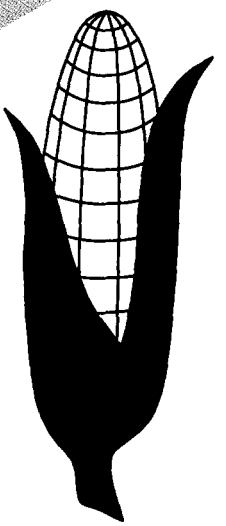
Corn Production Guide



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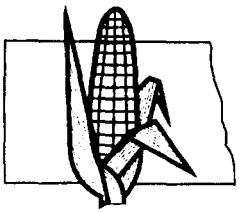

North Dakota Corn Utilization Council
The North Dakota Corn Growers Association

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INTRODUCTION

Corn Production and Management

Modern technology, fluctuating export markets, chang- ing USDA farm policies, and environmental regulations al contribute to corn growers' needs for careful planning anc management to assure high yields and profitable produc- tion.

Fluctuating weather, varied rainfall amounts and storec soil moisture levels also require corn growers to make careful decisions as to type of tillage system, fertility man- agement, seedbed preparation, weed control strategies rotations, and corn pest management practices.

This guide has been developed to help you make timely management decisions. However, detailed and extensive details on any one area are not provided, because of limitec space. More detailed and complete discussions of soil fertil ity, weed, disease, and insect control, hybrid performance harvesting and storage are available in other Extensior circulars as listed in the back pages.

The pesticide use suggestions in this guide are basec on federal label clearances and on some state labels in Nortl Dakota. Also suggestions are based on research informa tion collected on North Dakota State University trials o trials in other states. All pesticides listed had a federal o state label at the time of this publication. Check all labels a time of use for the most current label registration.

The publishers and contributors do not assume an responsibility, make any guarantees, or offer any warrantie in regards to the results obtained from use of the dat appearing in this guide.

Hybrid Corn Selection

One of the most important management decisions a corn grower makes each year is the selection of corn hybrids for spring planting. During the past 50 years there has been a continuous improvement in the genetics of corn hybrids. These improvements have greatly contributed to steady increases in grain yield potential ranging from 0.5 to 2.0% per year. To stay competitive growers should introduce new hybrids to their planted acreage on a regular basis.

Growers should select hybrids best suited to their farm operation. Size of corn acreage, soil type, tillage practices, pest problems and desired harvest moisture determine needs for such traits as drydown, disease resistance, insect tolerance, early plant vigor, plant height and relative maturity.

End use of corn should always be considered: is corn to be used for grain or silage? Is it going to be utilized for wet milling? Is it to be sold directly to the elevator or the wet milling plant, or primarily used on the farm to feed livestock? Capacity to harvest, dry and store grain corn also needs consideration.

The key factors to use in choosing corn hybrids are:

- **Maturity** – Select hybrids with maturity ratings appropriate for your geographic area or circumstances.
- **Yield** – Select hybrids with consistently high yields across a number of locations or for two years.
- **Standability** – Use hybrids that stand well throughout the season with tolerance to stalk rots and green snap.
- **Disease resistance or tolerance** – Grow hybrids with tolerance/or resistance to stalk rots, foliar diseases and ear rots.
- **Seed quality** – Plant only high quality seed and seed sized to match your planters capabilities.

- **Drydown rate** – Choose hybrids that drydown rapidly or lose kernel moisture while in the field.
- **End use** – Choose hybrids which best fit the final utilization needs; wet milling, feeding, silage, waxy corn or others.

Growing Degree Days and Corn Maturity

"Growing-degree days" (GDD) or heat units has been developed to more accurately rate corn maturity. It is based on the number of growing degree days between emergence date and physiologic maturity of a hybrid (Table 1). Growing degree days vary in North Dakota from 2400 GDDs in southeastern areas to 1900 GDDs in the northern areas (Table 2).

In calculating growing degree days (GDD), temperatures from a lower limit of 50°F and an upper limit of 86°F are accumulated for the growing season by applying the following formula to each day's maximum and minimum temperatures.

$$GDD = \frac{(\text{Max. Temp.} + \text{Min. Temp.})}{2} - 50$$

Maximum temperatures higher than 86°F are entered as 86 and temperatures below 50° F are entered as 50 in the formula. GDDs are accumulated from seedling emergence until physiological maturity. Kernel moisture content at physiological maturity generally averages about 34%. At physiological maturity a "black layer" will form under the outer layer of the kernel tip. When this forms it signals that kernel dry matter accumulation has reached the maximum level. Corn will not be hurt by frost after that point. Hybrids may vary up to 10% in kernel moisture at physiological maturity.

Table 1. Approximate GDD heat units and relative maturity for corn in the northern growing regions (North Dakota and Minnesota).

Accumulated GDD (Heat Units)	Relative Maturity (Days)
1750-1850	70
1850-1950	75
1950-2050	80
2050-2150	85
2150-2250	90
2250-2350	95
2350-2450	100
2400-2500	105

Table 2. Growing degree day accumulations at various North Dakota locations (1970-96).

Location	Accumulated Growing Degree Days* (GDD)
Fargo	2166
Barney	2311
Oakes	2248
Larimore	2009
Mandan	1981

Corn Growth Stages and Development

The corn staging system divides development into vegetative (V) and reproductive (R) stages (Table 3). Subdivisions of the V stages are designated numerically as V1, V2, V3, etc. through V(n), where (n) represents the last leaf stage before VT for the specific hybrid under consideration. The first and last V stages are designated as VE (emergence) and VT (tasseling). The (n) will fluctuate with hybrid and environmental differences. The six subdivisions of the reproductive (R) stages are designated numerically with their common names.

Table 3. Vegetative and reproductive stages of a corn plant.*

Vegetative Stages	Reproductive Stages
VE emergence	R1 silking
V1 first leaf	R2 blister
V2 second leaf	R3 milk
V3 third leaf	R4 dough
.	R5 dent
.	R6 physiological maturity
.	
V(n) nth leaf	
VT tasseling	

Planting Dates

Higher corn grain yields will be obtained with early plantings. In most regions this means seeding between the last week of April and May 15. Early planting is recommended because risk of fall frost damage is greater with each day planting is delayed. The risk increases rapidly after May 20 and seeding corn for grain production is not recommended after June 1. Select and plant early-maturing, short-season hybrids when planting is delayed because of wet, cold planting conditions. Date of planting studies have been conducted at Oakes, Casselton and Fargo, ND. In these studies approximately one bushel per day was lost by delay of planting during the month of May. For silage corn, later plantings can be tolerated without great yield losses but can result in frosted corn, thus lowering quality of forage.

