/Drive	
Photosystem II Inhibitors (5) (different than 6)	atrazine	Atrazine/other	Axiom AT, Basis Gold, Bicep/II/Lite, Buctril+Atrazine, Bullet, Contour, Cy-Pro AT, Degree Xtra, Extrazine II, FieldMaster, FulTime, Guardsman, Harness Xtra, Laddok, Lariat, LeadOff, Liberty ATZ, Marksman, Readymaster ATZ, Shotgun
Triazines	cyanazine	Bladex	Cy-Pro AT, Extrazine II
	simazine	Princep	Derby
Triazones	hexazinone	Velpar	
	metribuzin	Lexone/Sencor	Axiom DF, Axiom AT, Canopy, Domain, Epic, Salute, Turbo
Uracils	bromacil	Hyvar X	Krovar I, WeedBlast
	terbacil	Sinbar	
Phenyl-carbamates	desmedipham	Betanex	Betamix, Progress
	phenmedipham		Betamix, Progress

Photosystem II Inhibitors (6) (different than 5)	bromoxynil	Buctril/Broclean/Moxy	Bison, Bromac, Bronate, Buctril + Atrazine, Brozine, Moxy AT, Rezult
	bentazon	Basagran	Galaxy, Laddok, Storm
	pyridate	Tough	
Photosystem II Inhibitors (7) (diff. than 5 or 6)	diuron	Diuron/Direx/Karmex	Krovar, Sahara, WeedBlast
	linuron	Lorox, Linex, Linuron	
	tebuthiuron	Spike	
Amide	propanil	Stampede	Stampede CM
Lipid Synthesis Inhibition (8)	cycloate	Ro-Neet	
	EPTC	Eptam/Eradicane	DoublePlay
Thiocarbamates	triallate	Far-Go	Buckle
Difenzoquat	difenzoquat	Avenge	
EPSP Synthase Inhibitors (9)	glyphosate-ipa	Roundup	Backdraft, Bronco, Campaign, Extreme, FieldMaster, Landmaster BW, FallowMaster, ReadyMaster ATZ Some commercial names for glyphosate: Roundup/RT, Roundup Custom, Roundup Ultra/RT, Roundup Ultra Max, Roundup Original/RT, Rodeo, Glyphos, Glyphomax, Glyphomax Plus
	glyphosate-NH3	Roundup Ultra Dry	
	glyphosate-tms	Touchdown	
Glutamine Synthetase Inhibitors (10)	glufosinate	Liberty/Finale/Rely	Liberty ATZ
Pigment Inhibitors (13)	clomazone	Command	Commence
PPO Inhibitors (14)	acifluorfen	Blazer/Blazer Ultra/Status	Conclude, Galaxy, Scepter OT, Storm
	fomesafen	Flexstar/Reflex	Tornado, Twister
	lactofen	Cobra	Stellar
Diphenylethers	oxyfluorfen	Goal	
N-phenylthalimides	fluthiacet	Action	
	flufenpur		
	flumiclorac	Resource	Stellar
	flumioxazin	Valor	
Trizolinones	carfentrazone	Aim/Affinity	
	sulfentrazone	Authority/Spartan	Canopy XL

Mechanism of Action	Common Name	Herbicide Tradename	Premix Tradenames
Action unknown (15) Acetamides	acetochlor alachlor dimethenamid flufencact metolachlor propachlor	Harness/Surpass/ TopNotch/ Degree Lasso/others Frontier Dual/Dual II/ Magnum Ramrod__	Degree Xtra, DoublePlay, FieldMaster, FulTime, Harness Xtra Bronco, Bullet, Freedom, Lariat Detail, Guardsman, LeadOff, OpTill Axiom, Axiom AT, Domain, Epic Bicep/II/Lite, Broadstrike+Dual, Turbo Ramrod and Atrazine
Auxin Inhibitor (19)	diflufenzopyr		Distinct, Celebrity, Celebrity Plus
Photosystem I Inhibitors (22)	diquat paraquat	Diquat Gramoxone Extra/Starfire	
Carotenoid Inhibitors	isoxaflutole	Balance	Epic
(28)	mesotroine		
Cold, Hard STEEL (29)	Plow, cultivator, rotary-hoe, etc.		

Adapted from Weed Sci. Soc. of Am. (WSSA) Herbicide Classification System For Resistant Weed Management. Weed Tehchnol. 11:384-389.

PESTICIDE COMBINATIONS: The recommended sequence of addition of formulations for tank mixes is a) water, b) wettable powders or dry flowables plus agitation, c) liquid flowables, d) emulsifiable concentrates, and e) solutions. Compatibility testing as described in the herbicide + liquid fertilizer section can be used to determine if tank mixes of pesticides will form a uniform mixture in the spray tank. The effect of postemergence herbicides often is increased when applied to areas already treated with a preemergence or preplant herbicide. Combinations of certain herbicides may give better weed control than use of the individual herbicide alone. However, loss of weed control or increased crop damage may result from the use of certain other herbicides in combination. Herbicide combinations should be used with caution until experience or research has shown that the combination is effective and safe.

Sugarbeet injury is sometimes increased by applying herbicides plus other pesticides compared to the herbicides used alone or the other pesticides alone. Use of an oil adjuvant with some fungicides or insecticides may increase sugarbeet injury. Some herbicides require an oil adjuvant to be effective and combinations of herbicides plus oil plus another pesticide may cause excessive sugarbeet injury. For example, tin fungicides plus a grass control herbicide plus an oil adjuvant sometimes causes severe sugarbeet leaf burn with greater injury when application was made in high temperatures. The micro-rate (herbicides plus oil adjuvant) should not be applied in combination with tin fungicides or Quadris since severe sugarbeet injury is possible. Quadris should never be applied with an oil adjuvant. Lorsban in a spray solution acts like an oil adjuvant. Lorsban can be safely combined with the micro-rate or a grass herbicide plus oil but Lorsban should not be combined with conventional rates of Betanex, Betamix, Progress or Stinger
*Or generic equivalent
since excessive sugarbeet injury may result. Efficacy data is not available on all herbicide-pesticide combinations so use combinations with caution until experience or research has shown them to be effective and safe.

Several herbicide combinations with other pesticides have been shown to increase crop injury compared to either pesticide applied alone. For example, sugarbeet injury has increased when tin fungicides have been combined with Poast + oil or when Betamix*/Betamix* has been combined with Lorsban. Efficacy data on herbicide-pesticide mixtures are limited because of the number of potential combinations. Non-registered tank-mixtures should be used with caution until experience or research has shown that the combination is effective and safe.

Agricultural pesticides that are tank mixed are often registered for use as a mixture by the Environmental Protection Agency. Non-registered tank mixes may be applied if all pesticides in the mixture are registered by the Environmental Protection Agency on the crop being treated. However, the user must assume liability for crop injury, inadequate weed control and illegal residues if the combination is not a labeled tank mixture.

HERBICIDE-LIQUID FERTILIZER COMBINATIONS: Thorough mixing and continuous vigorous agitation are required to obtain an even application of herbicide-liquid fertilizer combinations. Some herbicide-liquid fertilizer combinations will not form a uniform mixture even with thorough agitation. Compatibility of the herbicide in the liquid fertilizer should be tested before the herbicide is added to the tank. The compatibility test may be conducted by combining small quantities of the components being mixed in the same proportions used in the spray tank. Generally, mix 1 pint of fertilizer and 2 teaspoons of the liquid herbicide. For wettable powders, mix 2 teaspoons of powder with a small quantity of water to form a slurry, and add the slurry to the fertilizer. Close the jar and shake well. Watch the mixture for several seconds and check again 30 minutes later. If the mixture does not separate, the combination is compatible. If the mixture separates or gets very thick or syrupy, do not combine for field application. Mixing ability may be improved by adding a compatibility agent such as Compex or Unite. Different batches of fertilizer may differ in their mixing properties so each should be tested separately.

HERBICIDE-DRY FERTILIZER COMBINATIONS: Many preplant incorporated herbicides are registered for impregnation on dry bulk fertilizer. Ammonium sulfate, ammonium phosphate-sulfate, diammonium phosphate, potassium chloride, superphosphate, treble superphosphate, and urea are some of the approved fertilizer materials for impregnation. Impregnated fertilizer should be applied immediately and incorporated according to label instructions. Accurate spreader calibration and uniform fertilizer distribution are essential. Consult the herbicide label for minimum amounts of fertilizer per acre and for maximum amounts of herbicide per given weight of fertilizer. Ranges of 200 to 400 lb/A of dry bulk fertilizer are recommended to maintain uniformity of herbicide application.

HERBICIDE CARRYOVER: or the persistence of phytotoxic levels of a herbicide for more than one year can be a problem with some of the herbicides used in North Dakota and Minnesota. Herbicide residues are most likely to occur following years with unusually low rainfall because chemical and microbial activity needed to degrade herbicides is limited in dry soil. Herbicides generally do not disappear from soil due to leaching. Therefore, the rate of herbicide degradation is similar with adequate rainfall or excessive rainfall. Crop damage from herbicide residues can be minimized by application of the lowest herbicide rate which will give good weed control, by using band rather than broadcast applications, and by moldboard plowing before planting the next crop. Moldboard plowing reduces phytotoxicity of some herbicides by diluting the herbicide residue in a large volume of soil and by providing untreated surface soil in which sugarbeet can germinate and begin growth.

Herbicide residues often can be detected by use of a bioassay for herbicide residue. A soil sample representative of the whole field must be obtained by sampling at many places to the depth of the tillage layer. A field which was only tilled shallowly after herbicide application the previous year should be sampled shallowly while a deep tilled field should be sampled as deep as the tillage tool was operated. Also, a sample of soil known to be free of herbicide residue must be obtained from near the treated field to serve as the untreated check. The samples should be dried and the clods broken so that the largest particles are no larger than a wheat kernel. Prepare at least two samples each of the untreated check soil and the test soil. Place the soil in pots or other containers with holes in the bottom for water drainage. The crop to be grown in the field should be used as one bioassay species. Preparing extra pots and testing a more susceptible species may be helpful in detecting residues. In each pot, plant 12 seeds of large-seeded crops like corn or soybeans, or 20 seeds of small-seeded crops like sugarbeet, cereals, or flax. Water the soil as needed for optimum germination and plant growth, but do not over-water. When the plants are about 2 inches tall, thin to about 6 large-seeded or 12 small-seeded uniform seedlings in each container. The containers should be placed in a warm place at about 70 to 75 F and in direct sunlight during the day. Observe the plants in the untreated check and test samples for 2 to 3 weeks after emergence. Some tangible measurements, such as plant height and leaf length, can be taken for evaluation, along with visual observation of abnormalities. Some herbicides, like atrazine and metribuzin, have slow developing symptoms that appear after food reserves in the seed have been depleted so symptoms may not be apparent soon after emergence. The soil should be washed from the roots to observe root growth, especially for dinitroaniline herbicides such as Sonalan, Prowl, and Trifluralin. Window bioassays do not always provide accurate information on Glean, Ally or Classic carryover.

Field Bioassay: Using typical tillage, seeding practices and timings for the particular crop, plant strips of the desired crop variety across the field previously treated with the herbicide. Plant the strips perpendicular to the direction of application. The strips should also be located so that different field conditions are encountered, including differences in soil texture, pH, and drainage. If the crop does not show visible symptoms of injury, stand reduction, or yield reduction, the field can be seeded with the test crop in the growing season following the bioassay. If visible injury, stand reduction, or yield reduction occurs, the test crop should not be seeded, and the bioassay must be repeated the next growing season. Herbicide persistence into the next growing season restricts rotational crops. The following information explains degradation herbicide chemistries that are known to carryover.

General Rules For Herbicide Breakdown

1. Herbicides are broken down in soil by microbial decomposition and chemical reactions like acid hydrolysis.

2. Soil microorganisims do not degrade herbicide molecules when herbicides are adsorbed to soil particles.

3. Greater herbicide adsorption to soil particles occurs in dry soils than in moist soils.

4. Acid hydrolysis affects primarily triazines and most sulfonylurea herbicides.

5. Chemical degradation of herbicides in soil is affected by soil pH. Acid hydrolysis nearly ceases at soil pH above 6.8.

Effect of pH on Herbicide Activity and Persistence
Negative charges on soil particles and organic matter adsorb positive charged compounds or substances. Soil pH influences

adsorption and availability of the following herbicides by determining the electrical charge of the herbicide chemistries: Imidazolinones, SU's, and Triazolopyrimidines (TPS).

Molecules become negatively (-) charged when a proton is removed or become positively (+) charged when a proton is added. Most herbicides become positively charged in acid (H+) pH conditions. Positively charged herbicide molecules are adsorbed to soil particles due to the attraction between (-) charges on soil particles and (+) charges on the herbicide molecule.

Breakdown of Imidazolinone (Imi) Herbicides:
Assert, Plateau, Pursuit, Lightning, Raptor, and Scepter.

In general, Imi herbicides leave a residue in soil for more than one year. Breakdown occurs by soil microbes rather than acid hydrolysis which is a chemical reaction. **Breakdown occurs more rapidly and herbicide activity increases as soil pH increases.** Rate of breakdown decrease in dry conditions.

Imi Herbicides are:
1. Broken down by microbes - not broken down by hydrolysis.

