SUGARBEET

M1. Sugarbeet herbicides may be used to supplement cultural practices. Hand labor, mostly hoeing, may be needed for optimum weed control but can be reduced or eliminated by timely cultivations and herbicide applications.

M2. Herbicide tank-mixtures are commonly used on sugarbeet. Non-labeled herbicide combinations may be tank-mixed legally if all herbicides in the mixture are registered for use on sugarbeet. However, the user must assume liability for any crop injury, inadequate weed control, or illegal and/or harmful residues.

M3. Betanex / Alphanex (desmedipham) and **Betamix / Phen-Des 8+8** (desmedipham & phenmedipham) applied POST occasionally causes sugarbeet injury. Sugarbeet with four true leaves are more tolerant than smaller plants and continue to gain tolerance with increased size. Application rates totaling 3 pt/A or less should be followed by a second application in 5 to 7 days if living weeds are present after 5 days. Split application with reduced rates reduces sugarbeet injury and increases weed control compared to one full-rate application. See Table 1 below. Risk of sugarbeet injury is reduced by starting application in late afternoon so cooler temperatures follow application. Risk of injury increases during recent flooding, high temperature, and especially, a sudden change from cool, cloudy conditions to hot, sunny weather. Allow a 75 day PHI for Betanex* and Betamix*.

Betanex*, Betamix*, Broadcast Rate.

	No soil herbicide			
Sugarbeet stage	Low pressure (<100 psi)		High pressure or aerial	
	(lb/A)	(pt/A)	(lb/A)	(pt/A)
Coty-2-leaf	0.25	1.5	0.16	1
2-leaf	0.33	2	0.25	1.5
4-leaf	0.5	3	0.4	2.5
6-8-leaf	0.75	4.6	0.75	4.6

	With soil herbicide			
Sugarbeet stage	Low pressure (<100 psi)		High pressure or aerial	
	(lb/A)	(pt/A)	(lb/A)	(pt/A)
Coty-2-leaf	0.16	1	0.12	0.75
2-leaf	0.25	1.5	0.16	1
4-leaf	0.33	2	0.25	1.5
6-8-leaf	0.5	3	0.5	3

* Or generic equivalent.

M4. Clopyralid is enhanced the most with MSO type adjuvants. Clopyralid controls small weeds in the Composite, Polygonum, and Legume, and Nightshade families. Apply to wild buckwheat in the 3- to 5-leaf stage before vining begins. Apply clopyralid at 0.5 to 0.66 pt/A to Canada thistle in the rosette to pre-bud growth stage. Rosette application will give better control than later application.

M5. Dimethenamid-P on medium to fine-textured soils may be used as a lay-by treatment when sugarbeet has 4 to 8 leaves. Apply once or sequentially but the total must not exceed 21 fl oz/A. Precipitation after application is required for activation. Weeds that emerge prior to activation will not be controlled.

*Or generic equivalent.

M6. Eptam (EPTC) may cause sugarbeet stand reduction and temporary stunting without yield reduction if adequate sugarbeet population remains after thinning. Injury increases in light soils with low OM. Ro-Neet or Nortron* cause less sugarbeet injury on the low OM soils where Eptam injury may be excessive.

Ro-Neet (cycloate) gives better control than Eptam when spring rainfall is adequate to excessive but Eptam tends to give better weed control than Ro-Neet on fine-textured, high OM soils or under relatively dry conditions. Ro-Neet causes less injury than Eptam and is safer on more coarse-textured, low OM soils. Eptam and Ro-Neet can be applied in the fall.

M7. Eptam (EPTC) plus **Ro-Neet** (cycloate) has less potential for sugarbeet injury and is less expensive than Ro-Neet alone. The rate of the mixture must be adjusted for soil texture and OM.

Suggested Eptam + Ro-Neet rates.

Soil type	OM	Eptam + Ro-Neet Rate	
Fall applied	%	------ pt/A ------	
–	<3	--	5.3
Loam or coarser	3	1.1	4
Loam to clay-loam	3-4	1.7	3.3
Clay-loam	3.5-4.5	2.3	2.7
Clay to clay-loam	>4.5	2.9	3.3
Spring applied			
Loam or coarser	<3	--	4
Loam or coarser	3-3.5	1.1	3.3
Loam to clay-loam	3.5-4.5	1.7	3.3
Clay loam or finer	>4	2.3	2.7

Adjust rates on certain fields or with certain incorporation tools based on individual experience. Eptam, Ro-Neet, or Eptam plus Ro-Neet require immediate incorporation for best weed control.

M8. Far-Go (triallate) requires immediate incorporation after application at 3 to 4 inches deep for best wild oat control. Delaying the second incorporation for three days or longer after the first incorporation improves wild oat control. Delaying the second incorporation is especially important for granular formulations. One incorporation in the fall followed by spring seed-bed preparation is sufficient for fall-applied Far-Go. Far-Go should be fall-applied when temperatures are consistently below 50 F. Far-Go may be applied until snow cover or soil freeze up. Far-Go will control wild oat that have developed resistance to ACCase-inhibitor POST herbicides for grass control.

M9. S-metolachlor applied preplant incorporated or preemergence has caused excessive sugarbeet injury. Growers must sign a liability form that releases Syngenta from all liability for sugarbeet injury before use. Apply PPI or PRE in the spring or fall and adjust rate depending on soil texture and OM content. Make fall applications after October 15 but before ground freezes. Lay-by applications can be done without signing a liability release form. Apply lay-by after sugarbeet has four true leaves. Multiple lay-by applications can be made but the total applied must not exceed 2.6 pt/A per season. Precipitation after application is required for activation.

M10. Micro-rate or Mid-rate programs use low rates of herbicides in combination applied three or more times at 5 to 7 day intervals starting when weeds are just emerging. The micro-rate treatment is Betanex* / Betamix* / Progress* plus UpBeet plus Stinger* plus a methylated seed oil (MSO) adjuvant at 8 to 12 / 8 to 12 / 5.7 to 8.7 fl oz/A plus 0.125 oz/A plus 1.3 fl oz/A plus 1.5% v/v. The MSO is essential to increase weed control when low herbicide rates are used.

The mid-rate treatment includes Betanex*/Betamix*/Progress* at 12 to 16 / 12 to 16 / 8.7 to 11.6 fl oz/A after sugarbeet has four leaves along with the same rate of UpBeet, Stinger* and MSO. Add Assure II at 4 fl oz/A or Select* at 2 fl oz/A or Poast at 5.3 fl oz/A to the micro-rate to improve grass control. The micro-rate will not control lanceleaf sage or ALS-resistant kochia.

The micro-rate and mid-rates applied a minimum of three times generally gives better weed control than two applications of conventional rates. Three applications of conventional rates may give better weed control than three applications of the micro-rate. Four micro-rate applications may give better weed control than three applications of conventional rates or the micro-rate due to controlling late-emerging weeds.

Precipitation and nozzle plugging is common with ground application of the micro-rate.
Several factors may reduce nozzle plugging.
1) Start with a clean sprayer, spray out the tank load immediately after mixing, spray until tank is dry, flush sprayer between loads, clean sprayer frequently, and avoid spray solution to set in the tank. 2) Allow the sprayer tank water to warm before mixing and increase the pH of water to 8 or 9 by adding ammonia or Quad 7.
3) Pre-mix the UpBeet in hot water or water with pH 8 to 9. Put UpBeet in the tank first and be sure it is dissolved before adding, in order, Betanex*/Betamix*/Progress*, Stinger*, and MSO type oil adjuvant. A 2% solution of household ammonia at 1 gal/100 gal of water will give about pH 9. Add ammonia slowly as the tank fills so water pH does not go much over pH 9.
4) 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 and Select* but all had an effect.
5) Use gentle agitation.

M11. Nortron / Ethotron (ethofumesate) is the best of the soil-applied herbicides for kochia control providing fair to good control. Nortron* may be applied PRE but PPI improves weed control. Incorporation at 2 to 4 inches may give better weed control than incorporation at 1 inch deep. Band application of Nortron* reduces cost and soil residue. Nortron* has been relatively safe on sugarbeet but use of Nortron* with Ro-Neet or fall-applied Eptam can cause sugarbeet injury especially on medium to coarse textured soils. Nortron* plus spring-applied Eptam may cause serious injury and should only be used on fine textured soils with over 6% OM. See labels for Nortron* rate adjustment for various soil types.

Use the following recommendations to reduce nozzle plugging or incompatibility issues with Nortron:
1) Fill partially used Nortron jugs with water to prevent formation of insoluble Nortron residue. Mark the level of remaining Nortron in the jug before adding water.
2) Flush lines and clean nozzles and screens daily.
3) Use warm water.
4) Addition of liquid nitrogen may help.
5) Use 50 mesh or larger screens.
6) Use spray volumes of 40 to 60 gpa.