Plant Population

Hybrids react differently to various plant populations, and producers should consult with their seed dealer on recommendations. Plant populations should be based on available moisture, potential rainfall during the growing season, and soil type. Populations of 14,000 to 18,000 plants per

acre are recommended in western low rainfall areas and on light sandy soils. Populations of 22,000 to 28,000 plants per acre in eastern, high rainfall areas and 28,000-32,000 plants per acre for corn grown under irrigation are recommended for plant population at harvest. The seeding rate should be 10-15% higher than the desired harvest populations.

Table 4. Estimation of plant population on a per acre basis.

Row Width	Row Length
	(1/1000 acre)
20"	26'2"
22"	23'9"
28"	18'8"
30"	17'5"
36"	14'6"

Count the number of plant in row length and multiple x's 1000 to determine number of plants per acre. **Example:** 24 plants counted in 17'5" row length of 30 inch spacing = 24,000 plants/A.

Table 5. Plant-to-plant spacing for various plant populations.

	Inches between kernels			
Seeds/ac	20" row	22" row	28" row	30"row
15,000	20.9	19.0	14.9	13.9
16,000	19.6	17.8	14.0	13.1
17,000	18.4	16.7	13.2	12.3
18,000	17.4	15.8	12.4	11.6
19,000	16.5	15.0	11.8	11.0
20,000	15.7	14.2	11.2	10.5
22,000	14.3	12.9	10.2	9.5
24,000	13.1	11.8	9.3	8.7
26,000	12.1	11.0	8.6	8.0
28,000	11.2	10.2	8.0	7.5
30,000	10.5	9.5	7.5	7.0
32,000	9.8	8.9	7.0	6.5

Rotations and Corn

Crop rotations and crop sequences are management tools that can be used to exploit available resources more efficiently. Evaluation of cropping systems is complex with rotations and crop sequences only one part of the system. Research on corn rotations usually compares monocropping (continuous corn) to various other cropping sequences with some legume crop or small grain. Biological systems research usually shows an advantage to rotation of crop species. The factors involved include but not limited to are: soil fertility, water use, soil tilth, soil erosion, crop residues, weed control, insect control and disease.

Differences between continuous corn and rotational corn yields are greatly reduced as N rates are increased to attain maximum yield productivity in non-legume cropping sequences. However in many rotations, the difference in yields can't be made up by N application alone. Factors which causes these additional rotational benefits include reduced disease problems, less insect pressure, improved soil physical properties, elimination of phytotoxic substances in corn residues and the addition of growth promoting substances in legume residues.

One exception to the advantage of using legumes in a corn rotation can occur in years when a perennial legume such as alfalfa can deplete soil moisture during the fall, prior to spring corn planting. Disease pathogen populations can be reduced or suppressed by rotations to certain broadleaf or legume crops. The key function of a rotation with corn is not to eradicate the pathogen but to reduce it to a low enough level so a profitable yield can be produced when the susceptible crop (corn) is replanted into the crop sequence at a later time.

A mystery does remain, however, in that most research data show higher corn yields using rotations even when all factors known such as fertility, pest pressures, water available, and hybrids are equal. Yield benefits have been obtained by rotating to legumes, from non-row crop to corn, from row-crop to corn, and even from one hybrid to another hybrid the second year in a sequence. In a recent national survey, corn yield increases due to rotations ranged from 6 to 30 bushels per acre. The best recommendation is to rotate, rotate, rotate.

Weed Control

The weed control suggestions in this production guide are based on the assumption that all herbicides mentioned will have a registered label with the Environmental Protection Agency. Corn treated with with a non-registered herbicide may have an illegal residue which, if detected, could cause condemnation of the crop. Nonregistered herbicide use is illegal and a user could be subject to a heavy fine even without detectable residue.

Chemical Weed Control for Corn

Roundup Ultra/RT, Glyphos (glyphosate)

Rate: 0.5 to 2 pt of a 3 lb ae/gal conc. (0.19 to 0.75)
Weeds: Emerged grass and broadleaf weeds.
Apply: Preplant or anytime prior to crop emergence.
Remarks: A nonselective, translocated, foliar herbicide. No soil activity. Refer to label for adjuvant use.

Gramoxone Extra (paraquat) RUP

Rate: 1.5 to 3 pt (0.47 to 0.94)
Weeds: Emerged annual grass and broadleaf weeds.
Apply: Preplant or anytime prior to crop emergence.
Apply: A nonselective, foliar herbicide. No soil activity. Apply with a NIS at 0.12 to 0.25% v/v. Good plant coverage is essential.

Eradicane (EPTC & safener)

Rate: 4.75 to 7 pt, 16 to 24 lb 25G (4 to 6)
Weeds: Grass and some broadleaf weeds.
Apply: PPI
Remarks: Immediate incorporation is required for best results. Use high rate for wild-proso millet control. Weak on wild mustard.

DoublePlay (EPTC + acetochlor + safener) RUP

Rate: 4.5 to 8 pt/A (3.15 to 5.6 + 0.78 to 1.4)

Weeds: Most annual grass and some broadleaf weeds.

Apply: PPI

Remarks: Immediate incorporation is required using water as spray solution. Incorporation can be delayed up to 4 hours if using liquid fertilizer as carrier or up to 1 day if impregnated on dry bulk fertilizer. Partial control of volunteer grains, wild-proso millet, and field sandbur at 5 to 7 pt/A.

Lasso (alachlor) RUP

Rate: 2 to 3.5 qt 4EC/MT, 3 to 5.3 lb 65WDG, 13 to 26 lb 15G (2 to 3.5)

Weeds: Grass and some broadleaf weeds.

Apply: PPI, PRE or EPOST: Up to 5 inches tall.

Remarks: Weak on wild mustard. Less effective PRE than Ramrod on many soils. PPI gives more consistent weed control. EPOST is for reduced competition of labeled weeds.

Dual (metolachlor)

Rate: 1.5 to 3 pt, 6 to 12 lb IIG/25G (1.5 to 3)

Weeds: Grass and some broadleaf weeds.

Apply: PPI or PRE. Fall: After Oct 15 but before ground freezes.

Remarks: Weak on wild mustard. Less effective PRE than Ramrod on many soils. PPI gives more consistent weed control.

Frontier (dimethenamid)

Rate: 13 to 25 fl oz (0.76 to 1.46)

Weeds: Grass and some broadleaf weeds.