2. Not degredaded in anaerobic (waterlogged soil) conditions.

3. Not volatile nor photodegraded by sunlight.

4. Not leached beyond 12 inches.

5. Weakly bound to soil but strongly bound to OM.

6. Adsorbed more strongly as soil dries and through time. Sorption is reversible when soil becomes wet. Dry conditions through the year of application will cause Imi herbicide molecules to be adsorbed to soil OM and when adsorbed are NOT available for plant uptake and microbial degradation. Winter and spring precipitation reverses sorption and causes Imi molecules to be free for plant uptake and microbial breakdown. For sensitive crops like sugarbeet, the adsorption and desorption process may occur over several years causing crop injury from herbicide residues that become available each spring and summer.

7. Weakly adsorbed to soil at soil pH greater than 6.5.

8. Bound stronger to OM at soil pH below 6.5 and amount adsorption changes little from 6.5 to 8. At soil pH less than 6.5, small differences or reductions in pH (0.2 to 0.4 pH units) can **DOUBLE** amount adsorbed.

Soil pH is not uniform across fields and may fluctuate greatly. Soil pH may vary by one or even two pH units in a few feet. Crop injury from chemical residue may be expressed in high pH areas of the field. High soil pH can cause crop injury that does not fit a pattern and it can be used to explain injury situations that do not match sprayer application or misapplication.

At soil pH between 6.5 to 8, Imi herbicides are (-) charged molecules are NOT adsorbed by OM that also have (-) charges. Therefore, molecules in a free state are available for plant uptake and microbial degradation.

In summary, Imi herbicide adsorption increases as OM matter increases and as soil pH decreases. All factors increasing microbial activity also increase Imi herbicide degradation (warm, moist soils). Degradation increases in soils with pH above 6.5 because herbicide molecules are not absorbed and are in a free state in soil solution for plant uptake and microbial breakdown.

Breakdown of Sulfonylurea (SU) Herbicides:
Accent, Ally, Amber, Beacon, Classic, Escort, Glean, Maverick, Muster, Peak, and premixes containing active ingredients of the above herbicides: Accent Gold, Basis, Basis Gold, Canvas, Celebrity Plus, Exceed, Finesse, Rave, Spirit, Steadfast and Synchrony.

Short residual herbicides of Express, Harmony Extra, Harmony GT, UpBeet are rapidly broken down by soil microbes
In general, most SU herbicides leave residue in soil for more than one year and in some cases for several years. Breakdown occurs primarily by hydrolysis, a chemical reaction, rather than by soil microbes. Hydrolytic breakdown ceases at soil pH above 6.8. Rate of breakdown may decrease in dry conditions.

Exception: **Permit** (halosulfuron) and **Matrix** (rimsulfuron) are broken down faster by hydrolysis as pH increases above and below pH of 7.0. Herbicide breakdown is slowest in neutral soil pH of 7.0 for both herbicides.

Most SU herbicides are:
1. Not volatile nor broken down by photodegradation.

2. Not leached.

3. Affected by soil pH. Water solubility greatly increases as pH increases.

4. Broken down primarily by acid hydrolysis. Microbial degradation is very slow with residual SU herbicides. Short residual SU herbicides (Express, Harmony GT, and Harmony Extra) are rapidly broken down by microbes and hydrolysis.

5. Non-microbial hydrolysis for most residual SU herbicides ceases at soil pH above 6.8.

6. SU herbicides are more highly adsorbed to soil particles and OM at low soil pH.

SU herbicides are bound more tightly in the neutral form at low pH than in (-) charge form at high pH. SU herbicides are undissociated (neutral charge) in soil with pH less than 7.0. As soil pH increases above 7.0 more molecules will be (-) charged. The (-) charged molecules are in a free form and do not bind with (-) charged soil particles. In a free form they are available for plant uptake.

However, even at low pH ranges, SU herbicides are so biologically active at low concentrations that plant response may still occur.

SU herbicides carryover more in high pH soils (above 6.8) because acid hydrolysis ceases at pH levels above 6.8. Hydrolysis is a chemical reaction that takes place in the soil and in minimally affected by soil moisture, organic matter, soil texture, soil microbes, and soil compaction or aeration. Hydrolysis is affected by soil temperature and soil pH. As temperature increases, the chemical reaction (hydrolysis) increases at an exponential rate rather than a linear rate. Also, hydrolysis sharply increases at soil pH below 6.8.

Soil pH is not uniform across fields and may fluctuate greatly. Soil pH may vary by one or even two pH units in a few feet. Crop injury from chemical residue may be expresses in high pH areas of the field. High soil pH can cause crop injury situations that do not match sprayer application or misapplication.

Breakdown of TPS Herbicides:

Broadstrike, FirstRate, Python and premixes containing the active ingredients in above herbicides: Accent Gold, Broadstrike + Dual, Broadstrike + Treflan, Hornet.
In general, TPS herbicides leave a residue in soil for more than one year. Breakdown occurs by soil microbes rather than acid hydrolysis which is a chemical reaction. Breakdown occurs more rapid and herbicide activity increases as soil pH increases. Rate of breakdown decrease in dry conditions.

TPS herbicides are:
1. Degraded by microbes.
2. Not volatile, nor broken down by **hydrolysis.**
3. Adsorbed more tightly to OM than clay.
4. Adsorbed more in low pH and less in high pH soils.
5. Lower in activity in low pH, more activity in high pH soils.

Soil pH below 7.0 increases binding to OM because more molecules are NOT (-) charged. As soil pH increases beyond 7.0, more molecules are (-) charged, as a result, fewer molecules will be bound to OM and free molecules are available for plant uptake and microbial degradation.

In summary, adsorption of TPS molecules increases as soil pH decreases. Activity and degradation of TPS herbicides increase as soil pH increases. Degradation increases in soils with high pH because herbicide molecules are not adsorbed and are in a free state in the soil solution and available for plant uptake and microbial breakdown. All factors that increase microbial activity also increase TPS herbicide degradation (warm, moist soils).

Breakdown of Triazine Herbicides:

Atrazine, Sencor, and Princep and all premixes containing the active ingredients list above.

In general, triazines leave a residue in soil for more than one year and in some cases for several years. Breakdown occurs primarily by hydrolysis, a chemical reaction, rather than by soil microbes. Hydrolytic breakdown slows at soil pH above 6.8. Rate of breakdown may decrease in dry conditions.

Triazine herbicides are:
1. More active and persistent in high pH soils.
2. Not volatile, but broken down by photodegradation only when herbicide remains on soil surface for extended periods.
3. Broken down slowly by microbial degradation.
4. Broken down primarily by hydrolysis at soil pH of 6.8 to 5.5.
5. Hydrolysis ceases at soil pH above 7.5.

Triazines are broken down mainly through hydrolysis, which is s chemical reaction in the soil and is affected little by soil moisture content. Hydrolysis is affected more by soil pH than other factors. Hydrolysis is reduced in high soil pH. An exception is Bladex (cyanazine). Cyanazine contains a nitrile group C-N which is especially prone to microbial deactivation and allows more rapid breakdown than atrazine.

6. Triazines are more active in high pH soils.

More triazine herbicides molecules are (+) charged at soil pH less than 7.5. Positive charged triazine molecules bind to (-) charges on soil and OM making them unavailable for plant uptake and microbial breakdown. At low soil pH, more herbicide molecules are adsorbed on the soil particles and not available for plant uptake. This is why pH sensitive herbicides like atrazine and Sencor can be used with less risk of crop injury in low pH soils. However, as pH fluctuates across the field, herbicide availability may radically fluctuate. Applying one rate across an entire field may result in variability in crop tolerance and weed control in various soil pH levels. Also, more molecules will be bound to soil and OM in dry conditions. As soil wets, triazine molecules will move into soil solution as water displaces triazine molecules.

At high soil pH the opposite reaction occurs. At soil pH greater than 7.5, triazine herbicide molecules donate protons (H*) ($H + OH = H_2O$ = water). At pH greater than 7.5, more triazine molecules have a net neutral charge. More neutral triazine molecules do not bind to soil particles and OM and are free for plant uptake and microbial decomposition.
The persistence of phytotoxic levels of a herbicide for more than 1 year can be a problem with some herbicides used. Herbicide residues are most likely to occur following years with low rainfall because chemical and microbial activity needed to degrade herbicides are limited in dry soil. Crop damage from herbicide residues can be minimized by applying the lowest herbicide rate required for good weed control, by using band rather than broadcast applications, and by moldboard plowing before planting the next crop. Moldboard plowing

reduces phytotoxicity of some herbicides by diluting the herbicide residue in a large volume of soil. Moldboard plowing is effective in reducing the residual effects of trifluralin, Sonalan, Prowl, Nortron /Etho/Ethotron , atrazine, and Sencor.

Rotation Restrictions for Crops Grown in North Dakota

erbicide	Alf-alfa	Bar-ley	Can-ola	Corn	Cra-mbe	CRP grss	Dry bean	Field pea	Flax	Oat	Edibl Leg.*	Pot-ato	Saff lowr	Soy-bean	Sgr-beet	Sun-flwr	HRS/Drm
	------------------------ (months after application) --------------------------																
O NOT USE IN ND = Beacon, Canopy, Canopy XL, Classic, Concert, Exceed, Scepter, Spirit, Steel, Synchrony																	
ccent (a)	12	8	18	0	18	18	10	10	18	8	10	18a	18	0.5	18a	11/18a	8
ccent Gold	10.5	8	26b	0	B	26	10.5	18	26b	8	18	18	B	10.5	26b	18	8
lly XP (c)	34d	10	34d	34e	34d	6	34e	34d	34e	10	34d	34d	34e	34d	34d	34e	1/10
lly Extra (0.2 oz) e	22	10	22	22	22	6	22	22	22	10	22	22	22	22	22b	22	1/10
mber	4b	18c	B	22b	B	B	B	B	B	18c	B	B	B	36b	B	24b	0
ssert	15	NCS	12/15f	NCS	12/15	4	NCS	15	15	15	15	15	NCS	NCS	20	NCS	NCS
trazine (0.38 lb ai)	NCS	NCS	NCS	0	NCS	NCS	NCS	NCS	NCS	NCS	NCS	NCS	NCS	12	NCSb	NCS	NCS
trazine (0.38-0.5 lb ai)	2CS	NCS	2CS	0	2CS	2CS	2CS	2CS	NCS	2CS	2CS	NCS	2CS	12	2CSb	2CS	2CS
trazine (0.5-1 lb ai)	2CS	2CS	2CS	0	2CS	2CS	2CS	2CS	2CS	2CS	2CS	2CS	2CS	12	2CSb	2CS	2CS
uthority	12	4	24	10	24	12	0	0	10	12	0	0	10	0	36	0	4
alance Pro (j)	10	6	18	0	18	18	18	18	18	6	18	6	6	6	18	10	6
asis	10	8	18	0	18	18	8	8	18	8	18	0	18	0.5	10	10	8
asis Gold	18	18	18	0	18	8	18	18	18	18	18	18	18	10	18	18	18
eacon (r)	8	8	18	0.5	18	18	8	8	18	8	8	2CS	18	8	B	8	8
oundary	4.5	8	18	8	18	12	18	8	18	8	12	8	18	0	18	-	8
uckle	NCS	0	NCS	16	NCS	18	NCS	NCS	NCS	16	NCS	NCS	NCS	NCS	14g	NCS	NCSg
allisto	10	4	NCS	0	18	18	18	18	18	4	18	10	18	10	18	10	4
elebrity Plus	12	8	18	0.25	18	18	10	10	18	8	10	18a	18	4	18a	10/18a	8