M12. Progress / BNB Plus (desmedipham & phenmedipham & ethofumesate) applied POST gives increased control of some weeds and greater risk of sugarbeet injury than Betamix* alone. The active ingredients are in a 1:1:1 ratio. Adjust the rate of Progress* so the total lb/A of the active ingredients is equal to the lb/A of Betamix* if the Betamix* were applied alone. For example, if the normal rate of Betamix* was 0.3 lb/A then Progress* also should be applied at 0.3 lb/A. Risk factors are the same as for Betamix* alone.
*Or generic equivalent.

M13. UpBeet (triflusulfuron) should be used with an adjuvant when applied with clopyralid but without adjuvant when applied with Betanex*, Betamix*, or Progress* except in the micro-rate. Apply UpBeet in combination with other labeled broadleaf herbicides. UpBeet will antagonize grass control from Assure II, clethodim, or Poast similar to antagonism caused by Betanex*, Betamix* or Progress*. Research in eastern ND and MN has shown that Betamix* + UpBeet applied once at 1.5 pt + 0.5 oz/A followed 7 days later by 2 pt + 0.5 oz/A generally gave less control than Betamix* + UpBeet applied three times at 7 day intervals using 1 pt + 0.25 to 0.3 oz/A in each treatment.

M14. Trifluralin will provide residual weed control. Broadcast and incorporate immediately with cultivators or tillage tools adjusted to mix the herbicides in the soil without excessive sugarbeet stand loss. The crop should be clean cultivated before application since established weeds are not controlled. Trifluralin with good moisture conditions will control late germinating weeds that may become a problem late into the season.

M15. Combinations of postemergence herbicides give more broad spectrum and greater total weed control compared to individual treatments. Clopyralid* + Betanex* or clopyralid* + Betamix* have controlled wild buckwheat, eastern black nightshade, lambsquarters, buffalobur, giant ragweed, ladysthumb, lanceleaf sage, and Russian thistle superior to clopyralid* alone and superior to Betanex* or Betamix* alone.

UpBeet* plus Betanex*, Betamix* or Progress* has provided improved control of redroot pigweed, prostrate pigweed, kochia, common mallow, nightshade, ladysthumb, 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 + clopyralid has given good to excellent control of all common broadleaf weeds in sugarbeet in research conducted in ND and MN except ALS-resistant kochia.

HERBICIDE-RESISTANT SUGARBEET

Roundup Ready Sugarbeet

M16. Glyphosate may be applied from emergence to 30 days before harvest to Roundup Ready sugarbeet. Refer to labels for adjuvant use. Glyphosate is formulated from 3 to 5 lbs acid equivalent (ae) per gallon. Use registered formulations and rates in Roundup Ready sugarbeet. The total amount of glyphosate that can be applied to sugarbeet at various times is listed in the tables. Glyphosate may be applied up to four times POST to sugarbeet with at least 10 days between applications. Apply glyphosate in the least amount of spray volume allowed but avoid drift of spray droplets. Apply with AMS at 4 lbs/100 gallons of water, or more for hard water.

*Or generic equivalent.

POTATO

N1. Tillage through hilling and cultivation and herbicides are the two primary means of controlling weeds in potato. The first tillage operation after planting is usually a "blind" cultivation or harrowing before the crop emerges. The number of tillage operations will vary, but three cultivations and two hilling operations are common. After emergence, inter-row cultivation is used to control weeds and to form a ridge or hill over the seed piece and developing tubers. Besides controlling weeds, the ridge or hill helps protect tuber from sunburn (tuber greening), late season frosts, excessive rainfall or irrigation and reduces the amount of soil to be moved at harvest. Deep cultivation may cause root and tuber pruning.

N2. Matrix (rimsulfuron) applied PRE or POST alone or with metribuzin controls annual grass and some broadleaf weeds. Use the low rate of metribuzin for PRE applications to coarse textured soil. Soil residual of Matrix and metribuzin may injure susceptible crops the following year.

Matrix controls eastern black nightshade and may control or suppress hairy nightshade but gives no black nightshade and lambsquarters control. Apply PRE to potato and weeds after hilling or drag-off but before potato emerge or POST before potato is 14 inches tall and annual weeds are less than 1 inch tall and quackgrass 4 to 6 inches tall. Best results occur when 0.75 inches of water occur soon after application. Apply with MSO type adjuvants or PO at 1% v/v or NIS at 0.25% v/v to emerged weeds. Matrix can be applied in a sequential program of 1 oz 25DF/A PRE followed by 1 oz 25DF/A POST. Matrix may be tank-mixed with Eptam, metolachlor, metribuzin, or Prowl. Follow label directions when tank-mixing Matrix plus metribuzin. See metribuzin paragraph for additional information.

N3. Metribuzin applied PRE or POST controls many broadleaf weeds and suppresses some grasses. Use lower rate on coarse textured soils and for weeds under 1 inch tall. Do not apply to red-skinned, early maturing, white-skinned varieties; or within 3 days after cool, wet, cloudy weather. Follow varietal restrictions according to metribuzin label. Injury may occur to russet type or white skin potato varieties; therefore, use only the low rate of metribuzin and consider the risk of weed control vs potato injury prior to application to "at risk" varieties. Refer to label for application information and restrictions.

FORAGE LEGUMES

P1. Seedling legumes are poor competitors with weeds. Use good management practices in preceding crops, such as clean cultivation in row crops and post-harvest tillage to reduce weed seeds in soil. Weed control for establishment of legumes sown alone can be aided by mowing (except sweetclover), herbicides, or by seeding a companion crop. Strong alfalfa competition may improve control of weeds that escape herbicide activity. Except for use of glyphosate in Roundup Ready alfalfa, there is no chemical control for absinth wormwood.

CRP BREAKOUT

R1. CRP breakout or vegetation management when breaking land out of CRP is difficult. Heavy vegetation produced from many years of growth without grazing or haying will make cultivation difficult. For most situations, haying in the summer will help remove much of the vegetation found in CRP. Burning may destroy standing plant residues but will not kill underground roots and is not recommended. Removing vegetation by burning may increase weed seed germination. Methods to control vegetation without destroying residues should be used to enhance soil quality and control erosion.

Cultivation alone will not give satisfactory control of CRP vegetation. A herbicide treatment applied several weeks prior to tillage will reduce the amount of vegetation. Fall-applied herbicides are needed if conventional tillage methods will be used to prepare a seedbed the following year. Fall application allows breakdown of foliage and root plant biomass. Cultivators and some tillage equipment tend to plug during spring tillage when a fall-applied herbicide is not used. Mechanical and cultural vegetation control methods should be followed by a vigorous weed control program the following spring. CRP grasses and forbs may become a problem in the planted crop. Seeding a broadleaf crop after CRP breakout will provide chemical control options not available in grass crops.

NDSU research found that glyphosate at 0.75 lb ae/A applied fall or spring gave less than 70% alfalfa and smooth bromegrass control. Glyphosate at 1.5 lb ae/A applied in fall gave 98% early season alfalfa and smooth brome control but regrowth occurred by mid-summer. A fall application followed by a spring application of glyphosate each at 0.75 lb ae/A or a spring application of Roundup at 1.5 lb ae/A was required for greater than 90% control of smooth brome. A spring application of glyphosate at 1.5 lb ae/A also provided over 90% alfalfa and smooth brome control. Tillage improved control of perennial regrowth (15 to 20% increase) from fall applications of glyphosate but did not improve control from spring applications.

ANNUAL WEED CONTROL

S1. Wild buckwheat is especially troublesome in broadleaf row crops where few chemical control options are available Vining wild buckwheat climbs up crops in a manner similar to field bindweed. Wild buckwheat makes swathing or combining extremely difficult as it wraps itself around the crop and becomes entangled on the sides of the header. In heavily infested fields, wild buckwheat can essentially pull a crop to the ground and severely impact yield. NDSU weed control trials have shown that several herbicides will provide good to excellent wild buckwheat control in small grains including bromoxynil, clopyralid, clopyralid & fluroxypyr, dicamba, Huskie, Python, thifensulfuron at small grains rates, and metribuzin, Prowl, Sonalan, trifluralin, and Valor will suppress wild buckwheat. Python, Pursuit or Pursuit Plus applied PPI or PRE, and glufosinate POST provide excellent wild buckwheat control while glyphosate may need two applications or apply with Resource for control.

S2. Foxtail is most competitive when small grains are seeded late and soil temperatures are warm for foxtail germination and rapid growth. Fields regularly chisel plowed generally have more foxtail than moldboard plowed fields. Moldboard plowing buries the foxtail seed, which prevents emergence and reduces viable seed for subsequent years.