Apply: EPP, PPI or PRE

Remarks: Use rate based on CEC or soil texture and OM. Frontier has provided equal grass control compared to Lasso or Dual.

Harness (acetochlor + safener) RUP

Rate: 1.25 to 3 pt (1.1 to 2.6)

Weeds: Grass and some broadleaf weeds.

Apply: PPI or PRE

Remarks: Harness has provided equal or greater weed control compared to Lasso, Dual or Frontier.

TopNotch (microencapsulated acetochlor + safener) RUP

Rate: 4 to 7.25 pt (1.6 to 2.9)

Weeds: Grass and some broadleaf weeds.

Apply: Reduced or No-till: EPP and PRE

Remarks: May be tank-mixed with Gramoxone Extra or Roundup Ultra/RT for EPP. Can be tank-mixed with Atrazine, Bladex or Banvel for PPI or PRE applications in conventional till systems. Refer to label for rates based on soil texture and interval between application and planting.

Surpass (acetochlor + safener) RUP

Rate: 1.5 to 3.75 pt, 6 to 15 20G
Early POST: 1.2 to 3 pt (1.2 to 3)

Weeds: Grass and some broadleaf weeds.

Apply: PPI, PRE and EPOST

Remarks: Surpass has provided equal or greater weed control compared to Lasso, Dual or Frontier.

Ramrod (propachlor)

Rate: 4 to 6 qt, 20 to 30 lb 20G (4 to 6)

Weeds: Grass and some broadleaf weeds.

Apply: PRE

Remarks: Weak on wild mustard. More effective PRE than Lasso or Dual in North Dakota. PPI decreases control.

Prowl (pendimethalin)

Rate: 2.4 to 4.8 pt EC, 1.67 to 3.33 lb DG (1 to 2)

Weeds: Grass and some broadleaf weeds.

Apply: PRE

Remarks: DO NOT INCORPORATE. Do not use on sands or loamy sands. Use the high rate on fine textured soils high in OM.

Atrazine RUP

Rate: 1 to 2 lb ai/A

Weeds: Broadleaf and some grass weeds.

Apply: PPI and PRE: Spring only.

Remarks: Use higher rate on fine-textured soils. Soil residue may injure some crops planted the following year. Consult label for crop rotation restrictions.

Bladex (cyanazine) RUP

Rate: 1.3 to 5.3 lb 90DF (1.2 to 4.75)

Weeds: Broadleaf and some grass weeds.

Apply: PPI and PRE

Remarks: Soil residues unlikely the year after application. Weak on redroot pigweed. Use higher rates on fine-textured, high OM soil. Do not use on sands, loamy sands or soil with less than 1% OM.

Broadstrike + Dual (flumetsulam + metolachlor)

Rate: 1.75 to 2.75 pt (0.04 to 0.0625 + 1.6 to 2.33)

Weeds: Most grass and broadleaf weeds.

Apply: EPP, PPI or PRE

Remarks: EPP may be made up to 30 days before planting. Preplant incorporate into the top 2 inches of soil. Use low rate on coarse textured, low OM soils and the high rate on fine soils with >3% OM or applied EPP.

Hornet (flumetsulam + clopyralid)

Rate: 0.2 to 0.3 lb DF (0.64 to 1 oz + 2 to 3 oz)

Weeds: Broadleaf weeds

Apply: EPP, PPI or PRE

Remarks: Early preplant (EPP) may be made up to 30 days before planting. Preplant incorporate into the top 2 to 3 inches of soil. Use low rate on coarse textured, low OM soils and the high rate on fine soils with >3% OM or applied EPP.

Hornet (flumetsulan + clopyralid)

Rate: 1.6 to 4.8 oz DF (0.4 to 1.12 + 1 to 2 oz)

Weeds: Broadleaf weeds

Apply: POST: Corn up to 24 inches tall.

Remarks: Apply to broadleaf weeds less than 8 inches tall. Use NIS at 0.25% v/v or PO at 1% v/v. Use 28% UAN at 2.5% v/v/ during dry conditions. Do not cultivate within 10 days before or after application. Refer to label for rate range for various weeds. Apply with Stinger at 2.67 fl oz/A for improved Canada thistle control. Do not exceed 0.07 lb ai/A flumetsulam per year.

Shotgun (atrazine + 2,4-D) RUP

Rate: 2 to 3 pt (0.56 to 0.84 + 0.25 to 0.375)

Weeds: Broadleaf and some grass weeds.

Apply: Preplant, PRE or EPOST

Remarks: Lower atrazine rates reduce potential for carryover. Do not use on coarse textured soils with less than 1% OM.

Atrazine + oil additive RUP

Rate: Appropriate rate + oil additive (1 to 2 lb ai/A)

Weeds: Broadleaf weeds and some grasses.

Apply: POST: Weeds less than 1.5 inches tall.

Remarks: Apply before corn is 12 inches tall. Apply with an oil additive at 1 qt/A. Provides partial control of foxtail. Atrazine soil residue may injure subsequent crops.

Bladex (cyanazine) + NIS or vegetable oil additive RUP

Rate: 1.3 to 2.2 lb 90DF (1.2 to 2.0)

Weeds: Grass and some broadleaf weeds.

Apply: POST: Weeds less than 1.5 inches. Corn up to 4-leaf stage.

Remarks: Do not use petroleum based crop oils. Vegetable oil additive increases weed control and risk of crop damage compared to NIS. Use only 90DF for POST applications. Avoid application under cool, wet conditions.

Banvel, Clarity (dicamba)

Rate: 0.5 to 1 pt of a 4 lb/gal conc. (0.25 to 0.5)

Weeds: Broadleaf weeds.

Apply: EPOST: Corn from spike to 8 inches tall.

Remarks: Do not apply Clarity after corn is 8 inches tall. Apply Banvel with drop nozzles after corn is 8 inches tall to increase crop safety and reduce drift. Use low rate on coarse textured or low OM soil Can be applied with Accent for grass control.

Rate: 0.5 pt of a 4 lb/gal conc. (0.25)

Weeds: Broadleaf weeds.

Apply: POST Directed: Corn at 8 to 36 inches or 15 days prior to tassel.

2,4-D

Rate: 0.5 to 1 pt of a 4 lb/gal conc. (0.25 to 0.5)

Weeds: Broadleaf weeds.

Apply: POST and POST Directed: Corn from 3-leaf to 30 inches tall.

Remarks: Use drop nozzles when corn is over 8 inches tall but before tasseling.