urtail/M	10.5m	1	5	1	5	1	10.5m	18	5	1	18	18	10.5m	10.5m	5	10.5m	1
egree (n)	2CS	2CS	2CS	0	2CS	2CS	2CS	2CS	2CS	2CS	2CS	2CS	2CS	2CS	2CS	2CS	4
icamba (<1.5 pt) h	4	4h	4	0h	4h	4	4	4	4	4h	4	4	4	4	4	4	0h
omain	12	12	18	1	18	12	12	12	12	12	12	1	12	0	18	12	12
istinct (h)	4	4	4	4h	4	4	4	4	4	4	4	4	4	4	4	4	0
pic	12	12	12	0	12	12	18	12	12	12	12	6	12	6	12	12	12
verest	NCS	9	9	NCS	NCS	NCS	NCS	11	NCS	18	24	9	NCS	9	9	NCS	4
xtreme	4	9.5	40b	8.5	40b	4	4	4	26	18	4	26	18	0	40b	18	4
ar-Go	NCS	0	NCS	NCS	NCS	NCS	NCS	NCS	NCS	18	NCS	NCS	NCS	NCS	NCS	NCS	0
inesse	B	16	B	B	B	4	B	B	B	10	B	B	B	B	B	B	0
irstRate/Amplify	9	30b	30b	9	B	9	9	9	30b	9	9	18	B	0	30b	30b	3
lexstar	18	4	18	10	18	4	10	10	18	4	10	18	18	0	18	18	4
angster	12	B	B	9	B	9	9	B	9	9	9	18	B	0	30b	30b	3
auntlet	12	12	24	10	24	12	12	12	B	12	12	B	B	0	30	30	4
erbicide	**Alf-alfa**	**Bar-ley**	**Can-ola**	**Corn**	**Cra-mbe**	**CRP grss**	**Dry bean**	**Field pea**	**Flax**	**Oat**	**Edibl Leg.***	**Pot-ato**	**Saff lowr**	**Soy-bean**	**Sgr-beet**	**Sun-flwr**	**HRS/ Durm**
	------------------------- (months after application) -----------------------------																
lean	B	16	B	B	B	4	B	B	B	10	B	B	B	B	B	B	0
arness (n)	2CS	2CS	2CS	0	2CS	2CS	2CS	2CS	2CS	2CS	2CS	2CS	2CS	NCS	2CS	2CS	4
ornet/WDG	10.5m	4	26b	0	B	12	10.5m	10.5m	26b	4	10.5m	18	B	10.5m	26b	18	4
ightning	9.5	9.5	40b	8.5	40b	40	9.5	9.5	40b	18	9.5	26	18	9.5	40b	18b	4
umax (<3 pt/A)	18	4.5	18	0	18	18	18	18	18	NCS	18	18	18	NCS	18	18	NCS
latrix	12	9/18p	18	0	18	18	10	18	18	9	18	0	18	4	18	10	9
laverick	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	0
luster	22	10	22	22b	22b	22	22	22	10	10	22	22b	22b	22b	22b	22b	10
orthStar (r)	8	8	18	0.5	18	18	8	8	18	8	8	8r	18	8	36r	8	8
ption	Corn is 7 days, soybean is 14 days, and all other crops are 60 days.																
aramount	10	10	10	10	10	10	10	24	24	10	24	10	10	10	24	10	0
eak (r)	22	0	22	1	22	10	22	10	22	0	10	22r	22	22	22r	22	0
ermit	9	2	15	1	B	2	9	9	B	2	9	9	B	9	36	18	2
lateau	36	24	48b	36	36	0	36	36	36	24	36	48b	36	18	48b	36	12
rowl/Pendimax	NCS	NCS	NCS	0s	NCS	NCS	0	0	NCS	NCS	0	0	NCS	0	2CS	0	NCS
ursuit	4	9.5	40b	8.5	40b	4	4	4	26	18	4	26	18	0	40b	18	4
ursuit Plus	9.5	9.5	40b	8.5	40b	NCS	4	4	26	18	4	26	18	0	40b	18	4
ython	4	4	26b	0	26b	12	4	4	26b	4	4	12	26b	0	26b	18	4
aptor/Beyond	9	4	18	8.5	18	9	9	9	18	9	9	9	18	0	18t	9	3
ave	B	18c	B	22	B	B	B	B	B	18c	B	B	B	36b	B	24b	0
eflex	18	4	18	10	18	4	10	10	18	4	10	18	18	0	18	18	4
encor (u)	4	8u	12	4	12	4	12	8	12	12	8	4	12	4	18	12	8u
onalan	NCS	NCS	0	NCS	0	13w	0	0	NCS	NCS	0	NCS	NCS	0	2CS	0	NCS
partan	12	4	24	10	24	12	0	0	10	12	0	0	10	0	36	0	4
pirit (r)	18	3	18	1	18	10	18	10	18	3	10	18	18	18	18r	18r	3
teadfast	12	8	18	0	18	18	10	10	18	8	10	18a	18	0.5	18a	11a	8
tinger	10.5	0	0	0	0	0	10.5m	18	0	0	18	18	10.5	10.5m	0	10.5m	0
urpass (n)	2CS	2CS	2CS	0	2CS	2CS	2CS	2CS	2CS	2CS	2CS	2CS	2CS	NCS	2CS	2CS	4
ordon (1.5 oz)	2CS	NCS	2CS	2CSx	2CS	1	2CS	2CS	NCS	NCS	2CS	2CS	2CS	2CS	2CS	2CS	NCS
opNotch (n)	2CS	2CS	2CS	0	2CS	2CS	2CS	2CS	2CS	2CS	2CS	2CS	2CS	NCS	2CS	2CS	4
rifluralin (y)	0	NCS	0	NCS	0	18/21	0	0	0	18	0	0	0	0	2CS	0	NCS
alor	12b	4	12b	1	12b	12b	4	4	12b	12b	4	12b	12b	0	12b	1	1

*Edible legumes = chickpea/garbanzo bean and lentils.
NCS = Next cropping season after herbicide application.
2CS = Second cropping season after herbicide application.
MAA = months after application.

Field Bioassay Instructions - Refer to label or paragraph Y7 in the Narrative Section.

a Soil pH <7.5 = 10 MAA for sorghum and 11 MAA for sunflower.
Soil pH >7.5 = 18 MAA for sorghum and sunflower
Soil pH <6.5 = 10 MAA for sugarbeet and all other crops not listed.
Soil pH >6.5 = 18 MAA for sugarbeet, potato, and all other crops not listed and cumulative precipitation in the 18 MAA period must exceed 28 inches.

B or b = Bioassay. Do not plant until field bioassay indicates it is safe.
Crop rotation after atrazine is rate and soil pH dependant. Accent Gold/WDG, Python, and Hornet/WDG require a 26 month rotation and a successful field bioassay.
FirstRate requires a 30 month rotation and a successful field bioassay. Lightning, Pursuit, and Pursuit Plus requires a 40 month rotation and a successful field bioassay.

c Do not use on soil with pH greater than 7.9. Barley and oat can be planted 6 months after Ally XP application west of highway 83.

d Requires soil pH of 7.9 or less and a 34 month minimum rotation interval and 28 inches of cumulative precipitation.

e Requires soil pH of 7.9 or less, 22 months and 22 inches of precipitation west of Hwy 1 or 34 months and 34 inches of precipitation east of Hwy 1. The previous restriction also applies to Ally Extra at rates greater than 0.2 oz DF/A.

f Imi resistant canola varieties may be planted the season after application.
Conventional canola varieties may be planted the following season after application at 1 pt/A in ND counties of Cavalier, Pembina, Ramsey, Rolette, Towner, and Walsh and MN counties of Kittson, Marshall, Pennington, Red Lake, and Roseau.

g Sugarbeet requires 20 months in areas that received less than 20 inches of precipitation during the growing season.
Buckle is labeled as a fall treatment in durum wheat and spring PPI application for durum and HRSW (some varieties excluded).

h Any rotational crop may be planted 120 days following application of dicamba at 1.5 pt/A or less, excluding days when ground is frozen. For wheat, barley, oat, and grass seedings, allow 45 days per pint/A of dicamba after application before planting.
For all crops and for rates greater than 1.5 pt/A allow 45 days per 1 pt/A of dicamba used excluding days when ground is frozen.

j Balance requires 15 inches of cumulative precipitation from application to planting of rotational crop. Furrow or flood irrigation should not be included in total. No more than 7 inches of overhead irrigation included in total.

m Do not plant dry bean, soybean or sunflower for 18 months on soil with less than 2% OM and rainfall less than 15 inches during the 12 MAA OR may be planted 12 MAA if risk of injury is acceptable.
Do not plant lentil, pea, potato or any other broadleaf crop grown for seed for 18 months unless risk of injury is acceptable.
Perform a field bioassay prior to planting for areas that receive less than 15 inches of rainfall and have less than 2% OM.

n Restriction applies to Degree, DoublePlay, FulTime, Harness, Surpass, and TopNotch.
Label restricts crops allowed to be planted the next season as corn, soybean, sorghum, and wheat only.
Restriction to other crops is based on incomplete residue data and not on crop safety.

p Barley can be planted 9 months after application in Cass, Grand Forks, Pembina, Towner, Traill, and Walsh counties of ND.
In all other counties of ND allow an 18 month rotation restriction before planting barley.

r Do not apply Beacon, NorthStar, Peak, or Spirit in the Red River Valley of ND and MN or on soil with pH greater than 7.8.
User must follow crop rotation restrictions as given on labels. Refer to label for additional information on soil pH, rotation intervals, maximum use rates, application timing and other restrictions. The number of months after application given in the previous table are applicable only on soil with a pH less than 7.8, only using less than maximum rates allowed, only using approved application timings, and only on approved locations (inside or outside Red River Valley) as indicated on the label.
Do not replant to any broadleaf crop if less than 10 inches of precipitation has occurred since Peak application.
For situations not covered on the label or in the previous table, conduct a soil bioassay to determine if Peak soil residue will allow successful planting of desired rotational crop.

s Corn can be planted only if Prowl/Prowl H20 is applied PRE. DO NOT APPLY PPI.

t Rotation to sugarbeet is after 26 months if soil pH is less than 6.2.

u Must add 2 months if soil pH is 7.5 or above. Wheat and barley can be planted 4 MAA following lentils or soybeans.

w CRP grasses may be planted 13 MAA under the following conditions:
1. By label this is deemed as a non-standard rotation.
2. Dow assumes no liability for injury.
3. Fall is recommended as the best time to plant CRP grasses.
4. A field bioassay is recommended prior to planting CRP grasses.

x Do not plant corn or sorghum until soil samples analyzed for Tordon residue indicates no detectable levels present.
Restriction is based on non-legal residue that may be found in corn and sorghum and not on crop safety.

y Oats, sorghum, and annual or perennial grass crops may be planted at least 12 MAA in areas that received 20 inches or more of precipitation during the growing season. CRP grasses may be planted 18 MAA if trifluralin is spring applied or 21 MAA if fall applied.

PREEMERGENCE CONTACT OR TILLAGE SUBSTITUTION HERBICIDES

Glyphosate (several trade names) is applied postemergence to the weeds but before sugarbeet emergence for weed control at 0.5 to 2 pt/A. Glyphosate must be used in combination with a nonionic surfactant of at least 50% active ingredient at 0.5% v/v. Addition of

ammonium sulfate at 17 lb/100 gallons of water will improve the consistency of weed control with glyphosate, especially when weeds are under environmental stress. Add ammonium sulfate to the water slowly and wait until it is completely dissolved before adding glyphosate or surfactant. Glyphosate at 0.5 pt/A controls foxtails (pigeongrass), 0.75 pt/A controls volunteer small grains, and 1 pt/A controls wild oats and downy brome when applied to plants less than 4 inches tall.

The 1 pt/A rate may not control wild buckwheat, Russian thistle, or kochia. Glyphosate should be used at 2 pt/A for control of winter wheat or winter rye seeded as a cover crop. Use the higher rate on larger weeds, more resistant weeds, or if the plants are under moisture stress. When low rates of glyphosate are used, apply in 3 to 10 gallons of water per acre by ground or in 3 to 5 gpa by air. Delay tillage for at least 3 days after treatment. Apply glyphosate at 2 pt/A when quackgrass is at least 8 inches tall (3 to 4 leaf stage) and actively growing. Apply glyphosate at 4 to 6 pt/A when Canada thistle is actively growing and at or before the bud stage. Fall treatment of Canada thistle should be before frost for best results but glyphosate will give good control of quackgrass after frost. Do not till until 3 or more days after treatment. Glyphosate can be used in the spring before or after planting but before emergence of barley, corn, oats, soybeans, dry beans, forages, potatoes, sugarbeet, wheat, and sorghum (milo), or in the fall when these crops will be planted the next growing season.

Gramoxone Extra, a nonselective contact herbicide, can be used at 1.5 to 3 pt/A alone or in combination with a residual herbicide as a substitute for tillage. Gramoxone Extra may be applied before or after planting until just before crop emergence. Apply Gramoxone Extra in 5 to 10 gallons per acre of water by air or in 20 to 60 gallons per acre of water by ground. Add nonionic surfactant to the spray solution at 0.12 to 0.25 % v/v. Gramoxone Extra is corrosive to exposed aluminum spray equipment and aircraft structures so rinse equipment immediately after use. Gramoxone Extra is toxic so avoid contact with the skin; small amounts could be fatal if swallowed. Gramoxone Extra is a restricted use herbicide.

PREEMERGENCE SOIL APPLIED AND PREPLANT INCORPORATED HERBICIDES

Good weed control with preemergence herbicides depends on many factors including rainfall after application, soil moisture, soil temperature, soil type, and weed species. For these reasons, preemergence herbicides applied to the soil surface sometimes fail to give satisfactory weed control. Herbicides which are incorporated into the soil usually require less rainfall after application for effective weed control than unincorporated herbicides. Weeds emerging through a preemergence herbicide treatment may be controlled by rotary hoeing or harrowing without reducing the effect of the herbicide unless the harrow or rotary hoe removes the herbicide from a treated band.

The reasons for using a Pre or PPI herbicide in sugarbeet include the following:

1) To reduce early season weed competition.

2) To make postemergence herbicides more effective by

*Or generic equivalent
increasing weed susceptibility and by reducing the total
weed population.

3) To provide weed control if unfavorable weather prevents timely cultivations or postemergence herbicide applications.

4) To provide a herbicide residual in soil to control late germinating weeds.

5) A Pre or PPI herbicide followed by postemergence herbicides often will improve weed control compared to Pre or PPI herbicides alone or postemergence herbicides alone.

INCORPORATION OF HERBICIDES: Many herbicides applied before crop and weed emergence need to be incorporated to give optimum weed control. Included in this group are Far-Go, Ro-Neet and Eptam. Weed control from Nortron* and Pyramin generally is improved by incorporation. Far-Go, Ro-Neet and Eptam should be incorporated immediately after application regardless of whether the liquid or granular formulation is used. Nortron* and Pyramin may be used preemergence but incorporation usually improves weed control, especially on fine-textured soils or with limited rainfall after application. Incorporation may reduce weed control if heavy rains follow application and incorporation may increase sugarbeet injury compared to surface application. Experience indicates that lack of rainfall is more common than excess rainfall following planting.