Making a decision on whether to control foxtail in small grains is not always easy. Research from NDSU and in Canada has shown that foxtail often will not decrease wheat and barley yields; however, heavy foxtail infestations can cause harvest problems (especially when straight combining) and can cause dockage at the elevator. Herbicide treatment for foxtail may not be warranted when foxtail infestations are light - less than 30 plants/sq. ft and when foxtail emerges after the crop is in the 3- to 4-leaf stage. This is especially true for barley. Once the small grain is in the 3- to 4-leaf stage, it can usually out-compete emerging foxtail. Chemical control is warranted when the foxtail population is heavy (100 plants/sq ft or more). Foxtail also may contribute to moisture stress and cause greater yield loss under drought conditions. Foxtail emerging at the same time or before small grain is more competitive than when emerging after small grain. Some options to consider for foxtail control are:
1. If the foxtail infestation is heavy, and just emerging with the crop, consider harrowing or rotary hoeing as soon as possible. Harrowing or rotary hoeing is not effective once foxtail has 2 to 3 leaves. Small grains can be harrowed or rotary hoed until the 3- to 4-leaf stage with little effect on yield. If a harrow or rotary hoe is not an option, then consider a herbicide.

2. If the foxtail infestation is light to moderate, chemical control is optional but weed seed may contribute to weed infestations in subsequent crops. Herbicides can still be used if foxtail is a problem after small grain is in the 5- to 6-leaf stage.

S3. Kochia is an exceptionally competitive weed and a few uncontrolled plants can cause severe yield losses. ALS herbicides provide good control of susceptible kochia populations. Tank-mixing ALS herbicides with other effective broadleaf herbicides with differing modes of action is required to slow development of resistant kochia. Clopyralid & fluroxypyr, dicamba, fluroxypyr, and Huskie control ALS-susceptible and -resistant kochia. Bromoxynil & MCPA or Aim also give good control of small kochia, but plants should be small and spray coverage adequate. Tordon and clopyralid are not effective on kochia and 2,4-D and MCPA no longer control kochia due to resistance from repeated use and near eradication of susceptible kochia biotypes. 2,4-D and MCPA do not translocate readily in kochia. Treat plants when small (less than 3 inches tall). Kochia seed is short-lived in soil so one or two years of excellent control can greatly reduce kochia populations. DNA herbicides do not give consistent kochia control. However, Sonalan may improve control. Soil-applied Spartan and Valor gives good to excellent kochia control. Flexstar or Reflex applied with MSO adjuvant in high water volumes of 20 gpa to small kochia may give good postemergence control.

S4. Nightshades have become a serious weed problem in North Dakota due higher rainfall and human activity associated with crop production, like moving tillage and harvesting equipment from field to field or planting crop seed contaminated with nightshade seed. Also, birds and wildlife consume nightshade berries and can transport seed through droppings.

Four nightshade species are found in North Dakota: black nightshade, eastern black nightshade, hairy nightshade, and cutleaf nightshade. Hairy nightshade is the only species densely covered with small hairs. The berries of cutleaf and hairy nightshade remain green at maturity. Only the underneath side of black and eastern black nightshade leaves are black or dark-purple and berries turn black or dark purple at maturity. Eastern black nightshade is very difficult to distinguish from black nightshade before berry formation. Eastern black nightshade forms berries in umbrella-like clusters with berry stems arising from a common point, the calyx of eastern black nightshade is the smallest of the four, and the lobes of the calyx recurve away from the berry. Black nightshade and hairy nightshade berries connect in a racemose fashion (similar to grapes). The calyx of black nightshade is mid-size and the lobes extend outward, while the calyx of hairy nightshade is large and encloses half the berry. It has been reported that leaves from eastern black nightshade plants are translucent and leaves from black nightshade are opaque when held to sunlight.

Nightshade emergence may continue from June through September and is strongly influenced by moisture. Rain events cause multiple flushes of nightshade, so plants can emerge even after normal crop spraying is complete. Hairy nightshade emerging in early fall can produce viable seed before frost while eastern black nightshade requires a longer growing season. Nightshade can compete after crops form a shaded canopy. Consequently, growth of nightshade can accelerate after small grain harvest, which exposes nightshade to sunlight. Nightshade seeds become viable shortly after berry formation and seeds can remain viable in soil for 15 years when deeply buried. Studies show that one nightshade plant can produce 178,000 seeds under competitive situations or 800,000 without competition. Therefore, successful nightshade management requires prevention of seed production.

Nightshade plants remain green after several frosts and can cause harvest problems. Berries are poisonous and the juice from ruptured berries can stain crop seed and glue nightshade seed and dirt to harvested seed. In addition, dry nightshade berries are similar in size to soybean or field pea seed and are difficult to separate. Nightshade can be spread to other fields by equipment and contaminated seed used for planting.

Nightshade biotypes are tolerant to many classes of herbicides, including SUs (except Express). Eastern black nightshade resistance to imidazolinone herbicides has been documented in North Dakota. Thus, herbicides may remove competing broadleaf weeds allowing nightshades to proliferate.

Only a few residual soil herbicides, e.g. Balance Flexx, Extreme, Gangster, Pursuit, Python, Spartan, and Valor control nightshade flushes and may leave a residue the following year. Use of herbicide resistant crops (Clearfield, Ignite, and Roundup Ready) to control nightshade. Basagran may control hairy nightshade but not eastern black nightshade. Black nightshade is more tolerant to some herbicides (Matrix) than eastern black nightshade. Flexstar/Reflex gives poor hairy nightshade control. Refer to pages 6 to 11 for chemical control options. Other options for nightshade management include planting of uncontaminated seed, using crop rotations, multiple herbicide applications to control late flushes, and inter-row cultivation.

S5. Pigweed control requires higher rates of most herbicides than rates for wild mustard control. All ALS, PPO, and HPPD herbicides give good control. Dicamba and 2,4-D also give good control. MCPA is not as effective as 2,4-D in controlling pigweed. The esters of 2,4-D generally are more effective than the amines. Bromoxynil and bromoxynil & MCPA are generally poor on pigweed. A redroot pigweed population resistant to imidazolinone herbicides has been documented in Cass county.

Waterhemp, a related pigweed species, has biotypes that are resistance to glyphosate, ALS, PPO, and triazine herbicides in the U.S. Geographic distribution of waterhemp is across the midwest and has been documented in the Red River Valley. For more information on pigweed species refer to publications “Pigweed Identification” from Kansas State University Ext. Service, (913) 532-5776 ($1.50) or “Waterhemp Management in Agronomic Crops” (No. X855) from University of Illinois Ext. Service, (217) 333-0005 ($2.00).

S6. Wild oat is difficult to eradicate because the seeds shatter before crops are harvested and because seed dormancy causes delayed germination. Wild oat is a cool season plant and seeds germinate in the spring and fall when favorable temperature and moisture conditions exist. Cultural approaches available for wild oat control in small grains include delayed small grain seeding, post seeding cultivation, and competitive crops. The most practical cultural method of wild oat control is delayed small grain seeding, which involves early soil cultivation to stimulate wild oat germination followed by tillage or chemical control to kill emerged wild oat prior to crop seeding. Delayed seeding may cause a significant wheat yield reduction when compared with early seeding.

Other cultural control practices are planting competitive crops like barley and rye. Wild oat eradication is not practical or economically sound; therefore, a combination of cultural and chemical control methods should be used to manage wild oat populations and minimize yield losses.

Apply POST wild oat herbicides to wild oat and crops at precise leaf stages. Early application may result in better yield because of less competition with the crop, but later flush of wild oat may require a second application. In general, any population warrants chemical control to prevent yield losses and reduce seed production. Wheat yield reduction from foxtail and wild oat competition in NDSU research follows.

Grass Weed Competition in Wheat

Weeds/sq. yard	Foxtail	Wild oats
	% wheat yield reduction	
10	0	8-9%
50	4-5%	18%
75	6-7%	25%
100	8-9%	34%
150	15%	40%

S7. Wormwood (annual or biennial) plants in ND emerge throughout the year, behave like an annual species, and produce up to 1 million seeds/plant. B. wormwood seeds are very small and can be dispersed easily by wind, water, and all human-related operations. B. wormwood thrives in undisturbed (no- or minimum-till) areas, low areas, and areas where soil may remain wet for extended periods of time. Consequently, with every rain event a new flush of wormwood seedlings may appear.

Biennial wormwood survives most PPI, PRE, and POST herbicides and is misidentified as common ragweed. Also, biennial wormwood can emerge late after most POST herbicides have been applied. Rescue treatments with herbicides that control common ragweed, such as Ultra Blazer and FirstRate, have little or no effect on wormwood. Wormwood plants can grow six feet tall with a woody stem that averages 1 to 2 inches in diameter and can impede grain harvest, including damage to harvesting equipment.