Buctril, Buctril Gel (bromoxynil)

Rate: 1 to 1.5 pt EC, 3.33 to 5 A/pack (0.25 to 0.37)

Weeds: Most annual broadleaf weeds.

Apply: POST: Corn prior to tasseling.

Remarks: Apply to weeds in the seedling stage. Weak on wild mustard. Could be used when drift of dicamba or 2,4-D may injure susceptible broadleaf crops.

Basagran (bentazon)

Rate: 1.5 to 2 pt 4S (0.75 to 1)

Weeds: Wild mustard, cocklebur, Canada thistle, and sunflower.

Apply: POST: Mustard: 4 to 6 leaf. Thistle: 6 to 8 inches.

Remarks: Could be used when drift of Banvel/Clarity or 2,4-D may injure sensitive crops. Thorough coverage is essential. Avoid application to stressed plants. Split applications needed for Canada thistle control.

Sencor (metribuzin) + broadleaf herbicide

Rate: 1.6 to 2 oz 75DF, 2.4 to 3 fl oz 4F + rate of broadleaf herbicide (0.075 to 0.09 + labeled rate)

Weeds: Most broadleaf weeds.

Apply: POST: Prior to tassel but MUST also follow crop stage restrictions of tankmix broadleaf herbicide.

Remarks: Tankmix with Atrazine, Basagran, Laddok, Buctril, Banvel, Clarity, Marksman, or 2,4-D. Do not use oil additive with any tankmix. Refer to label for adjuvant use with each broadleaf herbicide tankmix. Do not apply more than 5 oz 75DF per season.

Permit (halosulfuron) + additive

Rate: 2/3 to 1.33 oz (0.032 to 0.064)

Weeds: Redroot pigweed, common cocklebur, Venice mallow, common and giant ragweed, and sunflower.

Apply: POST: Corn up to 36 inches tall. Drop nozzles must be used from 24 to 36 inches tall.

Remarks: Good crop safety. Use NIS or oil additive with the addition of 28% UAN at 2 to 4 qt/A. Liquid fertilizer increases control pigweed and other species. Common lambsquarters is not controlled. Can be tank-mixed with Atrazine, Banvel, Clarity, Marksman, 2,4-D, Buctril, and Accent for greater weed control.

Scorpion III (flumetsulam + clopyralid + 2,4-D acid)

Rate: 1/4 lb (0.023 + 0.063 + 0.125)

Weeds: Most broadleaf weeds including nightshade, cocklebur, sunflower, ragweed, and suppression of Canada thistle.

Apply: POST: Corn up to 8 inches tall. Weeds: 2 to 4 leaf stage.

Remarks: Apply with NIS at 0.25% v/v or NIS + 28% UAN at 2.5% v/v. Addition of 28% UAN may improve control of weeds under dry conditions. Do not apply liquid fertilizer solutions as total carrier. Do not apply to corn previously applied with any Broadstrike product. Delay harvest until 85 days after application. Do not apply by air. There are no insecticide restrictions. Refer to label for crop rotation restrictions.

Stinger (clopyralid)

Rate: 1/3 to 2/3 pt (0.12 to 0.25)

Weeds: Canada thistle and other broadleaf weeds.

Apply: POST: Corn up to 24 inches tall. Thistle from 4 inches in diameter but before bud stage.

Other weeds: Before 5-leaf stage.

Remarks: Apply only to field corn. Majority of thistle shoots should be emerged at time of application. Wait 14 to 20 days after application before cultivating. Restrict livestock grazing or harvest treated corn within 40 days after last application. See narrative for rotational restrictions.

Basis (rimsulfuron + thifensulfuron) + additive

Rate: 1/3 oz (0.015)

Weeds: Barnyardgrass, foxtails, redroot pigweed, wild mustard, common lambsquarters, annual smartweed, and other grass and broadleaf weeds.

Apply: POST: Corn spike to 4-leaf (2 collar) stage.

Weeds 1 to 2 inches tall.

Remarks: Apply with NIS or oil additive. Always add 28% UAN. Addition of 28% nitrogen enhances weed control. Do not apply to corn previously treated with Counter insecticide. See narrative rotational restrictions and registered tank-mix options.

Basis Gold (nicosulfuron + rimsulfuron + atrazine)

Rate: 14 oz (0.188 oz + 0.188 oz + 0.76)

Weeds: Most all annual grass and broadleaf weeds including quackgrass.

Apply: POST: Corn up to 12 inches tall.

Remarks: Apply with oil adjuvant at 1 to 2% v/v. Use on corn hybrids of 88 or more days maturity. May be tank-mixed only with Banvel, Clarity, Hoernet, or Tough. Basis Gold at 14 oz/A contains 0.76 lb ai/A atrazine. Follow label for crop rotation restrictions.

Accent (nicosulfuron) + additive

Rate: 2/3 oz (0.0313)

Weeds: Emerged grasses including wild-proso millet and quackgrass plus pigweed and smartweed.

Apply: POST: Corn up to 36 inches.

Remarks: Drop nozzles must be used from 24 to 36 inches tall. Apply with oil additive and 28% UAN. Do not apply to corn previously treated with Counter 15G insecticide. See narrative rotational restrictions and registered tank-mix options. Addition of 28% nitrogen enhances weed control.

Accent (nicosulfuron) + atrazine

Rate: 2/3 oz + 0.42 to 1.7 lb 90DF (0.5 oz + 0.375 to 1.5)

Weeds: PRE and POST control of most grass and small-seeded broadleaf weeds.

Apply: POST: Corn up to 12 inches tall. Weeds actively growing.

Remarks: Add an oil adjuvant. MVO adjuvants enhances weed control. Addition of 28% UAN is recommended. Do not apply to corn taller than 12 inches tall.

Accent (nicosulfuron) + Banvel, Clarity (dicamba)

Rate: 2/3 oz + 0.5 to 1.5 pt 4S (0.5 oz + 0.25 to 0.5)

Weeds: POST control of most grass and broadleaf weeds and suppression of Canada thistle.

Apply: POST: Corn up to 8 inches tall. Apply with drop nozzles from 8 to 24 inches tall.

Remarks: NIS is required. Do not apply the 1 pt/A rate of Banvel to corn greater than 8 inches tall. Addition of 28% UAN is recommended. Do not substitute oil additive for NIS.

Sencor (metribuzin) + broadleaf herbicide

Rate: 2 to 3 oz + rate for broadleaf herbicide (0.09 to 0.14) + rate for broadleaf herbicide)

Weeds: Broadleaf weeds.