An estimate of the efficiency of an incorporating tool can be obtained by operating the tool through flour or lime which has been spread thickly over the soil. A thorough incorporation should cover most of the flour or lime and give uniform mixing through the soil. Several tillage tools have been used successfully for the incorporation of herbicides. Some herbicides require more thorough incorporation than others and the incorporation method should be matched to the herbicide. Far-Go, Ro-Neet and Eptam require a thorough incorporation and should be incorporated by one of the following methods or a method which will incorporate similarly.

a) A tandem disk should be set at a depth of 4 to 6 inches for Eptam or Ro-Neet, a disk is not recommended for Far-Go incorporation. Operating speed should be 4 to 6 mph. Tandem disks with disk blades spaced 8 inches or less and disk blade diameter of 20 inches or less have given good herbicide incorporation. Larger disks often give streaked incorporation and poor weed control.

b) Field cultivators of various types may be used. These should have overlapping sweep shovels with at least three rows of gangs and the operating depth should be 4 to 6 inches for Eptam and Ro-Neet or 3 to 4 inches for Far-Go. A harrow should follow the field cultivator. The operating speed necessary to achieve a satisfactory incorporation will vary somewhat depending on the type of field cultivator but the speed usually will be 6 to 8 mph.
c) Field cultivators with Danish tines plus rolling crumblers behind have given good herbicide incorporation. These tools should be operated 4 inches deep and at 7 to 8 mph or faster. Adequate incorporation with one pass may be possible with these tools if soil conditions are ideal for herbicide incorporation. However, a second incorporation maybe good insurance against poor weed control.

d) Power driven rototiller-type equipment will give adequate incorporation when set to operate at a depth of 2 to 4 inches at the manufacturer's recommended ground speed.

A single incorporation with a power driven rototiller is sufficient for Far-Go, Ro-Neet or Eptam. However, a second tillage at right angles to the initial incorporation should be done if the disk or field cultivator is used. The second incorporation has two purposes: a) Most of the herbicide left on the surface after the first incorporation will be mixed into the soil with the second tillage, and b) the second tillage will give more uniform distribution of the herbicide in the soil which will improve weed control and may reduce crop injury. Nortron/Ethotron and Pyramin do not require deep incorporation. A tillage tool operating at a minimum depth of 2 inches will give adequate incorporation if the tool mixes the herbicide uniformly through the soil.

Incorporation of soil-applied herbicides	Herbicide treatment
Deep incorporation required. Tillage tool 4 inches deep.	Eptam, Ro-Neet, Eptam + Nortron*
Shallow incorporation required. Tillage tool 2 inches deep.	Ro-Neet + Nortron*
Shallow incorporation usually improves weed control compared to no incorporation.	Nortron*, Pyramin.

Relative safety to sugarbeet of soil-applied herbicides.	Herbicide treatemnt
Low risk of injury.	Ro-Neet, Nortron*, Fall Eptam, Eptam + Ro-Neet, Pyramin, Far-Go.
Moderate risk of injury.	Ro-Neet + Nortron*
High organic matter, high clay content soils only.	Spring Eptam + Nortron*

THE SOIL ORGANIC MATTER TEST: Certain herbicides are partially adsorbed and inactivated by soil organic matter, so knowledge of the organic matter level will serve as a guide in selecting an effective herbicide and an effective herbicide rate. Herbicides such as Ro-Neet,
*Or generic equivalent
Eptam, Nortron*, and Pyramin require higher rates to give good weed control in high organic matter soils. On the other hand, crop safety may be marginal on low organic matter soils. Herbicides also are adsorbed to the clay fraction in a soil, so clay content affects herbicide performance. However, organic matter level generally affects herbicide performance more than clay content.

Sugarbeet has marginal tolerance to Eptam so the rate must be adjusted on various soils to give good weed control without crop injury. The following discussion on selecting an Eptam rate only gives guidelines. Other factors such as method of incorporation also affect Eptam performance (immediate and thorough incorporation gives best weed control). Rates must be adapted for individual conditions. The suggested spring-applied Eptam rate is 2 to 3 lb/A. The 3 lb/A rate should give good weed control without crop injury on a soil with a silty clay texture and more than 5% organic matter. The minimum rate of 2 lb/A may injure sugarbeet on a sandy loam or coarser-textured soil with less than 3% organic matter. The Eptam rate should be adjusted within the 2 to 3 lb/A range when the soil is intermediate between the two extremes. Eptam at 2.5 lb/A should give good weed control and little crop injury on clay loams or finer-textured soils with more than 4% organic matter.

Some herbicides give good weed control only when organic matter levels are low. Pyramin has not been effective in the Red River Valley, except on the coarser-textured soils with less than 5% organic matter and with above average rainfall. The lower the organic matter, the more effective. Most postemergence herbicides are affected only slightly by organic matter levels. Determine organic matter levels on each field where organic matter sensitive herbicides are to be used. Organic matter levels change very slowly and testing once every 5 years would be adequate.

FALL APPLICATION OF HERBICIDES: Certain herbicides may be applied in the fall for weed control the following spring. Included in this group are Far-Go, Eptam, and Ro-Neet. Fall treatments should be applied after October 15 and until soil freeze-up. Application of herbicide treatments after October 15 when soil temperature has cooled minimizes herbicide loss by volatilization. Applications made more than 3 weeks before soil freeze-up can result in poor weed control. Both granular and liquid formulations of the herbicides are registered for use in the fall. Fall applications of granular formulations generally have performed more effectively than the liquid formulations, especially under heavy crop residue or cloddy situations.

The use of fall herbicides a) eliminates the need for deep spring tillage thus improving the seedbed, b) may give less sugarbeet injury than spring herbicides and c) allows planting in the spring with no delay for herbicide application. On the negative side, fall herbicides a) may increase soil erosion over winter, b) give more variable broadleaf weed control then when spring applied, c) may require a higher rate and thus cost more than spring herbicides, and d) limit crop choice in the spring.

EPTAM preplant incorporated in the spring at 2 to 3 lb/A or fall applied at 4 to 4.5 lb/A gives good control of annual grasses and certain broadleaf weeds. Eptam sometimes causes sugarbeet stand reduction and temporary stunting. However, no yield reduction will result if enough sugarbeet remain to obtain an adequate plant population after thinning. Eptam should be used with extreme caution on sugarbeet grown in loam or coarser-textured soils with 3% or less organic matter because predicting a safe Eptam rate is difficult on such soils. See previous sections on soil organic matter test, fall application of herbicides and herbicide incorporation for more details.

RO-NEET spring applied at 3 to 4 lb/A or fall applied at 4 lb/A gives weed control similar to Eptam. Eptam tends to give better weed control than Ro-Neet on fine-textured, high organic matter soils or under relatively dry conditions while Ro-Neet gives better control than Eptam when spring rainfall is adequate to excessive. Ro-Neet causes less sugarbeet injury than Eptam and is safer for use on more coarse textured, low organic matter soils. Ro-Neet should be incorporated immediately and thoroughly the same as Eptam.

EPTAM + RO-NEET has less potential for sugarbeet injury than Eptam alone and is less expensive per acre than Ro-Neet alone. The rate of application of the mixture must be adjusted for soil texture and organic matter. Suggested fall applied rates are; Ro-Neet alone at 4 lb/A on soils with less than 3 percent organic matter, Eptam + Ro-Neet at 1 + 3 lb/A on loam or coarser soils with 3 percent organic matter, 1.5 + 2.5 lb/A on loam to clay loam soils with 3 to 4 percent organic matter, 2 + 2 lb/A on clay loam soils with 3.5 to 4.5 percent organic matter, and 2.5 + 2.5 lb/A on clay or clay loam soils with over 4.5 percent organic matter. Suggested spring applied rates are; Ro-Neet alone at 3 lb/A on loam or coarser soils with 3 percent or less organic matter. Eptam + Ro-Neet at 1 + 2.5 lb/A on loam or coarser soils with 3 to 3.5 percent organic matter, 1.5 + 2.5 lb/A on loam to clay loam soils with 3.5 to 4.5 percent organic matter, and 2 + 2 lb/A on clay loam or finer soils with 4 percent or more organic matter. These rates may need to be adjusted on certain fields or with certain incorporation tools based on individual experience. Eptam, Ro-Neet or Eptam + Ro-Neet require immediate incorporation for best weed control.

FAR-GO spring or fall applied at 1.5 pt/A or 15 lb 10G/A controls wild oat with excellent safety on sugarbeet. Far-Go should be incorporated immediately after application with a tillage tool set 3 to 4 inches deep. Deep and thorough incorporation generally will provide the best wild oat control. A second incorporation will often improve

*Or generic equivalent

wild oat control and a three-day or longer delay between the first and second incorporation may further improve control. A single incorporation in the fall followed by spring seedbed preparations is sufficient for fall applied Far-Go. Far-Go should be applied in the fall when temperatures are consistently below 50 F. This generally occurs after October 15. Far-Go may be applied until snow cover or until the soil is frozen too hard for incorporation. Far-Go will control wild oat that have developed resistance to ACCace inhibitor postemergence herbicides for grass control.

PYRAMIN spring applied at 3.8 to 7.6 lb/A controls most broadleaf weeds. Pyramin has been more effective on soils with less than 5% organic matter than on heavier soils. Weed control from Pyramin generally increases as soil organic matter content decreases. Shallow incorporation generally improves weed control from Pyramin. Large amounts of rainfall after application improves weed control from Pyramin.

NORTRON/ETHO/ETHOTRON at 2 to 3.75 lb/A gives good control of several broadleaf and grassy weeds. Nortron* is especially effective on redroot pigweed but is weak on yellow foxtail. Nortron* is the best available herbicide for control of UpBeet-resistant kochia. Nortron* generally gives less sugarbeet injury than Eptam especially on more coarse-textured, low organic matter soils. Nortron* may be applied preemergence but incorporation generally improved weed control in tests in North Dakota and Minnesota. Operating the tillage tool 1, 2, or 4 inches deep gave similar weed control with slightly better control at 2 and 4 inches compared to 1 inch. Preemergence Nortron* will give good weed control when relatively large amounts of rain follow application. The exact amount of rain needed is not known but field observations on fine-textured, high organic matter soils indicate that at least 1 inch of rain is needed to give best results from preemergence Nortron*. More coarse-textured, low organic matter soils probably would require less rain for Nortron* activation than fine textured, high organic matter soils. Nortron* often has a residue the year following use on sugarbeet. Crops most likely to be damaged by Nortron* residue are wheat, barley, and oats. Moldboard plowing usually will eliminate crop injury. Nortron* should be applied in a band to reduce cost and reduce potential crop injury from residues the following year.

Nortron* may form an insoluble deposit on the sides of a partially full container. This deposit may plug screens and nozzles. Sprayers should be cleaned immediately after use to avoid drying of spray solution. Partially empty containers of Nortron* should be filled with water to prevent drying in the container. Mark or record the level of remaining Nortron* before adding the water.

COMBINATIONS OF SOIL APPLIED HERBICIDES nearly always give improved weed control compared to the use of individual herbicides. Unfortunately the risk of sugarbeet injury also increases with herbicide combinations so selecting the proper rate for each herbicide combination and each farming situation is very important and also sometimes difficult. All agricultural pesticides which are tank mixed should be registered for use as a tank mixture by the Environmental Protection Agency. Agricultural pesticides may be tank mixed if all pesticides in the mixture are registered by the Environmental Protection Agency on the crop being treated.

However, users of non-labeled mixtures must assume liability for any possible crop injury, inadequate weed control, and illegal residues. Pyramin does not give grass control and Nortron* is sometimes weak on grasses; thus these herbicides often should be used in combination with a grass herbicide such as Eptam or Ro-Neet. Nortron* or Pyramin in combination with Eptam or Ro-Neet

sometimes have caused serious sugarbeet injury especially on lighter soils. Nortron* + spring applied Eptam has been especially damaging and this treatment only should be used on silty clay soils with over 6% organic matter. Spring applied Nortron* or Pyramin over fall applied Eptam has given less sugarbeet injury than combinations applied in the spring.

RELATIVE CONTROL OF WEEDS WITH PREEMERGENCE OR PREPLANT INCORPORATED HERBICIDES[a]

Weed	Eptam	Far-Go	Nortron/Etho Ethotron	Pyramin	Ro-Neet
Buffalo bur	G	N	F	-	G
Black nightshade, eastern	F-G	N	F-G	G	F-G
Barnyardgrass	G-E	N	P	P	G
Cocklebur, common	P	N	P	P-F	P
Canada thistle	N	N	N	P	N
Foxtails (pigeongrass)	G-E	N	F-G	P	G-E
Kochia	F	N	F-G	P-F	P
Ladysthumb (smartweed)	P	N	G	F-G	P
Lambsquarters, common	F-G	N	P-F	G	F-G
Mallow, common	F-G	N	P	-	F-G
Pigweed, redroot	F-G	N	G-E	G	F-G
Pigweed, prostrate	F-G	N	F-G	G	F-G
Ragweed, common	F	N	P	F-G	F
Russian thistle	P	N	F-G	P-F	P
Sunflower, volunteer	N	N	P	P	N
Wild buckwheat	P-F	N	F-G	P-F	P-F
Wild mustard	P	N	P-F	G	P
Wild oat	G	G-E	F-G	P	F-G
Herbicide persistence after 12 months	N	N	O	N	N

E = Excellent, G = Good, F = Fair, P = Poor, N = None, O = Often

[a] This table is a general comparative rating of the relative effectiveness of herbicides to certain weeds. Under very favorable weather conditions, control might be better than indicated. Under unfavorable conditions, some herbicides rated good or fair might give erratic or unfavorable results.