Biennial wormwood is difficult to control because of an extended emergence period and tolerance to many PPI, PRE (acetochlor, metolachlor, Prowl, Sonalan, and trifluralin) and POST (most ALS herbicides, Cobra, Flexstar/Reflex, and Ultra Blazer) herbicides used in row crops. Metribuzin, Python, Spartan, and Valor provide residual biennial wormwood control. Growth regulator herbicides of 2,4-D, clopyralid, clopyralid & 2,4-D, clorpyralid & fluroxypyr, dicamba, Hornet, Status, and the non-selective herbicides glufosinate and glyphosate control wormwood. However, biennial wormwood can emerge after most non-residual POST herbicides have been applied and produce seed the same season.

Basagran may not control wormwood with one application. Wormwood becomes tolerant to herbicides as plant size increases requiring application to small plants. Basagran applied as split applications will improve control. Refer to paragraphs E3 and F6 for additional information on Basagran.

S8. Common ragweed is an annual weed species in the Aster or Sunflower family. It is becoming more prevalent in North Dakota as soybean and dry bean production increases. It is possible for a common ragweed biotype to have resistance to glyphosate and ALS- and PPO-inhibiting herbicides. Therefore, special management of common ragweed in all crops is necessary to maintain effective control with herbicides into the future.

A sequential application of PRE herbicides followed by POST herbicides should provide the most consistent and effective common ragweed control in any crop. In soybean, Gangster, Valor plus metribuzin, Valor, or metribuzin followed by glyphosate in RR soybean or Ignite in LibertyLink soybean should provide the most effective common ragweed control. In dry bean, Prowl plus Permit followed by the NDSU micro-rate program or Basagran plus Reflex should provide the most effective common ragweed control.

In corn, Surestart or acetochlor plus Balance or Callisto applied PRE followed by glyphosate plus Status or Halex GT in RR corn, Ignite plus atrazine or Laudis/Impact in LibertyLink corn, Status, Impact or Laudis plus atrazine, or bromoxynil plus Impact or Laudis should provide the most effective common ragweed control.

Huskie and any product containing 2,4-D, dicamba, MCPA, bromoxynil, or clopyralid should effectively control common ragweed in wheat and barley. If sugarbeet is grown in the rotation many of the herbicides listed above can only be used two seasons prior to sugarbeet or not at all.

PERENNIAL WEED CONTROL

T1. Field bindweed. Paramount (quinclorac) at 0.33 lb DF/A controls field bindweed in fallow, postharvest, or preplant in spring prior to seeding wheat, including durum. Apply with MSO adjuvant at 1.5 pt/A to bindweed at least 4 inches long. Apply after harvest but prior to frost. Use in a 3-year program by applying 0.33 lb DF/A the first year and 0.17 to 0.33 lb DF/A in following years. Paramount also may control foxtails, barnyardgrass, and volunteer flax. Multi-state field research show excellent field bindweed control at rates of 0.33 to 0.5 lb/A. Yearly applications are required when rates less than 0.37 lb ai/A are used.

T2. Canada thistle is a major problem in ND due to reduced tillage, wet weather, lack of persistent control strategies, and expense of control. NDSU research has shown that clopyralid and clopyralid plus 2,4-D provide the best long-term Canada thistle control. Glyphosate alone or with 2,4-D gives good control applied pre- and post-harvest. However, control is reduced under dry conditions. Dicamba, and tribenuron give only season-long control. In small grains, applying tribenuron plus 2,4-D and dicamba enhances control. 2,4-D applied at jointing followed by clopyralid & 2,4-D applied post-harvest to rosette thistle provides good long-term control. Pre-harvest glyphosate treatments also give good control. Glyphosate applied alone is similar in control to clopyralid & 2,4-D but provides less control than glyphosate plus 2,4-D.

Clopyralid, clopyralid & 2,4-D, clopyralid & fluroxypyr, glyphosate, Tordon, and 2,4-D have the greatest activity on Canada thistle in annual cropping systems. Highest rates should be used without interfering with next years cropping pattern. Apply high rates of herbicides to patches before thistle infestations increase. Timing is a critical factor. Herbicides applied after a light frost may enhance control but application to leaf tissue destroyed by frost may result in less control due to lack of herbicide uptake.

Tillage can be a critical factor. Delaying tillage 1 to 2 weeks after application in late fall increases control and may add an additional 30 to 40% control for herbicide treatments that gave 30 to 50% control without tillage. If lower herbicide rates or less effective herbicides are used, tillage is very important. If tillage is not planned, implement a program of multiple applications of the most effective herbicides at the highest rates practical. Spray rosettes of actively growing plants using the rosette technique described below.

Milestone effectively controls Canada thistle, but is labeled only on noncropland, such as pastures, rangeland, and CRP, because of soil residual that adversely affects many crops in annual crop rotations.

Rosette Technique. The rosette technique maximizes long-term Canada thistle control by encouraging root buds to break dormancy but not initiate flowering. These vegetative shoots provide better absorption, translocation, and activity than flowering shoots. Greatest control occurs when herbicides are applied in the fall to new growth of Canada thistle in the rosette stage. Periodic tillage in fallow controls Canada thistle shoots and other weeds until mid July when the day-length is less than 15 hours. Canada thistle shoots that emerge when day-length is less than 15 hours do not bolt but remain in the rosette growth stage. Apply clopyralid, clopyralid & 2,4-D, glyphosate, or WideMatch to rosettes in late September or early October. For in-crop control, use herbicides and between-row tillage to prevent bolting. Continue cultivation until canopy closure in soybean and until early July in corn. Effective herbicides can be applied post-harvest until early October. Herbicides fall-applied to rosette Canada thistle provide greater control and root kill compared with treating bolted Canada thistle .

T3. Common milkweed has become a severe weed problem in cultivated cropland due to an extensive deep root system, insulating winter snow, moist to wet summer conditions, tolerance to many commonly used herbicides, reduced tillage, and lack of human persistence in control measures. Common milkweed is tolerant to most labeled herbicides. Control requires multiple herbicide applications. Preventing establishment and spread of milkweed patches requires continuous scouting and persistent control efforts. Prevent seed production. Milkweed seed is highly viable and will germinate readily. Pappus on seeds allows long-distance travel and is responsible for establishment. Common milkweed seedlings becomes perennial (capable of reproducing from underground roots) approximately 3 weeks after emergence. New shoots develop from established roots and begin emerging in late April and grow more rapidly than spring seeded crops.

Milkweed control is expensive. Individual plants and small patches are easier and less expensive to treat than entire fields. Patch spraying covers only a fraction of the area of a broadcast application. Patch spraying allows use of higher herbicide rates with less expense than broadcast spraying.

Common milkweed control and management.
NDSU Research. Herbicides applied in June.

		Months after application	
Herbicide	Rate	3 mo.	12 mo.
	pt/A	--- % control ---	
2,4-D ester	4	36	48
Dicamba	2	71	61
Dicamba + 2,4-D	0.5+2	26	15
clopyralid + 2,4-D	4	13	6
Tordon	2	86	83
Glyphosate	6	56	99

Express + 2,4-D + dicamba controls only top-growth.

Glyphosate at 1.5 lb ae/A applied preharvest will reduce milkweed densities 85 to 95% compared to in-crop applications, which reduce milkweed densities by less than 40%. Apply herbicides when milkweed is in the late-bud to flowering stage and actively growing. Control patches when small. Patch-spray glyphosate at 6 to 8 pt/A (up to 10 pt/A is allowed). Apply glyphosate with AMS at 4 to 8.5 lb/100 gallons of water. Patch-spray Tordon at 4 to 8 pt/A. Tordon residue will help prevent other shoots from emerging. CAUTION: Treated areas will contain Tordon residues for **several years** after application.

T4. Fall-applied herbicides can be effective for controlling perennial weeds provided most stem and leaf tissue has not been killed by frost. Weeds such as field bindweed, leafy spurge and Canada thistle should have 6 to 12 inches or more of stem or rosette tissue before treatment for adequate leaf area to absorb the herbicide. Good leafy spurge control can be expected through mid-October with auxin herbicides even after several light frosts when the leaves are green or red and still firmly attached to the stem.

T5. Mowing or tillage is a good means of reducing perennial weed seed production. If fall herbicide applications are planned, mowing or tillage should be discontinued early enough to allow adequate plant regrowth. Post-harvest treatments can be applied when weed growth is about 1 foot tall. Preharvest herbicide treatment should precede harvest by at least 5 days to allow adequate herbicide translocation in perennial weeds. Fortunately the minimum PHI for many preharvest treatments meets or exceeds this guideline.