Apply: POST Directed: Corn more than 8 inches tall.

Remarks: Apply with 2,4-D, Banvel, or Buctril. Refer to label for adjuvant use, application information, range of crop stage at application, cultivation, potential for injury, and other restrictions.

Gramoxone Extra (paraquat) RUP

Directed Spray Only

Rate: 13 to 24 fl oz (0.25 to 0.47)

Weeds: Broadleaf and grass weeds.

Apply: POST Directed: Corn more than 8 inches tall.

Remarks: Treat no more than lower 3 inches of corn stalk. Apply with NIS at 0.25% v/v. May be tank-mixed with atrazine.

Herbicide Tolerant Corn

IMI-Corn

Lightning (imazethapyr + imazapyr)

Rate: 1.28 oz (0.64 + 0.15 oz)

Weeds: Most all annual grass and broadleaf weeds plus season-long suppression of some perennial weeds.

Apply: EPOST and POST

Remarks: Apply only to IMI-Corn varieties. Apply with adjuvant and liquid fertilizer. Refer to label for weeds controlled, application information, and crop rotation restrictions. High risk of developing ALS kochia resistance if used without herbicides of a different mode of action or using other weed control strategies. Registration expected in early 1997. Pursuit may be applied EPOST with Dual, Frontier, Lasso, and Prowl or POST with Accent, Atrazine, Banvel, Basagran, Buctril, or Clarity. High risk of developing ALS kochia resistance if used without herbicides of a different mode of action or using other weed control strategies.

Liberty Tolerant Corn

Liberty (glufosinate)

Rate: 16 to 28 fl oz (0.2 to 0.365)

Weeds: Most annual grass and broadleaf weeds plus suppression of some perennial weeds.

Apply: EPOST and POST: Corn up to 24 inches tall (7 collars)

Remarks: Apply only to Liberty tolerant corn varieties. Liberty is a nonselective, nonresidual, contact type herbicide with limited translocation. May be applied with spray grade AMS fertilizer. Refer to label for weeds controlled, application information, and other restrictions. See label for tankmixed options with residual herbicides. Liberty has unique mode of action and can be used to control resistant weeds.

Sethoxydim Resistant (SR) Corn

Poast (sethoxydim)

Rate: 0.5 to 1.5 pt (0.1 to 0.3)

Weeds: Control or suppression of annual and perennial grasses including barnyardgrass, field sandbur, foxtails, wild proso millet, and quackgrass.

Apply: POST: Grasses: 2 to 6 inches tall.

Remarks: Apply only to Poast Tolerant Corn varieties. Apply with oil additive at 1 qt/A to actively growing grasses. Drift and off-site movement may cause injury or death to grass weeds and crops.

Chemical Names, Formulations and Manufactuer

Trade Name	Common Name	Conc.	Manufacturer
Accent	nicosulfuron	75DF	DuPont
Atrazine	atrazine	4L, 90DF	Novartis
Banvel	dicamba	4S	BASF
Basagran	bentazon	4S	BASF
Basis	rimsulfuron + thifensulfuron	75DF	DuPont
Basis Gold	nicosulfuron + rimsulfuron + atrazine	89.5DF	DuPont
Beacon	primisulfuron	75DF	Novartis
Bicep	atrazine + metolachlor	6L	Novartis
Bladex	cyanazine	4L, 90DF	DuPont
Broadstrike + Dual	flumetsulam + metolachlor	7.67E	DowElanco
Bromox	bromoxynil	2E	several
Buctril	bromoxynil	2E	Rhone-Poulenc
Buctril + Atrazine	atrazine + bromoxynil	3L	Rhone-Poulenc
Bullet	atrazine + alachlor	4L	Monsanto
Clarity	dicamba	4S	BASF
Cy-Pro	cyanazine	4L, 90DF	Griffin
Cy-Pro AT	atrazine + cyanazine	4L, 90DF	Griffin
DoublePlay	acetochlor + atrazine	7E	Zeneca
Dual II	metolachlor	7.8E, 25G	Novartis
Eradicane	EPTC	6.7E, 25G	
Exceed	primisulfuron + prosulfuron	64.6DF	Novartis
Extrazine II	atrazine +	90DF	DuPont
			cyanazine

Trade Name	Common Name	Conc.	Manufacturer
Frontier	dimethenamid	6E	BASF
FulTime	acetochlor + atrazine	—	Zeneca
Gramoxone Extra	paraquat	2.5S	Zeneca
Guardsman	atrazine + dimethenamid	5L	BASF
Harness	acetochlor	7E, 20G	Monsanto
Harness Xtra	acetochlor + atrazine	6L, 5.6L	Monsanto
Hornet	clopyralid + flumetsulam	85.6DF	DowElanco
Laddok S-12	atrazine + bentazon	5L	BASF
Lariat	atrazine + alachlor	4L	Monsanto
Lasso	alachlor	4L	Monsanto
Liberty	glufosinate	1.67S	AgrEvo
Lightning	imazapyr + imazethapyr		American Cyanamid
Marksman	atrazine + dicamba	3.2L	BASF
Moxynil	bromoxynil	2E	Terra
OpTil	dicamba + dimethenamid	—	BASF
Permit	halosulfuron	75DF	Monsanto
Poast	sethoxydim	1.5E	BASF
Prowl	pendimethalin	3.3E	American Cyanamid
Pursuit	imazethapyr	2S, 70DG	American Cyanamid
Ramrod	propachlor	4L, 20G	Monsanto
Ramrod/Atrazine	atrazine + propachlor	4L, 64DF	Monsanto
Roundup Ultra	glyphosate	3S	Monsanto

Trade Name	Common Name	Conc.	Manufacturer
Scorpion III	flumetsulam + clopyralid + 2,4-D acid	84.3DF	DowElanco
Sencor	metribuzin	4L, 75DF	Bayer
Shotgun	atrazine + 2,4-D	3.25L	UAP
Stinger	clopyralid	3S	DowElanco
Surpass	acetochlor	6.4E, 20G	Zeneca
Surpass 100	acetochlor + atrazine	5L	Zeneca
TopNotch	acetochlor	3.2E	Zeneca
Touchdown	glyphosate	6E	Zeneca
Tough	pyridate	3.75L	BASF
2,4-D	2,4-D	several	several

Herbicide Premixes

Prepackaged Mixtures Available for Corn

Most herbicides used in corn are labeled for tank-mixing with other herbicides for broadspectrum weed control. Several commercial herbicide mixtures are available for use in corn. Combinations best adapted to North Dakota are given in the chemical weed control tables. Consult the label and discussion of individual herbicides for a complete list of all possible registered combinations.