*Or generic equivalent

POSTEMERGENCE HERBICIDES

Betanex/Des/Aphanex, Betamix/D-P Mix/Phen-Des, and Progress/Des-Phen-Etho are postemergence herbicides for the control of annual broadleaf weeds. Betanex* and Betamix* occasionally cause sugarbeet injury. The conventional rates of Betanex* and Betamix* are 0.75 to 7.4 pt/A (0.12 to 1.2 lb/A) and conventional rates of Progress* are 0.5 to 3.3 pt/A (0.12 to 0.75 lb/A). Several factors should be considered when selecting a rate of Betanex*, Betamix* or Progress*.

1) Sugarbeet growth stage: Sugarbeet with four true leaves is less susceptible to injury than smaller sugarbeet and sugarbeet gains additional tolerance as plants become larger than the four leaf stage. Betanex*, Betamix* or Progress* at 0.12 to 0.33 lb/A can be applied to sugarbeet with less than four leaves and up to 0.5 lb/A on sugarbeet with four leaves. Applications totaling 0.5 lb/A or less should be followed by a second application in 5 to 7 days if living weeds are present after 5 days and if the sugarbeet plants were not injured significantly. Split application with reduced rates has reduced sugarbeet injury and increased weed control compared to single dose, full rate application. Sugarbeet becomes rather tolerant of Betanex*, Betamix* and Progress* after the plants reach the six- to eight-leaf stage but weeds become more difficult to control as they become larger. Betanex*, Betamix* or Progress* up to 0.75 to 1.2 lb/A can be used on large weeds and six to eight-leaf sugarbeet. Betanex*, Betamix* and Progress* should be applied at least 75 days prior to harvest.

2) Environmental Conditions: Betanex*, Betamix* and Progress* give the greatest weed control and sugarbeet injury with high temperatures, high soil moisture, and high relative humidity. Recent flooding or a sudden change from cool and cloudy to hot and sunny weather will increase the risk of sugarbeet injury. Risk of sugarbeet injury is reduced by starting application in late afternoon or later so that temperatures will be dropping rather than increasing after application. The control of weeds can be improved by applying higher rates of Betanex*, Betamix* or Progress* on the morning of a hot day. However, sugarbeet should have six to eight leaves before using this technique. The sugarbeet leaves may be damaged but death of six to eight leaf plants is unlikely and sugarbeet usually recovers from early season leaf burn without yield loss. The most effective rate of Betanex*, Betamix* and Progress* can change rapidly during a growing season. For example, Betanex* at 1.5 pt/A may be best with two-leaf sugarbeet, good moisture, and warm temperatures but Betanex* at 3 pt/A may be required for best results a few days later with larger weeds, dryer soil, and cooler conditions. Generally, rates must be adjusted during the spraying season.

3) Use of Soil Applied Herbicides: Sugarbeet and weeds that have been treated with a soil applied herbicide are more susceptible to Betanex*, Betamix* and Progress* than sugarbeet and weeds that have not been treated. Eptam and Ro-Neet precondition sugarbeet and weeds more than

*Or generic equivalent

Nortron* or Pyramin. Rates of Betanex*, Betamix* and Progress* should be lower when applied to fields previously treated with a soil applied herbicide than when applied to untreated fields.

4) Micro-rate: A discussion of the micro-rate program may be found in the following section on combinations of postemergence herbicides.

5) Application Method: Research has indicated that Betanex* and Betamix* applied at 200 psi spray pressure were more phytotoxic to cotyledon to 2 leaf weeds and sugarbeet that Betanex* and Betamix* applied at 40 psi. Weed control was greater with 15 to 20 gpa at 200 psi than with 8.5 gpa at 200 psi. Betanex* or Betamix* applied to plants approximately 4 to 6 inches tall were more phytotoxic at 40 psi than at 200 psi. Field observations suggest that aerial applications of Betanex* or Betamix* give results similar to applications at 200 psi. Similar results would be expected from Progress*.

Progress* (desmedipham + phenmedipham + ethofumesate) applied POST gives increased weed control and greater risk of sugarbeet injury than Betamix*. Progress* gives better control of kochia and wild buckwheat than Betamix*. Betanex* gives better redroot pigweed control than Progress* or Betamix*. The active ingredients of Progress* are premixed in a 1:1:1 ratio.

Determining the equivalent rates of Progress* as compared to Betanex* or Betamix*.

The following procedure can be used to determine the appropriate rate of the premix, Progress*.

1. Determine the appropriate or normal rate of Betanex* or Betamix* that would be used alone for a given situation.

2. Multiply the normal rate of Betanex* or Betamix* in pt/A by 0.75 to determine the rate of Progress* in pt/A so that the total pounds per acre of Progress* is approximately equal to the normal pounds per acre of Betanex* or Betamix*.

Example:
1. Normal rate = 2.0 pt/A of Betamix*.

2. 2.0 pt/A X 0.75 = 1.5 pt/A of Progress*
to substitute for 2.0 pt/A of Betamix* alone.

Sugarbeet becomes more tolerant to herbicides as sugarbeet size increases. Herbicides and herbicide combinations vary in potential for herbicide injury. The following groups of herbicide treatments listed by a sugarbeet leaf stage indicate that the treatments usually can be applied safely to sugarbeet in the given leaf stage or to larger sugarbeet. Leaf stage refers to the number of true leaves and does not consider cotyledonary leaves. Herbicide rates are broadcast. Treatments should be repeated in 5 to 7 days if necessary for adequate weed control.

RELATIVE CONTROL OF WEEDS WITH POSTEMERGENCE HERBICIDESa

	Benanex*	Betamix*	Progress	Stinger*	Betanex* + Stinger*	Betamix + Stinger*	Betanex*,Betamix* or Progress*+UpBeet	Bnex*,Bmix* or Progress*+UpBeet+Stinger	Assure II, Poast, Select*	Trifluralin (Lay-by)	Dual Magnum (Lay-by)
Barnyardgrass	P	P	P	P	P	P	P	P	E	G	G
Buffalo bur	G	G	G	F-G	G-E	G-E	G	G-E	N	P	P
Canada thistle	N	N	N	G-E	G-E	G-E	P	G-E	N	N	N
Cocklebur	P	P-F	F	E	E	E	F-G	E	N	P	N
Common lambsquarters	G	G	G-E	P-F	G-E	G-E	G-E	G-E	N	G	F
Common sunflower	P	P	P	G-E	E	E	G	E	N	N	N

Eastern black nightshade	F-G	F-G	G	F-G	G-E	G-E	G	E	N	N	P
Foxtails (pigeongrass)	P	F	F-G	P	P	F	F-G	F-G	E	G	G
Giant ragweed	P	P	P	G-E	E	E	P-F	E	N	P	P
Kochia	P-F	F	F-G	N	F	F-G	P-G	P-G	N	F-G	P
Ladysthumb (smartweed)[b]	P	P	F-G	P-F	G-E	G-E	G	G-E	N	P	P
Lanceleaf sage	P	P	P-F	F	F-G	F-G	P-F	F-G	N	P	N
Marshelder	G	G	G	E	E	E	G	E	N	P	N
Mallow, common	P	P	P	P	P	P	G-E	G-E	N	P	P
Mallow, Venice	P	P	P	P	P	P	F-G	G	N	P	N
Nightflowering catchfly	P	P	F	P	P	P	G-E	G-E	N	P	P
Pigweed, prostrate	G-E	G	G	P	G-E	G	G-E	G-E	N	G	G-E
Pigweed, redroot	G-E	G	G	P	G-E	G	G-E	G-E	N	G	G-E
Ragweed, common	F	F	F-G	G-E	G-E	G-E	F-G	G-E	N	P	P-F
Russian thistle	P	P	P	P-F	G	G	P	G	N	F-G	P-F
Wild buckwheat[b]	P-F	F	F-G	F-G	G	G-E	F-G	G-E	N	P-F	P
Wild mustard	G-E	G-E	G	P	G-E	G-E	E	E	N	P	P
Wild oat	N	N	N	N	N	N	P	P	E	F	P-F

E = Excellent, G = Good, F = Fair, P = Poor, N = None

[a] This table is a general comparative rating of the relative effectiveness of herbicides to weeds. Under very favorable conditions, control might be better than indicated. Under unfavorable conditions or with herbicide resistant weeds, some herbicides rated good to excellent might give erratic or unfavorable results.

*Or generic equivalent

Table. Suggested rates for Betanex*, Betamix* and Progress* with consideration of sugarbeet size, application method, and the presence of soil applied herbicide. The rates are conservative and assume adequate soil moisture, healthy unstressed sugarbeet, and that the weeds emerge about the same time as the sugarbeet. Betanex or Betamix should be applied in late afternoon or evening and another application should be made 5 to 7 days later if needed. Rates in the table may need to be increased for a dry, cool environment or reduced for a hot, wet environment.

	Betanex*, Betamix* Broadcast Rate							
	No soil herbicide				With soil herbicide			
Sugarbeet stage	Low pressure (<100 psi)		High pressure or aerial		Low pressure (<100 psi)		High pressure or aerial	
	(lb/A)	(pt/A)	(lb/A)	(pt/A)	(lb/A)	(pt/A)	(lb/A)	(pt/A)
Cotyledon-2 leaf	0.25	1.5	0.16	1.0	0.16	1.0	0.12	0.75
2 leaf	0.33	2.0	0.25	1.5	0.25	1.5	0.16	1.0
4 leaf	0.5	3.0	0.4	2.5	0.33	2.0	0.25	1.5
6-8 leaf	0.75	4.6	0.75	4.6	0.5	3.0	0.5	3.0

Progress* gives increased control and greater risk of sugarbeet injury than Betamix. In order to limit the risk of sugarbeet injury, the total pounds per acre of active ingredient in Progress* should be equal to the normal total pounds per acre of active ingredient of Betanex* or Betamix* that would be applied alone for a given situation. See the following table.

	Progress* Broadcast Rate							
	No soil herbicide				With soil herbicide			
Sugarbeet stage	Low pressure (<100 psi)		High pressure or aerial		Low pressure (<100 psi)		High pressure or aerial	
	(lb/A)	(pt/A)	(lb/A)	(pt/A)	(lb/A)	(pt/A)	(lb/A)	(pt/A)
Cotyledon-2 leaf	0.25	1.1	0.16	0.7	0.16	0.7	0.12	0.5
2 leaf	0.33	1.5	0.25	1.1	0.25	1.1	0.16	0.7
4 leaf	0.5	2.2	0.4	1.8	0.33	1.5	0.25	1.1
6-8 leaf	0.75	3.3	0.75	3.3	0.5	2.2	0.5	2.2

Sugarbeet injury from Betanex* or Betamix*. Sugarbeet in the mid-four-leaf stage (second pair of true leaves half expanded) is significantly more resistant to Betanex* and Betamix* than smaller sugarbeet. Sugarbeet becomes even more tolerant after the mid-four-leaf stage. However, research and field experience has shown that waiting for most of the sugarbeet plants to reach the mid-four-leaf stage prior to the first application of Betanex* or Betamix* often results in less than optimum weed control. Weeds become more tolerant to Betanex* and Betamix* as they become larger and unfavorable weather may prevent the first timely application. Generally, the best combination of weed control, safety to sugarbeet, and low cost is obtained when Betanex* or Betamix* is first applied at the cotyledon to two-leaf-stage of sugarbeet using reduced rates of 0.12 to 0.25 lb/A. Another treatment of Betanex* or Betamix* at 0.16 to 0.33 lb/A generally will be needed 5 to 7 days after the first. The need for additional treatments will be affected by continuing germination of weeds and level of control achieved by the first two treatments.

*Or generic equivalent

POAST at 0.5 to 1.5 pt/A plus adjuvant will control annual and perennial grasses. Research at North Dakota State University has indicated that methylated seed oil adjuvants, often give better grass control than other adjuvants when used with Poast. The improved grass control is observed most often with dry soil, large grass, or reduced rates of Poast. Addition of fertilizer to the spray solution often will increase grass control from Poast plus oil adjuvant. See the Poast label for rates for various grass weeds. Cultivation between 14 and 21 days after application will improve quackgrass control. Addition of ammonium sulfate at 2.5 lb/A or UAN at 2 to 4 qt/A to Poast plus oil adjuvant may improve control of wild proso millet, green foxtail, yellow foxtail, giant foxtail, barnyardgrass, and wooly cupgrass if the water carrier is high in carbonates or bicarbonates.

Poast should be applied at least 60 days prior to harvest with nozzles that deliver 0.1 gal/minute or less at 40 psi (examples, 4001E for banding or 8001XR for broadcasting). Poast band applied through two nozzles per row will give control similar to one nozzle per row if all nozzles are the same size. Poast applied at high spray

pressure (over 100 psi) often gives better grass control than applications at 40 psi. However, the risk of damaging spray drift is much greater from high pressure than from low pressure applications.

SELECT/ARROW at 6 to 8 fl oz/A or Prism at 12.8 to 17 fl oz/A postemergence will control annual and perennial grasses. Retreatment of quackgrass regrowth may be needed. Select* should be used with an oil adjuvant at 1% v/v for best grass control. Select* should be applied in 5 to 40 gallons per acre of spray solution at 30 to 60 psi by ground and in 3 to 10 gallons per acre by air. Drought and/or cold may reduce grass control. Use of Betanex*, Betamix*, Progress* as a tank-mix or within one day prior to Select* may reduce grass control. However, research in eastern North Dakota and Minnesota indicated that grass control from Select* was reduced less than grass control from Poast or Assure II by tank-mixing Betanex* or Betamix* with the grass herbicides. Select* should be applied at least 40 days prior to harvest.