PERENNIAL WEEDS IN CROPS

T6. Perennial weed control systems in crops should include in-crop (conventional and particularly Roundup Ready crops if available), preharvest, and postharvest herbicide applications. Regardless of application, retreatment once or twice per year will be required for successful control of perennial weeds. Once large patches are controlled, seedlings will require treatment annually with registered in-crop herbicides. Glyphosate use in Roundup Ready corn, soybean, canola, and sugarbeet is a very effective system to control perennial weeds. NDSU research has shown control of established Canada thistle patches with glyphosate applied preharvest. For postharvest herbicide applications to be effective, treatment of new plant growth is required. Tillage combined with any herbicide treatment enhances control. Tables for each crop or perennial weed listed in this guide gives most effective herbicide choices, rates, and application information.

T7. Glyphosate at 0.75 to 1.5 lb ae/A applied as a spot treatment will give season-long control of perennial weeds in wheat, barley, oat, corn, and soybean. Glyphosate is non-selective so the crop in the treated area will be killed. Avoid drift outside the target area. Glyphosate is non-residual so plants may emerge after treatment and unaffected rhizomes or roots from perennials will continue to grow. See label or tables for application stage and rates. Glyphosate at 0.75 lb ae/A applied preharvest gives good Canada thistle and quackgrass control. When tillage is used after harvest, glyphosate will give greater Canada thistle control when applied preharvest than post-harvest.

PERENNIAL WEEDS IN PASTURES
(See Z1 for haying and grazing restrictions)

T8. 2,4-D ester or amine at 2 to 4 pt/A controls many perennial weeds in pastures. Some perennials such as fringed sagebrush and western snowberry (buckbrush) are controlled with one application and perennials such as Canada thistle, field bindweed, and leafy spurge require retreatment annually. 2,4-D can be used where Tordon cannot, but avoid drift onto susceptible plants. Hi-Dep allows use at spray volumes as low as 1 gpa by ground or 0.5 gpa by air.

2,4-D formulations registered for use in water include Agriliance “AgriSolutions 2,4-D Amine 4", UAP “Savage” and “Amine 4 2,4-D Weed Killer”, Nufarm “Weedar 64", Van Diest “Cornbelt 4 lb Amine” and “Cornbelt Navigate", and Helena “Opti-Amine”. Use only 2,4-D formulations registered for use near or in water. Refer to 2,4-D labels for registered use and information.

T9. Crossbow (triclopyr & 2,4-D) at 1 to 6 qt/A can be applied to grass pastures for broadleaf weed and brush control. Crossbow plus 2,4-D generally provides better musk thistle and brush control than 2,4-D alone. Do not graze lactating dairy animals or harvest hay from treated areas for 1 year after application. Do not graze beef animals within 3 days of slaughter during the first year after treatment.

T10. Dicamba at 1 to 2 pt/A will suppress some perennials, especially field bindweed and weeds resistant to 2,4-D. Dicamba can be applied in 1 to 5 gpa in pasture, rangeland, and fallow. When applying dicamba at 2 pt/A or less, use 0.5% v/v surfactant or AMS at 2 to 6 lb/100 gal of spray solution. Long-term control generally is achieved with 4 to 16 pt/A but the high rates are economical only for spot treatment. Dicamba has a shorter soil residual than Tordon, but should not be applied where desirable plants may be damaged by herbicide leached to the root system. The label indicates the required delay between treatment and grazing of dairy animals or cutting for hay but varies with rate from 7 to 90 days.

T11. Metsulfuron at 0.1 to 0.3 oz 75DF/A or **metsulfuron & chlorsulfuron** can be applied in rangeland, grass pastures, and non-cropland for control of noxious and troublesome weeds. Spot treat at higher rates when practical. Spray foliage for thorough coverage but not to run-off. Add a NIS at 0.25 to 0.5% v/v or PO at 1% v/v. Use of NIS may cause temporary yellowing, stunting, and suppression of head development in annual and perennial grasses. To avoid grass injury, do not apply to desirable grasses under stress, nor to grasses grown for seed. Products with 2,4-D, dicamba, and many other herbicides increase control and reduce risk of resistant weeds. Some brands of metsulfuron at 1 to 1.5 oz DF/A can be applied by air (helicopter and fixed wing) for weed control to utility and pipeline right-of-ways, military installations, and rangeland and pasture.

T12. Milestone (aminopyralid) at rates up to 14 oz/A per annual growing season may be applied as a spot treatment to not more than 50% of an area. Milestone has no grazing or haying restrictions but allow 3 days for animals to graze in untreated areas before transferring them to areas with sensitive broadleaf plants. May be applied to waters edge and in seasonally dry wetlands. Do not apply directly to water or to areas where surface water is present. Milestone can be applied to the soil under the canopy of several trees. Refer to label for list of tree species. Apply only as a directed spray under the canopy. Do not apply Milestone over-the-top of any tree. Legume plant and tree species are very susceptible to Milestone.

T13. Plateau (imazapic) with MSO adjuvant at 1 qt/A and UAN at 1 qt/A applied from early September to mid-October controls many grass and broadleaf weeds, including foxtail and leafy spurge in right-of-ways, pasture, rangeland, and CRP. Warm- season grasses are more tolerant than cool-season grasses. Highest rate provides longer control but increases grass injury. Plateau does not control absinth wormwood. Plateau does not injure desirable forage grasses or some broadleaf species including lead plant (*Amorpha canescens*), purple prairie clover (*Dalea purpurea*), prairie wild rose (*Rosa arkansana*), willow, (*Salix species*), and wild raspberry (*Rubus* species).

T14-17 - PERENNIAL WEED CONTROL

T14. Redeem (clopyralid & triclopyr) at 1.5 to 4 pt/A + NIS at 0.25% v/v controls most annual and perennial broadleaf weeds in grass pastures, rangeland, CRP, and non-cropland. Apply 1.5 to 2 pt/A for annual broadleaf weeds, diffuse and spotted knapweed, and yellow starthistle control and at 2.5 to 4 pt/A for absinth wormwood, fringed sage, Canada thistle, perennial sowthistle, and Russian knapweed. Apply to thistle from rosette to bud stage and in the fall following light frosts but prior to a killing frost. Redeem is more cost-effective than Curtail at the same active ingredient use rate. For lactating animals, do not graze or harvest green forage for 14 days after application. Do not harvest for dry hay for lactating animals until the next growing season. There are no grazing restrictions for non-lactating animals. Do not harvest dry hay for non-lactating animals for 7 days after application.

T15. Tordon (picloram) at 4 to 8 pt/A applied as a spot treatment controls broadleaf perennial weeds such as leafy spurge, common milkweed, field bindweed, Canada thistle, and Russian knapweed on rangelands and permanent grass pastures. Tordon at 1 to 2 pt/A applied POST will suppress growth of perennial broadleaf weeds. Retreatment at the same rates is necessary the following year. The most cost-effective broadcast spring-applied treatment for leafy spurge control is Tordon at 1 pt/A plus 2,4-D at 2 pt/A applied annually for 3 to 5 years. Do not apply Tordon with dry fertilizers.

Tordon is a restricted pesticide because it is toxic to most broadleaf plants. Spray drift will damage broadleaf crops and plants. Tordon is water soluble and may leach in the soil; consequently, do not apply in areas where a sandy porous surface and substrata overlay ground water 10 feet or less below the surface. Tordon must not be allowed to drift into surface water (including wells), irrigation water and drainage ditches or near shelterbelts, shrubs, or trees.

Do not cut grass for feed within 2 weeks after treatment at Tordon rates greater than 2 pt/A. Tordon is excreted in the urine which restricts transfer of livestock from treated grass areas onto sensitive broadleaf crop areas for 12 months after application without first allowing 7 days of grazing on untreated grass. When the Tordon rate exceeds 2 pt/A, the total area treated should not exceed 25% of a land owner's acreage found in any particular watershed.

T16. Mixture of Tordon + Plateau applied in June has provided greater leafy spurge control than Tordon + 2,4-D. Use of 2,4-D with Tordon + Plateau is not necessary but will increase the spectrum of broadleaf weeds controlled. Research by NDSU has shown improved leafy spurge control both in-season and the season following application when Tordon and Plateau are used.

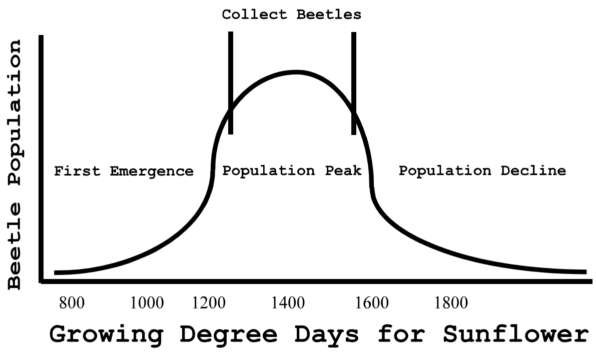
		Months after application		
Treatment	Product/A	3	12	15
		--------- % control ----------		
Tordon + 2,4-D	1 pt + 1qt	75	48	0
Tordon + 2,4-D + Plateau + MSO	1 pt+1 qt + 4 oz+1 qt	92	83	75

MSO adjuvant is required.
Do not apply after July 1.
Bromegrass species occasionally have shown short-term injury.