Trade Name	Common Name	Product/A
Basis	rimsulfuron+thifensulfuron	0.33 oz
Bicep, Bicep II	metolachlor + atrazine	1.8 to 3 qt
Bicep Lite	metolachlor + atrazine	1.5 to 3.5 qt
Broadstrike + Dual	flumetsulam + metolachlor	1.75 to 2.75 pt
Broadstrike Plus	flumetsulam + clopyralid	0.2 to 0.3 lb
Bronco	alachlor + glyphosate	3 to 5 qt
Buctril+Atrazine	bromoxynil + atrazine	1.5 to 3 pt
Bullet	alachlor + atrazine	2.5 + 4.5 qt
Extrazine II	cyanazine + atrazine	1.25 to 5.25 qt 1.4 to 5.8 lb DF
Guardsman	dimethenamid + atrazine	2.5 to 5 pt
Harness Extra	acetochlor+atrazine	1.8 to 2.3 qt
Laddok	bentazon + atrazine	2 to 3.5 pt
Lariat	alachlor + atrazine	2.5 to 4.5 qt
Marksman	dicamba + atrazine	3.5 pt
Ramrod + Atrazine	propachlor + atrazine	3.5 to 5.5 qt 5 to 8.6 lb DF
Scorpion III	flumetsulam + clopyralid +2,4-D	0.25 lb
Shotgun	atrazine + 2,4-D	2 to 3 pt
Surpass 100	acetochlor + safener + atrazine	1 to 3 pt

Herbicide Comments

Eradicane (EPTC plus safener) at 4.75 to 7 pt/A or 16 to 24 lb/A 25G controls grass and certain broadleaf weeds. Eradicane at 6 lb/A gives fair to good quackgrass control. Soil should be dry enough and in good tilth to permit immediate and thorough incorporation. Eradicane is registered as a tank-mixture with atrazine, Bladex and Surpass. Eradicane can be tank-mixed with Surpass to improve performance over a wider range of environmental conditions.

Lasso (alachlor) at 2 to 4 qt 4E/A and **Dual** (metolachlor) at 1.5 to 3 pt 8E/A are used PPI or PRE to control annual grasses and certain broadleaf weeds such as redroot pigweed, common lambsquarters and common ragweed. Lasso may also be applied POST to corn up to 5 inches tall for PRE control of weeds and reduced competition of labeled weeds. Use the higher rate on clay soils high in organic matter. Incorporation improves weed control with Lasso and Dual. Lasso is registered as a tank-mixture with atrazine, Banvel, Bladex, Roundup Ultra/RT, and Gramoxone Extra. Dual may be surface applied or incorporated in the fall after October 15 but before ground freezes or applied in the spring. Dual is registered as a tank-mixture with atrazine, Bladex, Banvel or with atrazine plus paraquat or Roundup Ultra/RT. Dual may be applied up to 45 days before planting. Lasso is a restricted use herbicide.

Frontier (dimethenamid) at 13 to 25 fl oz/A is used EPP up to 45 days before planting, PPI, PRE or early POST. Use the higher rate on fine textured soils with greater than 3% OM and the lower rates on coarse textured soils with less than 3% OM. Incorporation may improve weed control in drier conditions. Frontier is registered as a tank-mixture with atrazine, Banvel, Bladex, Roundup Ultra/RT, Marksman, paraquat, Prowl, 2,4-D, and Princep. NDSU field trials have shown Frontier to provide equal or greater weed control than Lasso or Dual. Frontier has shown greater and more consistent weed control in wet climates than Lasso or Dual.

Harness (acetochlor + safener) at 1 to 3 pt/A or **Surpass** (acetochlor + dichlormid (safener)) at 1 to 3 pt/A or **TopNotch** (encapsulated acetochlor + dichlormid (safener) at 4 to 7.25 pt/A applied PPI or PRE control annual grasses and certain broadleaf weeds such as pigweed species, common lambsquarters, kochia, nightshade, and common ragweed. Use the higher rate on clay soils high in organic matter. Do not apply Surpass on sands with less than 3% OM, loamy sands with less than 2% OM, or sandy loams with 1% OM, if ground water is within 30 feet of soil surface. Incorporation may improve weed control under dry conditions. Harness Plus is registered as a tank-mixture with atrazine, Eradicane, Prowl, Banvel, Bladex, Roundup Ultra/RT, and Gramoxone Extra. Harness Xtra may be applied up to 45 days before planting.

Prowl (pendimethalin) at 1.8 to 4.8 pt EC or 1.25 to 3.33 lb DG controls annual grasses and certain broadleaf weeds such as redroot pigweed. Prowl must be used only PRE in corn and not PPI. Do not use Prowl on sands or loamy sands or on soils with less than 1.5% organic matter. Prowl can be tankmixed with atrazine, Bladex and Banvel.

Broadstrike + Dual (flumetsulam + metolachlor) at 1.75 to 2.75 pt/A of the premix product or 0.04 to 0.07 lb/A of the Broadstrike component + 1.6 to 2.6 pt 8E/A of the Dual component applied EPP, PPI, or PRE will control some grass and broadleaf weeds. Broadstrike is not packaged individually and is only available as a premix. Broadstrike is very active on small-seeded broadleaf weeds like nightshade, pigweed, kochia, common lambsquarters, mustard, annual smartweed, marshelder, and Venice mallow. Broadstrike may also provide some control of common ragweed and lanceleaf sage.

Hornet (flumetsulam + clopyralid) at 0.2 to 0.3 lb/A of the premix product or 0.05 to 0.07 lb/A of flumetsulam + 0.13 to 0.19 lb/A of the clopyralid component can be applied EPP, PPI, or PRE. Use 0.2 to 0.25 lb/A on coarse textured soils

and 0.25 to 0.3 lb/A on medium and fine textured soils. Hornet controls a wide spectrum of broadleaf weeds including nightshade, kochia, pigweed, common lambsquarters, mustard, annual smartweed, wild buckwheat, Venice mallow, marshelder, Russian thistle, horseweed and common ragweed. Hornet has shown excellent activity on large-seeded broadleaf weeds such as common cocklebur and sunflower. Hornet has no activity on grasses, so a grass control herbicide is required either in tank mix or as a separate application.