ASSURE II at 7 to 10 fl oz/A plus an oil adjuvant will control annual grasses while 10 to 12 fl oz/A is needed for quackgrass. Assure II is especially effective on quackgrass compared to other similar herbicides although retreatment may be necessary. Assure II is less effective on yellow foxtail than on other annual grasses so a minimum of 8 fl oz/A should be used on yellow foxtail. See the label for weed sizes and rates for specific grasses. Suggested spray volumes on the label are from 10 to 40 gpa at 25 to 60 psi by ground and 3 to 5 gpa by air. The maximum use rate per season is 25 fl oz/A. Various stresses to grass weeds may reduce grass control from Assure II. Assure II should be applied at least 45 days prior to harvest.

STINGER/CLOPYR AG at 0.25 to 0.67 pt/A postemergence controls several broadleaf weeds and volunteer crops. Stinger* at 0.25 to 0.5 pt/A is most effective when applied to common cocklebur, giant ragweed, volunteer sunflower, wild sunflower, marshelder, volunteer alfalfa and volunteer soybeans up to the six-leaf stage, and common ragweed up to the five-leaf stage. Stinger* at 0.5 pt/A is most effective on wild buckwheat in the three to five-leaf stage before vining begins. Stinger* at 0.5 to 0.66 pt/A is most effective on Canada thistle in the rosette to pre-bud growth stage, but rosette application often gives better control than later application. Stinger* must be applied to sugarbeet in the two to eight-leaf stage and at least 45 days prior to harvest. Wheat, barley, oats, grasses, field corn, or sugarbeet can be planted anytime after Stinger* application. Do not plant alfalfa, canola, popcorn, sweet corn, or safflower for 10.5 months after application. Do not plant dry bean, soybean, or sunflower for 10.5 months after application, or 18 months after application if soils contain less than 2% organic matter and natural precipitation is less than 15 inches during the 12 months after treatment. Do not plant other crops including pea,

*Or generic equivalent

lentil, potato, and broadleaf crops grown for seed for 18 months after application. A field bioassay is suggested before seeding sensitive crops on soils with 2% or less organic matter and less than 15 inches annual precipitation. Stinger is a slow acting herbicide. The full effects of the herbicide may not be evident until 30 or more days after application.

UPBEET is a postemergence herbicide that should be used in combination with other broadleaf herbicides such as Betanex*, Betamix*, Progress* or Stinger*. UpBeet provides improved control of several broadleaf weeds such as kochia, redroot pigweed, prostrate pigweed, common mallow, Venice mallow, velvetleaf, nightshade, nightflowering catchfly, ladysthumb (smartweed), wild mustard and sunflower. UpBeet will antagonize grass control from Poast, Select* or Assure II similar to the antagonism caused by Betanex*, Betamix* or Progress*.

COMBINATIONS OF POSTEMERGENCE HERBICIDES give more broad spectrum and greater total weed control compared to individual herbicides. The risk of sugarbeet injury also increases with combinations so combinations should be used with caution.

All agricultural pesticides which are tank mixed should be registered for use as a mixture by the Environmental Protection Agency. Pesticides may be tank mixed if all pesticides in the mixture are registered by the EPA on the crop being treated. However, users of non-labeled mixtures must assume liability for any possible crop injury, inadequate weed control, and illegal residues.

A tank-mixture of one of the grass control herbicides (Poast, Select*, Assure II) plus an adjuvant plus one of the broadleaf control herbicides (Betanex*, Betamix* or Progress*) will often give less grass control than the grass herbicide plus adjuvant. The broadleaf herbicide antagonizes the grass control from the grass herbicide but broadleaf control is not reduced by the presence of a grass herbicide. Stinger* does not antagonize grass control. Antagonism of grass control by a broadleaf herbicide may not be significant if the environment and the condition of the grass favors excellent weed control. Antagonism is less likely to be a problem with small grass, optimum soil moisture, and a grass that is actively growing. A grass species that is very susceptible to the grass herbicide chosen will be antagonised less than a more tolerant grass species. For example, antagonism of Poast would be greater on wild oat and volunteer grain than on green or yellow foxtail while antagonism of Assure II would be greater on yellow foxtail than on wild oat and volunteer grain.

Antagonism will be less if an adjuvant is included in the mixture of grass herbicide plus broadleaf herbicide as compared to not using an adjuvant. However, excessive sugarbeet injury may occur from conventional rates of a broadleaf herbicide plus an adjuvant.

Antagonism can be nearly eliminated by applying the grass herbicide plus adjuvant 24 hours before the broadleaf herbicide or by applying the broadleaf herbicide 3 to 5 days before the grass herbicide. Also, research results indicated that a full rate of grass herbicide plus a broadleaf herbicide (no adjuvant) applied twice at a 7-day interval gave grass control nearly equal to a single application of the grass herbicide plus adjuvant.

Stinger* plus Betamix* or Betanex* split applied gave better control of common lambsquarters, Russian thistle, wild buckwheat, ladysthumb (smartweed), eastern black nightshade, common cocklebur, lanceleaf sage and buffalo bur than Betamix* or Betanex* alone or Stinger* alone. Stinger* alone controlled common sunflower, Canada thistle, and giant ragweed as well as Stinger* plus Betamix* or Betanex*. Sugarbeet injury from Stinger* plus Betanex* or Betamix* generally is similar to the total of % injury from Stinger* alone plus Betanex*/Betamix* alone. Sugarbeet injury from Stinger* at 0.5 pt/A averaged over 25 experiments in 1989 and 1990 was 3%. The highest observed injury was 8%. Therefore the risk of additional sugarbeet injury is low from adding Stinger* to Betanex* or Betamix*.

UpBeet plus Betanex*, Betamix* or Progress* has provided improved control of redroot pigweed, prostrate pigweed, kochia, common mallow, nightshade, ladysthumb (smartweed), Venice mallow, nightflowering catchfly, wild mustard and velvetleaf compared to Betanex*, Betamix* or Progress* alone. UpBeet generally has little effect on sugarbeet injury. A three-way combination of Betanex* + UpBeet* + Stinger* has given good to excellent control of all common broadleaf weeds in sugarbeet in research conducted in North Dakota and Minnesota.

Nortron* at 4 fl oz/A applied postemergence in combination with Betanex*, Betamix* or Progress* often will increase control of broadleaf weeds such as kochia, common lambsquarters and redroot pigweed. Crop rotation restrictions on the herbicide labels limit postemergence Nortron* to no more than two applications at 4 fl oz/A in combination with the micro-rate of Progress* or no more than three applications at 4 fl oz/A in combination with Betanex* or Betamix* at any labelled rate.

The MICRO-RATE program uses low rates of herbicides in combination applied three or more times at a 5 to 7 day interval starting when weeds are just emerging. The micro-rate treatment is Betanex* or Betamix* or Progress* plus UpBeet plus Stinger* plus a methylated seed oil adjuvant at 8.0 or 8.0 or 5.7 fl oz/A plus 0.125 oz/A plus 1.3 fl oz/A plus 1.5% v/v. The rate of Betanex*/Betamix*/Progress* can be increased to 12/12/8.7 fl oz/A when sugarbeet has four or more leaves. The amount of methylated seed oil adjuvant used per acre will vary with spray volume. Use at least 1.0 pt/A at low spray volumes and no more than 1.0
*Or generic equivalent

qt/A is needed at high spray volumes. The adjuvant is essential to increase weed control from the low herbicide rates. Assure II at 4 fl oz/A or Select* at 2 fl oz/A or Poast* at 5.3 fl oz/A can be added to the micro-rate to improve grass control. Kochia that was resistant to UpBeet has been observed in many fields and Progress* is the best alternative to UpBeet for kochia control. However, Progress* plus UpBeet plus Stinger* plus methylated seed oil at the micro-rate generally will not provide satisfactory control of ALS resistant kochia. The standard micro-rate often does not provide adequate control of lanceleaf sage. Increasing the Stinger* rate from 1.3 fl oz/A to 2.6 fl oz/A in the micro-rate usually will result in adequate lanceleaf sage control. However, sugarbeet injury also may be increased.

The micro-rate should be applied a minimum of three times. Three applications of the micro-rate generally has given better weed control than two applications of conventional rates. Three applications of conventional rates sometimes gave better weed control than three applications of the micro-rate. Four micro-rate applications frequently have given better weed control than three applications. Broadcast application of the micro-rate is encouraged since precise application is easier with broadcast rather than band application. If banding is done, the band width should be 11 inches or wider and wind velocity should be low.

Precipitation and nozzle plugging was a common problem with ground application of the micro-rate. No problems were reported with aerial application. The problem has occurred with conventional rates but nozzle plugging is more common with the micro-rate.

Several factors have been identified that may reduce nozzle plugging. 1) Start with a clean sprayer, spray out each tank load immediately after mixing, spray until tank is empty, flush sprayer between loads, clean screens frequently and never allow spray solution to set in the sprayer. The amount of precipitate in the spray solution increases with time. Frequent cleaning will slow or prevent the buildup of a layer of residue inside the sprayer. 2) Allow the spray tank water to warm before mixing the herbicides. Precipitation is less in warm water than in cold water. 3) Increase the pH of the spray tank water to pH 8 to 9 by using ammonia, Quad 7 or other pH increasing agents. A 2% solution of household ammonia at 1 gal/100 gallons of water will give about pH 9. The ammonia should be added slowly as the tank fills so the water pH does not go over pH 9.5. Raising the pH too high can cause increased precipitation. 4) Pre-mix the UpBeet in hot water or in water with pH 8 to 9. Put UpBeet in the spray tank first and be sure it is dissolved before adding, in order, Betanex*/Betamix*/Progress*, Stinger* and methylated seed oil adjuvant.

5) Add a grass herbicide. Tests using a single nozzle and a small volume of spray solution indicated that Assure II reduced precipitation more than Poast or Select* but all had an effect. 6) Gentle agitation of the spray solution resulted in less precipitate than vigorous agitation.
The first application of the micro-rate must be to small weeds, generally between 14 and 21 days after planting. The largest sugarbeet plants in the field should be in the early two-leaf stage at first application. Postemergence herbicides for sugarbeet do not provide sufficient soil residual to prevent later emergence of weeds. A residual soil applied herbicide can reduce late weed emergence or the postemergence herbicides must be repeatedly applied to control late-emerging weeds. A uniformly high population of sugarbeet will help reduce late emergence of weeds after the sugarbeet plants become large enough to shade the soil.

Some points of comparison between micro-rate and conventional-rate applications follow.

1) The micro-rate is less costly than conventional-rates but the micro-rate may need to be applied one more time than conventional rates to achieve similar weed control.

2) Generally, UpBeet, Stinger*, a grass herbicide and Betanex* or Betamix* or Progress* are all needed for broad spectrum control regardless of whether the application is micro-rate or conventional rate.

3) The conventional rates provide more consistent weed control than the micro-rate especially on ALS-resistant kochia and in dryer environments.

4) Early and timely application is more important with the micro-rate but the conventional rates are more likely to cause sugarbeet injury. Conventional rates should be applied no earlier than late afternoon to reduce the risk of sugarbeet injury while the micro-rate can be applied all day.

5) The micro-rate can be combined with a grass control herbicide plus oil adjuvant without significant antagonism to grass control. Conventional rates should not be applied with an oil adjuvant due to the risk of unacceptable sugarbeet injury. The grass herbicides need an oil adjuvant to be effective so grass herbicides plus oil adjuvant should be applied separately from conventional rates.

6) Conventional rates of Betanex*/Betamix*/Progress* should be adjusted for sugarbeet size, application method, and the presence of soil-applied herbicides. See the tables four pages previous in this paper for suggested rate adjustment.

7) All weeds must be totally controlled at sugarbeet planting through tillage or PRE Roundup* for the micro-rate to be fully effective. Weeds that get a head start on the sugarbeet plants may not be effectively controlled by the micro-rate.

*Or generic equivalent

RELATIVELY SAFE POSTEMERGENCE
TREATMENTS AT FOUR GROWTH
STAGES OF SUGARBEET, BROADCAST RATES.

Sugarbeet in the cotyledon to early two-true-leaf stage.
1) Grass herbicide + oil adjuvant.
2) Betanex* or Betamix* at 0.75 to 1.5 pt/A.
3) Betanex* or Betamix* at 0.75 to 1.5 pt/A + Grass herbicide (no oil adjuvant)
4) Stinger* + Betanex* or Betamix* at 0.25 pt + 0.75 to 1.5 pt/A.
5) Progress* at 0.5 to 1.1 pt/A.
6) UpBeet plus any treatment above.
7) The micro-rate program.

Sugarbeet in the two-true-leaf stage.
1) Betanex* or Betamix* at 1.0 to 2.0 pt/A.
2) Betanex* or Betamix* at 1.0 to 2.0 pt/A + grass herbicide (no oil adjuvant).
3) Stinger* at 0.25 to 0.5 pt/A.
4) Stinger* + Betanex* or Betamix* at 0.25 + 1.0 to 2.0 pt/A.
5) Progress* at 0.7 to 1.47 pt/A.
6) UpBeet plus any treatment above.