T17. NRCS Policy on Noxious Weed Control in CRP.
Taken from ND NRCS Exhibit 3, 2-CRP Manual, para. 210.
Established CRP Stands: Policy requires that no clipping or spraying of entire fields should be done during the primary nesting period (April 15 to August 1) for normal weed control. If noxious weeds are present and the critical control period for the weed falls in the primary nesting period, spot treatment of weeds is allowed. Herbicides chosen should maintain the grass and legume mixture. If this is not possible, control of the noxious weeds is a priority over maintaining legumes in the mix. Always notify your local USDA Service Center before making any herbicide applications.

New CRP Stands: Policy requires that weeds (noxious, common, volunteer grain, etc.) be controlled in CRP. Clipping and/or spraying during establishment should be used to control weed growth and reduce competition for the new seedlings. Clipping and/or spraying may be done at any time during the establishment period. If noxious weeds are present, control of noxious weeds is a priority over maintaining legumes in the mix. If the legume is killed after spraying and before the grass/alfalfa stand is established then a legume must be reseeded. Once the stand is established follow the above guidelines for established CRP stands. Always notify your local USDA Service Center before making any herbicide applications.

T18. Leafy spurge. Eight insects species have been released in North Dakota for biological control of leafy spurge. **Flea beetles** (*Aphthona* spp.) have been the most effective insects due to root feeding by larvae, rapid establishment, and increase after introduction, and ease in capture to transport to additional locations. Flea beetles are distributed through the ND Biological Control Program. Contact your county weed officer or board member for information. Release flea beetles on a well-drained south-facing slope with a moderate density of leafy spurge (60 to 90 plants/square yard) with minimal grass cover. Do not collect or move flea beetles, cultivate, burn site, or apply insecticide within 0.25 mile of release site for 3 to 5 years to allow establishment. During establishment, landowners should prevent expansion of the leafy spurge infestation by treating uninfested perimeters with herbicides. The best time to collect and distribute flea beetles is between 1000 to 1500 accumulated growing degree days (AGDD) for sunflower. Scout for establishment when the total AGDD for sunflower reaches 1100 to 1200. Flea beetle density prior to 1200 and after 1600 AGDD is low.



Use an insect sweep net to collect beetles to estimate density. Collect beetles from 10:00 am to 3:00 pm, greater than 70 F, little or no wind, sunny skies, and when leafy spurge foliage is dry. Sweep 5 times over an area of 1 m^2. Count the number of flea beetles by removing excess trash and non-flea beetle insects and pour beetles into a graduated container. Every 10 ml of flea beetles is approximately 1000 individuals.

Redistribute flea beetles to other leafy spurge infestations when 500 to 1000 beetles per 5 minute sweeping period are collected. Over-harvest of beetles is not possible because many flea beetles fall to the ground prior to being swept or are on the soil surface laying eggs. Redistribute flea beetles in a small area of 10 ft^2 or less. A successful release should result in 50 or more flea beetles in 5 sweeps the summer following release. If densities are less than 50 flea beetles per 5 sweeps then re-infest the site with additional flea beetles. A portion of the release area can be treated with Tordon (picloram) plus 2,4-D (2 pt + 2 pt) from early to mid-September to reduce leafy spurge stem density and increase insect establishment.

Research at North Dakota University has shown greater leafy spurge control when herbicides are combined with flea beetles compared to either used alone. Contact your county weed officer for date, time, and location of flea beetle collection in your area and information on purchasing collection equipment. An instructional video is available from the North Dakota Department of Agriculture, "How To Raise Leafy Spurge Flea Beetles, North Dakota's Biological Control Program".

Leafy spurge gall midge (*Spurgia esulae*) prevents galled stems from flowering, thereby decreasing seed production. The gall midge generally infests only part of a leafy spurge population so seed production is reduced but not eliminated. A second control method is needed to reduce the original infestation and prevent spread by roots and seeds of plants not galled.

Research at NDSU has shown that the leafy spurge gall midge is compatible with herbicide treatment in an integrated leafy spurge management program. Herbicides such as Tordon or 2,4-D should be applied at the optimum growth stage for leafy spurge control. Some of the area (perhaps 15 to 25%) must be left untreated to sustain the insect population. This integrated program may be most useful near wooded areas or rough terrain. Consult NDSU Ext. Service Circulars W-866, Integrated Management of Leafy Spurge; W-1088 Leafy Spurge Biology, Ecology, and Management W-1183; and Leafy Spurge Control Using Flea Beetles, for further details.

Grazing. Sheep and goats provide an alternative to herbicides for controlling leafy spurge top-growth in pasture and rangeland with large infestations or along waterways and tree areas. Grazing alone reduces but does not eliminate leafy spurge infestation. Grazing slows the spread and allows grasses to be grazed by livestock. Grazing should be started in spring when plants first emerge. Divide infested areas into sections so animals can repeatedly graze new growth. NDSU research has shown that grazing leafy spurge with goats followed by a fall-applied herbicide treatment provided more rapid and better long-term leafy spurge control than either method used alone. Consult NDSU Ext. Service Circular W-866, Integrated Management of Leafy Spurge, for details.

Recommended stocking rates vary with terrain, leafy spurge density, and rainfall during the growing season. Sheep should be grazed at about 3 to 6 head/A/month or 1 to 2 ewes/A. Angora goats should be grazed at 12 to 16 goats/A/month or 3 to 4 goats/A. Grazing with goats controls leafy spurge with little utilization of the grass species. The stocking rate will decline over time as the leafy spurge infestation is reduced. Animals should be contained for 3 to 5 days so viable seed can pass through the digestive system before they are moved to non-infested areas. Which animal to utilize will depend on a land manager's specific conditions, such as fencing, availability of animals, need to overwinter, and prevailing markets at the time. Consult NDSU Extension Service Circular R-1093, Controlling Leafy Spurge Using Goats and Sheep, for further details.

T19. Purple loosestrife. Six species of insects have been identified as having potential for biological control of purple loosestrife. Three species have been released into North Dakota. The insects and plant parts attacked are:
Galerucella pusilla - a leaf-feeding beetle
Galerucella calmariensis - a leaf-feeding beetle
Hylobius transversovittatus - a root-mining weevil
Biological agents hold promise for large infestations, thereby reducing the spread from neighboring states. However, purple loosestrife infestations in North Dakota are very small and isolated and **should be controlled by chemical and/or mechanical methods.** Biological control agents for purple loosestrife may not work well in urban areas because mosquito spraying severely reduces populations of biocontrol agents.

HERBICIDE RESISTANT WEEDS

X1. Herbicide resistance occurs with repeated use of a specific herbicide or a combination of herbicides 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(s) because the gene pool in the field will shift from susceptible to resistant. This shift may be 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, if a wild oat population is resistant to one ACCase herbicide, other ACCase inhibitor herbicides may or may not provide control.

Weed plants with a wide genetic diversity develop resistance rapidly, especially for herbicides with one mode of action. Kochia developed resistance rapidly in North Dakota to ALS herbicides because of diversity and the SU single mode of action. Kochia plants vary in resistance to various SUs, but in general kochia plants rapidly develop resistance to 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 species exhibit natural tolerance to most SU herbicides, but only recently developed resistance to Imi herbicides. Table X1 lists herbicides within various mode of action groups as a guide for possible cross resistance.

<u>Types of Resistance</u>

Altered target site - 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 metabolic processes - 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.

Herbicide sequestration / Altered herbicide localization - Movement of herbicide is impeded, is moved away from its target site, or is moved to a location where it is ineffective. This may be at the whole-plant or cellular level. This resistance mechanism appears to be important in glyphosate and paraquat resistance.

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

<u>Cross and Multiple Resistance</u>

A plant with a single resistance mechanism that enables survival when treated with different chemicals within the same mode of action is cross resistant to those chemicals. Resistance that develops to one ALS herbicide often confers cross resistance to other ALS herbicides. 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 within different modes of action 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. Plants with altered herbicide localization are also likely to exhibit this rate effect.

<u>Herbicide resistant weed species in ND:</u>
(#) = Herbicide mode of action, see pages 82-83.

ACCase inhibitor herbicides (1):
Wild oat (ACCase herbicides except clethodim)
Green foxtail (All ACCase herbicides except clethodim)
Yellow foxtail (All ACCase herbicides except clethodim)
Wild oat resistance has been documented in nearly every ND county.