Atrazine at 1 to 2 lb/A applied PPI or PRE gives good control of annual weeds without corn injury. Fine textured soils with high organic matter require 2 lb/A. Atrazine residues injurious to susceptible crops may remain in soils longer than one growing season. (See herbicide residue section for additional discussion). Atrazine is registered as a tank-mixture with Lasso, bromoxynil (Buctril, others), Sutan+, Bladex, Banvel, Dual, Ramrod. Atrazine is available as a prepackage mix with several herbicides; see table on package mixtures. Atrazine is a restricted use herbicide.

Bladex, Cy-Pro (cyanazine) at 1.3 to 5.3 lb 90DF applied PRE controls annual grass and broadleaf weeds in corn. Use the higher rates on fine textured, high organic matter soils, and the lower rates on coarse textured soils with low organic matter. Do not use on sandy or loamy sand soils, or on soils with less than 1% organic matter. Bladex requires 0.5 inch or more rain for activation, especially on fine textured soils. Bladex is a restricted use herbicide.

Banvel/Clarity (dicamba) at 0.5 to 1 pt/A 4S applied PRE in tank-mixtures with Lasso, atrazine, Accent, Bladex, Dual, or Prowl gives broadspectrum weed control. Banvel/Clarity mixtures are not recommended on coarse-textured sandy soils. Use the lower rate of Banvel on medium soil with 2% OM.

Atrazine at 0.38 to 2 lb ai/A should be applied to corn less than 12 inches tall, broadleaf weeds less than 4 inches tall, or grass weeds less than 1 inch tall. Atrazine gives good wild oat control, partial foxtail (pigeongrass) control, and excellent control of broadleaved weeds (including volunteer sunflower) when used in combination with petroleum oil concentrate or emulsifiable vegetable oil. Atrazine applied with vegetable or petroleum oil at 1 qt/A give similar weed control. Surfactants are less effective with atrazine than any oil additives. Refer to herbicide residue section for carryover precautions. Refer to label for information on application and restrictions based on a RUP status. Atrazine is a restricted use herbicide. See K13 for information on surface applications.

Bladex 90DF, Cy-Pro 90DF (cyanazine) at 1.3 to 5.28 lb 90DF applied as an early POST treatment for grass and broad-leaf weed control (including volunteer sunflower). Emulsifiable vegetable oil at 1 qt/A enhances weed control but may increase the risk of crop injury. Use only the 90DF formulation for POST applications. Bladex or Cy-Pro at 1.3 lb 90DF/A with 1 qt/A of vegetable oil has given good control of small weeds (less than 1.5 inches tall). Occasionally corn leaf burn occurs, but recovery is good. Higher rates will give more consistent weed control but also increase risk of corn injury. Corn should not be treated after the 4th leaf stage, when corn is under stress, or during extended cold, wet conditions. Bladex/Cy-Pro is unlikely to carryover and cause crop injury the next year. Bladex at 1.3 lb 90DF/A rate control emerged weeds in fine-textured soils. Bladex/Cy-Pro are restricted use herbicides.

Basis (rimsulfuron + thifensulfuron) at 0.33 oz 75DF/A can be applied to 4-leaf (2 collar) corn for foxtail, barnyardgrass, redroot pigweed, wild mustard, common lambsquarters, and annual smartweed control. Apply when grasses are 1 to 2 inches tall and broadleaf weeds are 1 to

3 inches tall. A cultivation or sequential application of Accent may be needed to completely eliminate weeds. Basis must be applied with NIS and 28% UAN. Under drought conditions, an oil additive (petroleum or MSO type oil) at 1 to 2% v/v may be substiuted for NIS. Do not use 28% UAN without an NIS. Corn varieties of 88 day maturity or less are more susceptable to injury from Basis than varieties greater than 88 days. Do not apply late.

Basis Gold (nicosulfuron + rimsulfuron + atrazine) at 14 oz 89.46DF/A applied POST to corn up to 12 inches tall controls most all annual grass and broadleaf weeds plus quackgrass. Apply with oil adjuvant at 1 to 2% v/v. NDSU research has shown greater herbicide enhancement from Accent and atrazine applied with MSO type adjuvants than NIS or petroleum oil adjuvants. Apply only to corn hybrids of 88 or more days maturity. Basis Gold at 14 oz 89.46DF/A contains 0.25 oz 75DF/A Accent, 0.75 oz 25DF/A Matrix, and 0.76 lb ai atrazine. NDSU research has shown that good safety exists to most all crops (including small grains and sugarbeet) planted the year following atrazine **applied at 0.38 lb ai/A** with normal rainfall the year of application. The atrazine in Basis Gold applied at a half rate (7 oz 89.46DF/A) would be equivelent to 0.38 lb ai/A. If a half rate of Basis is used, additional Accent may need to be added to achieve adequate weed control. Applying herbicides at lower than labeled rates makes user liable for product performance and crop injury on crops planted at a shorter interval than directed on the label.

Accent (nicosulfuron) at 0.67 oz 75DF/A can be applied to corn up to 36 inches tall. For corn 20 to 36 inches tall (free standing), Accent should be applied with drop nozzles. Do not apply to field corn taller than 36 inches or with 10 collars, whichever is most restrictive. When banding Accent over the row with a three-nozzle-per-row-system, plug the center nozzle to reduce corn injury from Accent from Accent concentrating in the whorl of the corn plant.

Always add an oil adjuvant at 1% v/v or NIS at 0.25% v/v. Research results at NDSU have indicated that adjuvant enhancement of weed control from Accent was greatest with Scoil (MSO type oil), followed by Sun-It II, petroleum oil, and least with NIS. Use of 28% UAN at 1% v/v with NIS has enhanced weed control compared to Accent plus NIS. Accent may be used POST to control foxtail species, fall panicum, barnyardgrass, field sandbur, woolly cupgrass, wild-proso millet, wild oat, quackgrass, pigweed species, smartweed, wild mustard, jimsonweed, and burcucumber. NDSU results show that Accent provides good control of kochia and fair control of Russian thistle.

Accent can be tank-mixed with atrazine, bromoxynil, (Buctril, others), Buctril + Atrazine, Banvel, Marksman, Scorpion III and many other herbicides. Oil adjuvants should always be used when tank-mixing Accent with atrazine. NDSU research has shown excellent and economic grass and small-seeded broadleaf weed control from **Accent tank-mixed with atrazine** at 0.38 lb/A with methylated seed oil adjuvants. Accent + atrazine does not adequately control common cocklebur. A sequential application of Banvel or other effective herbicides can be made to control common cocklebur.