Sugarbeet in the mid-four-leaf stage.
1) Betanex* or Betamix* aat 1.5 to 3.0 pt/A.
2) Betanex* or Betamix* at 1.5 to 3.0 pt/A + grass herbicide and oil adjuvant.
3) Stinger* at 0.25 to 0.67 pt/A.
4) Stinger* + Betanex* or Betamix* at 0.25 to 0.5 + 1.5 to 3.0 pt/A.
5) Progress* at 1.1 to 2.2 pt/A.
6) UpBeet plus any treatment above

Sugarbeet in the six leaf stage.
1) Betanex* or Betamix* at 3.0 to 4.6 pt/A.
2) Betanex* or Betamix* at 3.0 to 4.6 pt/A + grass herbicide + oil adjuvant.
3) Progress* at 2.2 to 3.3 pt/A.

4) UpBeet + any treatment above.

Application of the listed treatments at the proper leaf stage of sugarbeet does not guarantee that sugarbeet will not be injured because environmental conditions can affect postemergence herbicide performance.

High temperatures with good soil moisture and especially a sudden change from cool, cloudy, and wet conditions to hot and sunny can increase the phytotoxicity of postemergence sugarbeet herbicides. When existing or predicted weather conditions would be expected to cause increased sugarbeet injury, then a herbicide treatment with less risk of sugarbeet injury should be used. For example, a rate of 1.5 to 2.0 pt/A of Betanex* should be substituted for 3.0 pt/A of Betanex* on 4-leaf sugarbeet when the environment would be expected to cause increased sugarbeet injury.

FROST AND SUGARBEET INJURY

Field and greenhouse research on the interaction between frost and postemergence sugarbeet herbicides was conducted by Chris Mayo as his PhD thesis research. A programmable frost chamber was used in the greenhouse research and a portable outdoor frost chamber with compressors powered by two large diesel engines was used for the field research. The outdoor frost chamber was built by Richard Watkins of American Crystal Sugar Company and was loaned to NDSU-U of MN for the research. Most of the research was conducted with Betanex*, Betamix* or combinations of herbicides that included Betanex* or Betamix* since these are the postemergence sugarbeet herbicides most likely to injure sugarbeet. Herbicide was applied from 5 to 53 hours before and from 5 to 53 hours after the frost event.

The interaction observed between postemergence sugarbeet herbicides and frost was not as large as expected. The frost treatments caused sugarbeet injury, generally about 5% plant death, and the herbicide treatments caused sugarbeet stunting. In the greenhouse, frost did not increase the amount of injury from the herbicides. Larger plants were injured less than smaller plants and a time interval between herbicide treatments as small as 24 hours would result in less sugarbeet injury. Thus, in the greenhouse, treating plants with herbicide as little as 12 hours after a frost caused less injury than treating plants before a frost, probably because the plants grew and became more tolerant when the herbicide treatment was delayed.

In the field experiments, frost plus herbicide caused more
injury than frost alone or herbicide on non-frosted sugarbeet. Herbicide applied as little as 12 hours after the frost caused less sugarbeet injury than herbicides applied before the frost. Herbicides applied after the frost caused injury similar to the same treatments on non-frosted sugarbeet.

The conclusion from both greenhouse and field research is that treating sugarbeet with postemergence herbicides after a frost will cause less sugarbeet injury than treating before the frost. Herbicides applied after a frost would be expected to cause injury similar to the same herbicide treatments on non-frosted sugarbeet.

LAYBY HERBICIDES

TREFLAN* at 1.5pt/A is registered for use on sugarbeet when the sugarbeet is 2 to 6 inches tall and well rooted. Exposed beet roots should be covered with soil before application. Emerged weeds are not controlled. Treflan* may be applied over the tops of the sugarbeet and incorporated with a harrow, rotary hoe, or cultivator adjusted to mix the herbicide in the soil without excessive sugarbeet stand reduction. Use of Treflan* can reduce the emergence of late season weeds which often cause problems in sugarbeet. Occasional girdling of sugarbeet plants from
*Or generic equivalent
Treflan* has been observed. This girdling usually does not cause significant yield loss. Soil residue harmful to wheat or barley is not likely the year after application. However, barley is more tolerant of Treflan* than wheat and should be grown following layby Treflan* and a dry year.

Dual Magnum (s-metolachlor) at 1.33 pt/a on medium-textured soils or 1.67 pt/a on fine textured soils is registered as a layby treatment for sugarbeet. Dual Magnum should be applied after sugarbeet has four true leaves and can be applied more than once but the total applied must not exceed 2.6 pt/a. Rain or sprinkler irrigation after application is needed for activation.

HAND WEEDING

Proper use of herbicides can provide very good control of most common weeds in sugarbeet. However, herbicides rarely give 100% weed control even under optimum conditions and herbicides occasionally will provide only fair to poor weed control for a variety of reasons. Unfavorable environment, improper timing of application, rates too low for the situation, very high weed populations, and late season weed emergence are some of the most common reasons for disappointing weed control.

Hand weeding is an effective and widely used supplement to herbicides and cultivation for weed control in sugarbeet. Some advantages of hand weeding are:

1. Hand weeding will reduce losses due to weed competition. Losses due to weed competition are proportional to weed density. At some low weed density, the value of the increase in yield from weed control will be equal to the cost of the weed control. This economic threshold is very difficult to predict because many factors impact yield loss due to weed competition. Weed density, weed species biology, date of crop and weed emergence, rainfall, soil temperature, row width, date of weed removal, previous herbicide use and the planned method of weed control, all can affect the economic threshold of weeds in sugarbeet. However, competition experiments in sugarbeet suggest that one or fewer weeds per 100 feet of sugarbeet row will be lower than the economic threshold regardless of other factors. The economic threshold weed density often will be greater than one weed per 100 feet of row but a lower economic threshold is unlikely.

2. Hand weeding will prevent weed seed production and reduce weed densities in the future. Hand weeding densities of weeds that are below the economic threshold may be beneficial if the field has a relatively low level of weed seed in the soil. However, a few more weed seed produced in a field already loaded with seed would be of little consequence.

3. Hand weeding can prevent seed production by weeds that are resistant to the herbicides that were applied and slow the buildup of herbicide resistant weeds.

4. A weed-free field is more attractive than a weedy field.

Evaluation of Weeding and Thinning by Hand Labor in Sugarbeet
Each year a few disputes arise between sugarbeet growers and hand labor who weed and thin sugarbeet. Generally the disputes involve the relative quality of the work performed and the fair price for the work performed. The evaluation of quality and relative value of hand labor performed can be quite complicated.

A definition of an ideal result from hand weeding and hand thinning may be useful as a target. The ideal result will be defined here as 35,600 uniformly spaced sugarbeet plants per acre (150 plants per 100 feet of 22-inch rows) with zero weeds left alive. The ideal result will rarely be achieved for a variety of reasons, some of which follow.

Reasons why weed free fields with 35,600 plants per acre may not be achievable:

1. 1.The beginning sugarbeet population may be less than 35,600 plants per acre before the hand weeding and hand thinning.
2. Hand labor cannot be expected to find and remove 100% of the weeds in a field in a single operation.
3. Hand removal of weeds will also result in some removal of sugarbeet plants so hand weeding a field with a dense weed population may result in a less than ideal sugarbeet population.
4. Some weeds may emerge after the weeding is done.
5. Some sugarbeet plants die after the thinning is done.

The ideal result from hand weeding and hand thinning will only be achieved rarely. However, a very good level of hand weeding and hand thinning can be achieved. Some considerations in evaluating the quality of the hand weeding and hand thinning follow.
1. Not over 1% of the original weeds in the field should survive after a single hand weeding. Skilled labor may do better than this with low weed densities in small sugarbeet or with low weed densities that have become taller than the sugarbeet canopy. A higher percentage of weeds will be missed with high weed populations in large sugarbeet, especially with

small, late-emerging weeds.

2.Most sugarbeet growers will not be willing to pay labor enough to do finger weeding of weeds growing close to sugarbeet plant. Therefore, some sugarbeet stand loss from weeding must be expected. Sugarbeet stand loss from weeding will be greater in a weedy field than in a clean field since more weeds will be close to sugarbeet plants in a weedy field. Sugarbeet plants growing within 0.5 inch around each sugarbeet plant would be unhoeable without removing the sugarbeet plant.

1200 inches in 100 ft
------------------------------ = inches between beets.
beet plants/100 ft

1.0 inch unhoeable per beet plant
--- = portion of row
inches per beet plant that cannot be hoed without removing the sugarbeet plant.

Portion unhoeable X weeds per 100 ft = beets per 100 ft removed by hoeing.

The following table was developed using the formulas above.

Table 6. Mathematical estimate of surviving sugarbeet plants after hoeing with various levels of weeds assuming all weeds were hoed out and a starting sugarbeet population of 150 plants per 100 ft of row.

Starting weeds per 100 ft row	Starting beets per 100 ft row	Ending beets per 100 ft row
25	150	147
50	150	144
100	150	138
200	150	125
400	150	100
800	150	50

The numbers in Table 6 indicate that a population of 200 weeds per 100 feet of row or less can be hand weeded in a starting beet population of 150 plants per 100 feet of row with a very adequate remaining sugarbeet population of 125 plants per 100 feet of row or more left after weeding. Hoeing of weed populations of more than 200 weeds per 100 feet of row would result in less than desirable sugarbeet populations.

Table 6 indicates that hand labor cannot be expected to remove dense weed populations without a detrimental effect on sugarbeet populations. Herbicides should be used to lower the weed populations so that hand weeding can be done and an adequate population can be maintained. Increasing density of seeding in a weedy field would increase the probability of retaining an adequate population of sugarbeet.

An estimate of the hours required to hand weed a field can be determined by counting weed population and using the following formula developed by Dr. Steve Miller at the University of Wyoming using student labor. Skilled labor may work faster than indicated in the formula.

Time for hand weeding in hours per acre = 2 hrs per acre for walking and looking + 0.5 hr per 1000 weeds for weeding

As expected, higher weed populations will take longer for weeding and the cost per acre would be higher. In 22-inch rows, one weed per 25 feet of row could be removed in 2.5 hours per acre while one weed per foot of row would take 14 hours per acre according to the formula.

Disputes between sugarbeet growers and hand labor who do thinning and weeding can be reduced by the following actions.

1. Count sugarbeet and weed populations in the field before and after the hand weeding and hand thinning.
2. Leave a small unweeded, unthinned check area.
3. Establish a block of weeded and thinned sugarbeet as an example before the labor starts work.
4. Make clear the expectations on final sugarbeet population and final weed population before the labor begins. The expectations should be reasonable after considering the starting weed and sugarbeet populations.

CONTROL OF LIVING CROP COVER

Production of sugarbeet in association with a living cover crop will reduce soil erosion and will protect small sugarbeet plants from damage caused by wind. Living cover crop can be fall seeded or spring seeded. Winter rye is more winter hardy than winter wheat so winter rye is the better choice for a fall seeded cover crop that will still be alive in the spring in eastern North Dakota and Minnesota. A spring seeded cover crop in eastern North Dakota and Minnesota normally would be seeded a few days to a few hours before the sugarbeet. Barley and oats are good choices for a spring seeded crop since seed is relatively inexpensive and early spring growth is vigorous. The research conducted was with barley.

Living cover crops are potentially beneficial. However, a cover crop will compete with sugarbeet just like a weed. Timely control and proper seeding rate are important to minimize sugarbeet yield loss from competition. Fall seeded winter rye is much more competitive than spring seeded barley but the rye also provides more protection from wind damage and soil erosion.

Research in eastern North Dakota and Minnesota has shown that winter rye as a cover crop fall seeded at 22 lb/A caused more sugarbeet yield loss than winter rye seeded at 15 or 7.5 lb/A. Barley as a cover crop spring seeded at 48 lb/A caused more sugarbeet yield loss than barley seeded at 24 or 12 lb/A. Sugarbeet yield loss from the highest tested seeding rates probably was from increased competitive ability of higher populations of rye and barley and from the lower level of control by herbicides in the plots with higher populations of cover crop. Therefore, seeding rates of about

15 lb/A of winter rye or 24 lb/A of barley are suggested as a compromise between reducing competition and optimizing protection from the cover crop.

Living cover crop must be controlled on time to avoid sugarbeet yield loss from competition. Winter rye growing near the sugarbeet row must be controlled at or before sugarbeet seeding. A band application of Roundup would be an effective method of control. A one-week delay in controlling winter rye after seeding sugarbeet caused a loss in sugarbeet yield in research.

Living rye between the sugarbeet rows should be controlled by the time that the sugarbeet reaches the two-leaf stage. Sugarbeet still needs protection from wind at this small growth stage so the rye could be treated with one of the postemergence grass herbicides and then left uncultivated until the sugarbeet plants are large enough to be safe from wind damage. The field could be cultivated after the sugarbeet plants were safe from wind to remove rye plants not fully controlled by the herbicide and emerged weeds.

Spring seeded barley growing near the sugarbeet row should be controlled by the time the barley has three leaves. Barley between the rows should be controlled by the time the sugarbeet has four leaves and the barley has 4 to 5 leaves. Barley between the rows could be controlled by cultivation or by a postemergence grass herbicide. The postemergence grass herbicide option would allow an extended period of protection since the dead and dying cover crop will provide some protection.