ALS inhibitor herbicides (2):
Wild oat (Assert, Everest, Olympus, Rimfire, and Silverado)
Kochia (All ALS herbicides)
E. black nightshade (Imi herbicides: Raptor and Pursuit)
Redroot pigweed (Imi herbicides: Pursuit and Raptor)
Waterhemp (All ALS herbicides)
Wild mustard (All ALS herbicides)
Common ragweed (ALS herbicides)
Marshelder (Imi - Pursuit and Raptor, and SU - Express)

Mitotic inhibitor (3):
Green foxtail (Treflan, Sonalan, Prowl)

Growth regulator (4):
Kochia (2,4-D and dicamba)

Photosystem II inhibitor (5):
Kochia (atrazine)

Lipid synthesis inhibitor (8):
Wild oat (Far-Go)
Resistant wild oat biotypes were also found to be resistant to Avenge.

EPSP synthase inhibitor (9) (glyphosate):
Common ragweed

Unknown mode of action (26):
Wild oat (Avenge)
Resistant wild oat biotypes were also resistant to Far-Go.

Multiple Resistance:
Wild oat - ACCase (1) + ALS (2)
Kochia - Growth Regulator (4) + ALS (2)

<u>Herbicide resistant weed species in the U.S. - not in ND:</u>
Other weeds present in ND that have developed resistance to herbicides in other areas of the nation are listed below.

ALS inhibitor (2):
Yellow foxtail, giant foxtail, lambsquarters, sunflower, common cocklebur, giant ragweed, and Russian thistle.

Growth regulator (4):
Wild mustard and field bindweed.

Photosystem II Inhibitor (5):
Yellow foxtail, redroot pigweed, Powell amaranth, lambsquarters, and common ragweed.

EPSP Synthase Inhibitor (9) (Glyphosate):
Kochia, horseweed (marestail), giant ragweed, lambsquarters, waterhemp.

PPO inhibitor (14):
Common and giant ragweed and waterhemp.

Multiple Resistance:
Wild oat - ACCase (1) + ALS (2)
Kochia - Growth regulator (4) + ALS (2)
Powell amaranth - ALS (2) + triazine (5) - Canada
Horseweed/Marestail - ALS (2) + glyphosate (9) - on state
Multiple resistance (shown below) has been documented in biotypes of waterhemp, common ragweed, and giant ragweed:
ALS (2) + PPO (14) - up to 3 states
ALS (2) + glyphosate (9) - up to 3 states
ALS (2) + PPO (14) + glyphosate (9) - up to 2 states

Weeds expressing some natural tolerance to glyphosate: Cinquefoil, clover, lambsquarters, common mallow, dandelion, horseweed (marestail), kochia, nightshade, nutsedge, prickly lettuce, smartweed, velvetleaf, waterhemp, wild buckwheat.

Weeds expressing some natural tolerance to glufosinate (Ignite/Liberty): grasses, lambsquarters, yellow nutsedge.

Genetically engineered crops resistant to glyphosate and glufosinate may be used to control weeds resistant to other herbicides. However, heavy selection pressure from these herbicides may cause selection of multiple resistant biotypes.

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

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 Guidlelines:
1. Scout fields regularly and identify weeds that escape herbicide treatment. Monitor changes in weed populations early (a few plants in the field) and restrict spread of potentially resistant weeds that match the field history and herbicide pattern. If there are dead plants, unaffected plants, and plants with showing intermediate responses then resistance should be strongly considered. Use full rates of all products and use the most effective adjuvants when tank-mixing with glyphosate.

2. Rotate herbicides with different modes of action in consecutive years. New and novel sites of action are not likely to be discovered.

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. Antagonism among tank-mix partners should be avoided.

4. Rotate crops, particularly those with different life cycles, e.g. winter annual crops (winter wheat), perennial crops (alfalfa), and summer annual crops (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.

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. Resistance should occur in no-tillage fields before conventional tillage fields. The gene pool does not revert back in absence of the original selection, except when the resistant plants are poorly fit.

Fitness has not been greatly different for resistant and susceptible biotypes and should not be relied upon for resistance management.

Two options for resistance management are: 1. Use the desired herbicide until resistance occurs and then change to an alternative; and 2. Rotate control methods to delay the on-set of resistance.

5. Use high labeled rates of POST herbicides. Reduced rates may allow hybridization among plants with low-level resistance to produce plants with high-level resistance.

Method 1. Continued Herbicide Use - This approach allows for the use of the preferred treatment but will require more intense monitoring for resistance. The best resistance management strategy is early identification of resistant plants and then complete control (eradication) of the resistant plants while the infestation is small. Hand weeding, non-selective herbicides, cultivation, or combinations of methods can be used for eradication. 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.

Advantages:
1. Allow use of preferred herbicide.
2. Allow for use of the herbicide best suited for weeds in a given field.
3. The above may save costs as a herbicide with a second mode of action may not be needed for the weeds present before resistance develops.

Disadvantages:
1. Resistance will occur sooner and require earlier monitoring for resistance.
2. Does not save the herbicide for use in crops without alternatives.

Method #2. Rotate Herbicides - This system will delay resistance, but may use unnecessary or less desirable herbicides in rotation or in mixture. Delaying resistance by alternative herbicides in the crop rotation is a means of keeping a herbicide for use in a crop that does not have an effective alternative.

Advantages:
1. Monitoring for resistance is less essential but still very important.
2. Herbicide mixtures may give control of more weed species and reduce the need for scouting to choose the appropriate herbicide for the field.

Disadvantages:
1. May need to use herbicides other than the most desired.
2. Will select for multiple resistance.
3. Fewer herbicide options saved for future use.

Testing weeds for herbicide resistance:
Plant samples can be sent to Ag-Quest to test for weed resistance. Contact before sending to determine cost and packaging instructions.
Ag-Quest, Inc.
Haisheng Xie (Dr. Z), Ph.D
#210 South Railway Street, Box 144
Minto, Manitoba, Canada, R0K 1M0
Office 204 776-5565
haisheng.xie@agquest.com, www.agquest.com
ACCase or ALS (Group 1) herbicides = $80 CAN/sample
Dinitroaniline (Group 3) herbicides = $45 CAN/sample

On-line study coarse on herbicide mode of action can be found at: http://www.wsweedscience.org/Lessons/lessons.asp

HERBICIDE CARRYOVER

Y1. Herbicide persistence into the next growing season restricts rotational crops. The following information explains herbicide degradation for chemistries known to carryover.

General Rules For Herbicide Breakdown

1. Many herbicides are broken down in soil by microbial decomposition. In addition, SUs and triazines are broken down by chemical reactions like acid hydrolysis.
2. Herbicide molecules must be free from binding to soil particles or organic matter for soil microorganisms to degrade.
3. Most herbicide molecules are more tightly adsorbed to soil particles in dry soils than moist soils.
4. 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 molecules: Imidazolinones, SUs, Triazines, and Triazolopyrimidines (TPS).

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

Y2. Breakdown of Imidazolinone (Imi), TPS Herbicides, and some HPPD herbicides (Callisto).

In general, breakdown occurs by soil microbes and **breakdown occurs more rapidly and herbicide activity increases as soil pH increases.** Rate of breakdown decreases in dry conditions. Imi and TPS herbicides are:

1. Broken down by microbes - not broken down by hydrolysis.
2. Not degraded 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.

For Imi herbicides applied in dry conditions, herbicide molecules adsorb to OM. The next spring, winter moisture can displace herbicide molecules from soil and OM allowing the molecules to become 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 after moisture events.

7. Negatively (-) charged, not adsorbed, and free for plant uptake and microbial degradation at soil pH >6.5 for Imi herbicides and pH >7 for TPS herbicides.
8. Strongly bound to OM at pH <6.5 for Imi herbicides and pH <7 for TPS herbicides. For Imi herbicides: Amount adsorbed changes little from 6.5 to 8. At soil pH <6.5, pH reduction as small as 0.2 pH units can **DOUBLE** the amount adsorbed.

pH can widely vary across the same field. In low pH, residues of Imi herbicides can injure sensitive plants for many years.

In summary, activity and degradation of Imi and TPS herbicides increase as soil pH increases. Herbicide adsorption increases as OM matter increases and as soil pH decreases. All factors increasing microbial activity also increase herbicide degradation (warm, moist soils). Degradation increases in soils with pH above 6.5 (Imi) or 7 (TPS) because herbicide molecules are not adsorbed and are free in soil solution for plant uptake and microbial breakdown.

Y3. Breakdown of SU Herbicides (with exceptions):

In general, most SU herbicides are broken down by acid hydrolysis and can leave a residue in soil for more than one year. The chemical reaction ceases at soil pH above 6.8.

Exceptions: Thifensulfuron, tribenuron, foramsulfuron (Option), and triflusulfuron (UpBeet) are rapidly broken down by soil mirobes. Halosulfuron (Pemit), and rimsulfuron are broken down faster by hydrolysis as pH moves above and below pH of 7.0. Herbicide breakdown is slowest in neutral soil pH of 7.0.

Most SU herbicides are:

1. Not leached, nor volatile, nor broken down by photodegradation.
2. Affected by pH. Water solubility increases as pH increases.
3. Broken down primarily by acid hydrolysis. Microbial degradation is very slow.
4. Non-microbial hydrolysis for most residual SU herbicides ceases at soil pH above 6.8.
5. SU herbicides are undissociated (neutral charge) at pH less than 7.0 and are adsorbed to soil and OM. As soil pH increases above 7.0 molecules are (-) charged, are in a free form, do not bind with (-) charged soil particles, and are are available for plant uptake.

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 above that level. Hydrolysis is 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 and pH decreases below 6.8, hydrolysis increases.

Y4. Breakdown of Triazine Herbicides

Triazines are degraded by hydrolysis similar to SU herbicides. Therefore, the same factors affecting SU breakdown also affect breakdown of triazine herbicides - See Y3. Some slight differences are noted below. Triazine herbicides are:

1. More active in high pH soils.
2. Broken down by photodegradation only when herbicide remains on soil surface for extended periods.

Triazine molecules are (+) charged at soil pH < 7.5. Positive charged triazine molecules bind to (-) charges on soil and OM making them unavailable for plant uptake and microbial breakdown. This is why pH sensitive herbicides like atrazine and metribuzin can be used with less risk of crop injury in low pH soils. However, as pH fluctuates across the field, herbicide availability may be radically altered ranging from complete crop safety and erratic weed control at low pH to crop injury and adequate weed control at high pH.

At high soil pH, the opposite reaction occurs. At soil pH > 7.5, triazine herbicide molecules donate protons (H^+) resulting in ($H + OH = H_2O$) so the molecules have a net neutral charge, which do not bind to soil particles and OM, and are free for plant uptake and microbial decomposition.

Y5. Persistence of phytotoxic levels of a herbicide for more than 1 year can be a problem with some herbicides. 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 atrazine, metribuzin, Nortron SC, Prowl, Sonalan, and trifluralin.

Y6. Herbicide residues often can be detected by bioassay. Representative soil samples of the whole field are obtained by sampling many places to the depth of the tillage layer. A soil sample free of herbicide residues can 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 two or more samples of untreated check soil and the test 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. Alfalfa and canola also should be planted as an additional bioassay species because of their relative sensitivity to many residual herbicides. Plant seeds of large-seeded crops like corn or soybean at 1 seed per 1 to 2 square inches, or seeds of small-seeded crops like cereals or flax at about 1 seed/sq inch. Water as needed but do not over-water. Thin plant stands when seedlings are 2 to 3 inches tall to allow sufficient space for adequate growth. Position containers in direct sunlight and maintain temperature at 70 to 75 F. Observe the plants 2 to 3 weeks after emergence. Record visible and physical measurements such as plant height and leaf length for abnormalities.

Symptoms of some herbicides like atrazine and metribuzin do not develop until 2 to 3 weeks after emergence. Observe roots of plants grown in root inhibiting herbicides, such as dinitroanilines. Window bioassay does not provide accurate information for ALS herbicide carryover.

Field Bioassay Instructions: Plant several strips of desired crops across the field perpendicular to the direction the suspect herbicide was applied. Strips should be spaced to represent different field conditions (texture, pH, and drainage). If no visible signs of injury, stand reduction, or yield reduction occur, then the field can be seeded with the desired crop the next growing season. Do not plant if injury occurs and the bioassay must be repeated the next growing season to determine the safety of the crop to existing residues.

Y7. Atrazine at rates over 0.38 lb ai/A generally has residue the year following application to corn in North Dakota. If soil moisture is deficient, atrazine may cause injury to susceptible crops the following year. Corn and millet are tolerant to atrazine while other crops vary in susceptibility. The approximate ranking of crops from most to least tolerant is corn, sorghum, millet, flax, soybean, barley, wheat, oat, sunflower, canola/mustard, alfalfa, and sugarbeet.

Y8. Balance Pro / Flexx (isoxaflutole) may have a residue the following year. Breakdown is primarily by microbial activity. Risk of Balance Pro carryover increases as precipitation occurring during the growing season decreases. Balance Pro becomes more active as soil texture becomes more coarse and organic matter decreases. Rotation restrictions are found on pages 78-80.

Y9. Dicamba at rates greater than 1.5 pt/A may remain as a residue in soil. Most grass and broadleaf crops can be planted 4 months or more after application at 1.5 pt/A. Allow 45 days/pt/A of dicamba, excluding days when ground is frozen to rotate to any crop. NDSU research indicates dicamba at 1 qt/A applied in late September caused visible injury to wheat and barley planted the following spring, but effect on yield was minimal. Dicamba at 1 pt/A applied the previous fall prevented seed production in sunflower. The approximate ranking of crops from most to least tolerant is corn, barley, wheat, oat, potato, buckwheat, soybean, dry edible bean, sunflower, flax, and sugarbeet. Rotational crop restrictions for dicamba are found on pages 78-80.

Y10. Flexstar/Reflex (fomesafen) at 0.75 to 1 pt/A may have a residue the year following application to soybean or dry bean. Most crops can be planted the next growing season except canola, crambe, flax, potato, safflower, sugarbeet, and sunflower. Fomesafen is weakly adsorbed by OM but mobility and amount available for plant uptake increases as soil pH increases above 6.5. Degradation is through soil microbes and under anaerobic conditions. Conditions that inhibit microbial activity also reduce fomesafen breakdown. Cold or dry conditions after application reduce rate of breakdown. Northern production areas, like ND, have a shorter growing season and the soil temperature is colder for longer periods of time, which limits breakdown. Late applications in beans decreases the amount of time that breakdown can occur.

Ways to reduce potential for fomesafen carryover include lower application rates, banded herbicide applications, and tillage to dilute herbicide residues. The approximate ranking of non-labeled crops from most to least tolerant is cereals, potato, oil-seed rape/canola, field corn, sunflower, sugarbeet, sorghum, and alfalfa. Rotational crop restrictions for Flexstar/Reflex are found on pages 78-80.

Y11. Nortron SC (ethofumesate) often has a residue the year following use on sugarbeet. The approximate ranking of crops from most to least tolerant is sunflower, dry beans, soybean, corn, barley, and wheat. 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.

Y12. Metribuzin may not have residue the following year at 0.25 lb ai/A, but rates over 0.5 lb ai/A may damage susceptible crops the next year. Rotational crop restrictions for metribuzin are found on pages 78-80. The approximate ranking of crops from most to least tolerant is potato, soybean, dry edible bean, corn, barley, wheat, oat, sunflower, flax, and sugarbeet.

Y13. Sonalan (ethalfluralin), **Prowl/Prowl $H_2$0** (pendimethalin), and **trifluralin** are similar herbicides called dinitroanilines. Under dry soil conditions these herbicides can persist in soil for more than 1 year. Sonalan has less soil residue than trifluralin and Prowl. Land treated with Sonalan in the spring may be planted to any crop the next year except sugarbeet. Sunflower, soybean, potato, and dry edible bean are quite tolerant of dinitroaniline herbicides. Rotational crop restrictions for Prowl, Sonalan, and trifluralin are found on pages 78-80. The approximate ranking of other crops from most to least tolerant is soybean, flax, alfalfa, barley, wheat, corn, oat, and sugarbeet.

Y15. Spartan (sulfentrazone) residue may remain in soil the following season. Most grass and broadleaf crops can be planted the following year except canola, crambe, lentil, and sugarbeet. Sulfentrazone is degraded by soil microbes, is not affected by sunlight, and is not volatile. Sulfentrazone applied PRE does not degrade on the soil surface. Precipitation activates the herbicide by moving it into the soil. Sulfentrazone solubility increases as soil pH increases above 6.5, as soil texture changes from fine to coarse, and as OM decreases. As sulfentrazone solubility increases availability for plant uptake increases, weed control increases, and risk of crop injury increases. The approximate ranking of crops from most to least tolerant is soybean, flax, chickpea, mint, sunflower, potato, field pea, dry edible beans, safflower, crambe, canola, lentil, and sugarbeet. Rotational crop restrictions for Spartan are found on pages 78-80.

Y16. Susceptibility of certain crops from most to least tolerant:
Chlorimuron: soybean, wheat, oat, corn, sorghum, sunflower, alfalfa, canola, sugarbeet.

Imazethapyr: soybean, alfalfa, corn, wheat, oat, sunflower, sorghum, canola, sugarbeet.