SUGARBEET

Herbicide	Formulation/A (Act. Ingred.lb/A)*	Weeds	When to Apply	Remarks
Assure II (quizalofop)	8 to 10 fl oz (0.055 to 0.07) ________ 10oz (0.07)	Annual grasses ________ Quackgrass	Wild oat; 2 to 6 in tall Foxtail: 2 to 4 in tall Volunteer wheat or barley: 2 to 4 in tall. ________ Quackgrass: 6 to 10 inches tall	Apply with oil adjuvant. PHI is 45 days. ________ Treat quackgrass regrowth with 6 to 7 fl oz/A when 4 to 8 inches tall.
Betamix **D-PMix** **Phen-Des** (desmedipham + phenmedipham) ________ **Betanex** **Des** **Alphanex** (desmedipham)	0.75 to 7.5 pt (0.12 to 1.2) ________ 0.75 to 7.5 pt (0.12 to 1.2)	Most annual broadleaf weeds	Postemergence when broadleaf weeds are from cotyledon to 4-leaf stage. Sugarbeet with less than 4 leaves will tolerate 0.12 to 0.5 lb/A and sugarbeet with 4 leaves or more will tolerate higher rates.	Risk of sugarbeet injury is increased by morning or midday application and by certain environments. Split application with reduced rates has reduced sugarbeet injury and increased weed control compared to single full dose application. Rates should be reduced by 25 to 33% with small sugarbeet if aerial or high pressure (>100 psi) application is used or if the field was treated with a soil-applied herbicide. PHI is 75 days.
See herbicide brand options listed with individual herbicides (desmedipham or desmedipham & phenmedipham or desm & phen & ethofumesate + triflusulfuron + clopyralid + MSO type oil adjuvant MICRO-RATE PROGRAM	8 or 8 or 5.7 fl oz + 0.125 oz + 1.3 fl oz + 1.5% (v/v) 0.08 + 0.004 + 0.03 + 1.5% The desm or desm & phen or desm & phen & etho rate can be increased to 12 or 12 or 8.7 fl oz/A after sugarbeet has four leaves	Most annual broadleaf weeds. Fair to good annual grass control. Will not control ALS resistant kochia. Increasing the Stinger rate from 1.3 to 2.6 fl oz/A will improve control of lanceleaf sage with some risk of increased sugarbeet injury.	POST Apply a minimum of three times starting at cotyledon sugarbeet stage. Apply subsequent treatments at 5 to 7 day intervals.	Timely application is critical to success of the Micro-Rate Program. A grass control herbicide at 1/3 to 1/2 normal rate can be added. Herbicide precipitation in the spray tank and nozzle plugging has been a problem. Nozzle plugging can be reduced by mixing in warm water, raising water pH to 8 to 9, premixing UpBeet, use of a grass herbicide and frequent cleaning of sprayer.
Dual Magnum (s-metolachlor)	1.33 to 1.67 pt (1.25 to 1.6)	Late emerging annual grass and some annual broadleaf weeds	Postemergence to sugarbeet with four or more true leaves	Emerged weeds not controlled. Rain or sprinkler irrigation needed for activation. May be applied more than once but total applied must not exceed 2.6 pt/A. PHI is 60 days.
Eptam (EPTC)	2.3 to 3.4 pt (2 to 3) ________ 4 to 5 pt 7E, 17 to 22 lb 20G (3.5 to 4.38)	Annual grasses and some broadleaf weeds	Preplant incorporated ________ Fall incorporated after October 15 to freeze-up.	Some stand reduction and temporary stunting may occur from the use of EPTC. Weak on wild mustard.
Eptam (EPTC +) **Ro-Neet** (cycloate)	1.1 to 2.3 + 2.7 to 3.3 pt (1 to 2 + 2 to 2.5) ________ 1.1 to 2.9 + 2.7 to 4 pt (1 to 2.5 + 2 to 3)	Annual grasses and some broadleaf weeds	Preplant incorporated ________ Fall incorporated after October 15 until freeze-up.	Less sugarbeet injury than from Eptam alone and less expensive than Ro-Neet alone. See narrative for suggested rates for various soil textures and organic matter content.
Far-Go (triallate)	1.5 qt 15 lb 10 G (1.5)	Wild oat.	Fall incorporated after October 15 until freeze-up or snow cover. Spring PPI before wild oat germination.	Incorporate immediately after application with a tillage tool set 3 to 4 inches deep. A second incorporation at an angle to the first will improve uniformity of distribution. One pass in the fall followed by spring seedbed preparation is sufficient for fall application.
Glyphosate (various brand names)	1 to 2 pt of a 3 lb ac/gal conc. or equivalent (0.38 to 0.75 ae) See Remarks	Emerged grasses and broadleaf weeds and volunteer crops.	Preplant or anytime prior to crop emergence.	Product amount/A: 0.38 ae 0.57ae 0.75ae 1.125ae 3 lb ae (4 lb ai) = 16 fl oz 24 fl oz 32 fl oz 48 fl oz 3.7 lb ae (5lb ai) = 13 fl oz 20 fl oz 26 fl oz 39 fl oz 4 lb ae (5.4 lb ai) = 12 fl oz 18 fl oz 24 fl oz 36 fl oz 4.5 ae (5.5 lb ai) = 11 fl oz 16 fl oz 21 fl oz 32 fl oz Non-selective, non-residual, systemic, foliar herbicide. Apply with AMS fertilizer. Refer to label for adjuvant use. Several commercial mixtures available with 2,4-D and dicamba. A4-6 B1-2 Q1 Q3

SUGARBEET

Herbicide	Formulation/A (Act. Ingred.lb/A)*	Weeds	When to Apply	Remarks
Nortron **Etho** **Ethotron** (ethofumesate)	6.0 to 7.5 pt F (3.0 to 3.75)	Many annual grasses and broadleaf weeds. Especially good on redroot pigweed. Provides fair to good kochia control.	Preemergence or preplant incorporated	Incorporation generally improves weed control. Band application reduces cost and risk of carryover into the next year.
Nortron **Etho** **Ethotron** (ethofumesate)	4 fl oz (0.125)	Improves control of broadleaf weeds such as kochia, redroot pigweed, common lambsquarters.	Postemergence in combination with Progress, Betanex or Betamix.	Crop restrictions allow no more than two applications in combination with the micro-rate of Progress or no more than three applications in combination with any labeled rate of Betanex or Betamix.
Paraquat	1.25 to 2.7 pt of a 3 lb/gal conc. (0.47 to 1.0)	Emerged annual grasses and broadleaf weeds	Preplant or anytime prior to crop emergence.	A non-selective, non-residual, postemergence herbicide. No soil residual activity. Apply with nonionic surfactant. Good coverage is essential. Restricted use herbicide.
Poast (sethoxydim)	0.5 to 1.5 pt (0.1 to 0.3)	Annual and perennial grasses	Wild oats: 1 to 4 in. Foxtail: 3 to 8 in. Vol. wheat or barley: 1 to 6 in.	Always apply with an oil adjuvant and with ammonium sulfate or 28% liquid nitrogen for certain weed species. Apply to actively growing grasses. See narrative for rates for different grass species. PHI is 60 days.
Progress **Des-Phen-Etho** (desmedipham +	0.56 to 5.0 pt (0.12 to 1.13)	Most annual broadleaf weeds	Postemergence from cotyledon to 4-leaf stage of weeds. Sugarbeet with	Risk of sugarbeet injury is increased by morning or midday application and by certain environments. Split application with

phenmedipham + ethofumesate)			less than 4 leaves will tolerate 0.12 to 0.5 lb/A and sugarbeet with 4 leaves or more will tolerate higher rates.	reduced rates has reduced sugarbeet injury and increased weed control compared to single full dose application. Rates should be reduced by 25 to 33% with small sugarbeet if aerial or high pressure (>100 psi) application is used or if the field was treated with a soil-applied herbicide. PHI is 75 days.
Pyramin SC (pyrazon)	6 to 14.5 pt F (3.1 to 7.6)	Most broadleaf weeds	Preemergence or preplant incorporated.	Has been less effective on soils wit more than 5% organic matter. Incorporation improves weed control from pyramin.
Ro-Neet (cycloate)	4 to 5.3 pt 6E (3 to 4) 5.3 pt 6E (4)	Annual grasses and some broadleaf weeds	Preplant incorporated Fall incorporated after October 15 until freeze-up.	Sugarbeet has better tolerance to Ro-Neet than to Eptam. Weak on wild mustard. Weed control poor on fine textured, high organic matter soils.
Select **Arrow** **Prism** (clethodim)	6 to 8 fl oz 6 to 8 fl oz 12.8 to 17 fl oz (0.095 to 0.125)	Annual grasses	Wild oats: 2 to 6 in. Foxtail: 2 to 8 in. Vol. wheat or barley: 2 to 6 in.	Always apply with an oil additive. Apply to actively growing grasses. Use higher rate on dense and/or large grasses. PHI is 40 days.
	8 to 16 fl oz 8 to 16 fl oz 17 to 34 fl oz (0.125 to 0.25)	Quackgrass	6 to 10 in.	
Stinger **Clopyr Ag** (clopyralid)	0.25 to 0.66 pt (0.09 to 0.25) See "micro-rate program" for reduced rate in combination.	Canada thistle, cocklebur, sunflower, marshelder, wild buckwheat.	Postemergence to sugarbeet with 2 to 8 leaves	See narrative for rates and treatment sizes for various species. Clopyralid may be tank-mixed with desmedipham or phenmedipham. PHI is 45 days.
Trifluralin	1.5 pt 4 E (0.75)	Late emerging annual grass and some broadleaf weeds	Sugarbeet 2 to 6 inches tall and well- rooted to withstand incorporation.	Must be incorporated. Exposed beet roots must be covered with soil before application. Emerged weeds not controlled. May be applied over the tops of sugarbeet.
UpBeet (triflusulfuron)	0.5 oz (0.0156) See "micro-rate program" for reduced rates in combination.	Annual broadleaf weeds	First treatment to cotyledon to 2-leaf weeds.	Apply two or more times in combination with Betanex, Betamix, Progress or Stinger. Research in ND-MN has shown that three treatments including 0.25 to 0.3 oz/A of UpBeet generally gave better weed control than two treatments including 0.5 oz/A of UpBeet. Use is limited to a maximum of 2.5 oz/A per year. PHI is 60 days.

*Rates are shown as formulated product/A (top line) and lb/A active ingredient in parentheses. Some herbicides have more than one type formulation; in this case refer to lb active ingredient per acre and check herbicide label for formulated product/A.

TRADE NAME AND MANUFACTURER	COMMON NAME	CONCENTRATION AND COMMERCIAL FORMULATIONS	APPROXIMATE RETAIL COST
Alphanex (United Phosphorus)	Desmedipham	1.3 lb/gal E	$100/gal
Arrow (Makhteshim-Agan)	Clethodim	2.0 lb/gal E	$185/gal
Assure II (DuPont)	Quizalofop	0.88 lb/gal E	$130/gal
Betamix (Bayer CropScience)	Desmedipham + Phenmedipham	0.65+0.65 lb/gal E	$100/gal
Betanex (Bayer CropScience)	Desmedipham	1.3 lb/gal E	$100/gal
Clopyr Ag (AgValue)	Clopyralid	3.0 lb/gal S	$480/gal
D-P Mix (Ag Value)	Desmedipham + Phenmedipham	0.65+0.65 lb/gal E	$100/gal
Des (AgValue)	Desmedipham	1.3 lb/gal E	$100/gal
Des-Phen-Etho (Ag Value)	Desmedipham + Phenmedipham + Ethofumesate	0.6+0.6+0.6 lb/gal E	$106/gal
Dual Magnum (Syngenta)	s-metolachlor	7.62 lb/gal E	$100/gal
Eptam (Syngenta)	EPTC	20% G, 7 lb/gal E	$1.05/lb $32/gal
Etho SC (Ag Value)	Ethofumesate	4.0 lb/gal SC	$100/gal
Ethotron SC (United Phosphorus)	Ethofumesate	4.0 lb/gal SC	$100/gal
Far-Go (Monsanto)	Triallate	4 lb/gal E 10% G	$40/gal $0.95/lb
Nortron SC (Bayer CropScience)	Ethofumesate	4 lb/gal SC	$100/gal
Phen-Des (United Phosphorus)	Desmedipham + Phenmedipham	0.65+0.65 lb/gal E	$100/gal
Poast (Microflo)	Sethoxydim	1.5 lb/gal E	$65/gal
Prism (Valent)	Clethodim	0.94 lb/gal E	$91/gal
Progress (Bayer CropScience)	Desmedipham + Phenmedipham + Ethofumesate	0.6 + 0.6 + 0.6 lb/gal E	$106/gal
Pyramin SC	Pyrazon	4.5 lb/gal F	$82/gal

(Microflo)			
Ro-Neet (Monterey)	Cycloate	6 lb/gal E	$56/gal
Select (Valent)	Clethodim	2.0 lb/gal E	$185/gal
Stinger (Dow)	Clopyralid	3 lb/gal S	$480/gal
UpBeet (DuPont)	Triflusulfuron	50% DF	$45/oz
Several trade names	Glyphosate	3 lb/gal S	$30 to 45/gal
Several trade names	Trifluralin	4 lb/gal E	$25/gal
Several trade names (Syngenta)	Paraquat	3 lb/gal S	$35/gal

[1] The mention of trade name does not imply that they are endorsed or recommended over those of similar nature not listed.

[2] G = granule, E = emulsifiable concentrate, F = liquid flowable, S = solution, SC = suspension concentrate, SP = soluble powder, WP = wettable powder.