Banvel/Clarity (dicamba) at 0.5 to 1 pt/A 4S may be applied alone PRE or early POST to corn from emergence to 8 inches tall. Banvel/Clarity gives better control of Canada thistle, kochia, smartweed, wild buckwheat and volunteer sunflower than 2,4-D with less injury to corn. Banvel alone only at the 0.5 pt/A can be applied if corn is greater than 8 inches tall or at 0.25 to 0.5 pt/A when combined with 2,4-D. Banvel can be applied before corn is 3 feet tall or until 15 days before tassel emergence. Drop nozzles should be used after corn is 8 inches tall to reduce injury if Banvel is applied with 2,4-D and to reduce drift potential. Banvel/Clarity can be mixed with Accent, Bladex and atrazine.

2,4-D amine at 0.5 to 1 pt/A of a 4 lb/gal concentrate applied POST to corn 3 to 8 inches tall will control broadleaf weeds. 2,4-D at 0.5 pt/A will control susceptible weeds like wild mustard and 1 pt/A rate will control tolerant weeds, including volunteer sunflower, but risk of corn injured is greater. Do not apply MCPA to corn, as it is more injurious to corn than 2,4-D. Apply 2,4-D with drop nozzles when corn is over 8 inches tall to reduce corn injury by directing the spray away from the whorl. 2,4-D may cause brittle stalks that may lodge or break. Several brands of 2,4-D are available with some differences on application information; for example, Hi-Dep allows use at spray volumes as low as 1 gpa by ground or 0.5 gpa by air.

Buctril, Bromox, Moxynil, others (bromoxynil) at 1 to 1.5 pt/A or 3.33 to 6.67 A/Gel Pack applied to corn from emergence but before tasselling controls seedling wild buckwheat, volunteer sunflower, and most annual broadleaf weeds. Some corn leaf burn may occur when high temperatures follow application. Bromoxynil is a contact herbicide so thorough spray coverage is essential for adequate weed control. Bromoxynil can be mixed with atrazine to increase the spectrum of weed control. A commercial mixture of bromoxynil plus atrazine is available.

Basagran (bentazon) at 1.5 to 2 pt/A applied POST in corn controls many broadleaf weeds from 2 to 10 inches tall. Basagran will control common cocklebur, giant and common ragweed, smartweed, venice mallow, wild mustard, sunflower and yellow nutsedge. Basagran can control Canada thistle with sequential applications. Corn is tolerant to Basagran at all stages. Liquid fertilizer can be used with Basagran in place of oil concentrate for improved control of several weeds. Basagran can be applied in corn when drift of Banvel or 2,4-D may injure sensitive crops.

Sencor (metribuzin) at 1.6 to 2 oz 75DF/A or 2.4 to 3 fl oz 4F applied POST with another herbicide labeled for tankmix use with Sencor controls many broadleaf weeds.

Sencor can be tankmixed with atrazine, Banvel, Basagran, bromoxynil (Buctril, others), Clarity, Marksman, and 2,4-D. Use drift reducing methods when tankmixing with Banvel, Clarity, Marksman, or 2,4-D ester. Consult label for adjuvant use with the different tankmix options. Do not use oil additives with any Sencor tankmix. Corn can be grazed, or harvested for silage or grain 60 days after treatment.

Permit (halosulfuron) at 2/3 to 1 1/3 oz 75DF/A applied POST in corn controls nutsedge and some broadleaf weeds in corn. Permit provides excellent control of sunflower, common and giant ragweed, and common cocklebur. Permit must be tank-mixed with 2,4-D or Banvel/Clarity for common lambsquarters and pigweed control. Always add NIS or oil additive. Addition of 28% UAN may enhance control of larger pigweed. Unlike many sulfonylurea herbicides, high soil pH does not contribute to persistance in the soil. Degradation of Permit increases as soil pH increases. However, Permit can have a residue in the soil the year following application. Refer to the label or "Herbicide Residue" section of this guide for more information on crop rotation restrictions.

Scorpion III (flumetsulam + clopyralid + 2,4-D acid) at 0.25 lb 84.3DF/A of the premix product contains 0.023 of flumetsulam + 0.063 lb of clopyralid + 0.125 lb of 2,4-D acid. Apply POST to corn up to 8 inches tall (measured to the top of the whorl). Later applications may be made if the spray is directed below the whorl using drop nozzles. Do not apply less than 85 days before harvest. Do not apply by air. Always add NIS at 0.25% v/v. Under adverse environmental conditions, add NIS at 0.25% v/v **AND** 28% UAN at 2.5% v/v. Apply to weeds in the 2- to 4-leaf stage. Scorpion III provides excellent control of a wide range of broadleaf weeds including sunflower, kochia, Russian thistle, pigweed spp., lambsquarters, common and giant ragweed, mustard spp., marshelder, and nightshade spp.

Emergency control of broadleaf and grass weeds in corn can be obtained with Evik or Gramoxone Extra applied POST

directed. Evik at 2 to 2.5 lb/A or Gramoxone Extra at 0.25 lb/A should be applied as a directed spray to the weeds. A NIS must be used with both herbicides. These herbicides applied over the top of corn will cause severe injury and contact with the leaves will cause burning. Do not apply Evik before corn is 12 inches high or paraquat before corn is 10 inches high. Weeds should be less than 4 inches tall.

Herbicide Tolerant Corn

IMI-Corn

Lightning (imazethapyr + imazapyr) at 1.28 oz 70WDG/A (0.64 oz imazethapyr + 0.15 oz imazaquin) controls most annual grass and broadleaf weeds plus season-long suppression of perennial weeds including quack-grass and Canada thistle. Apply Lightning EPOST or POST only to IMI-corn varieties and to weeds 2 to 4 inches tall. Apply with adjuvant and liquid fertilizer. Refer to label for weeds controlled, adjuvants, application information and timing, tankmix options, insecticide interaction, and crop rotation restrictions.

Liberty Tolerant Corn

Liberty (glufosinate) at 16 to 28 fl oz/A (0.2 to 0.365 lb/A) control most annual grass and broadleaf weeds plus suppression of some perennial weeds. Apply Liberty EPOST or POST to Liberty tolerant corn up to 24 inches tall or with 7 collars (V7). Liberty is a nonselective, nonresidual, contact type herbicide with limited translocation. Liberty should be applied to small weeds because of limited translocation. Liberty is nonresidual which may require multiple applications or applying with a residual herbicide to control multiple weed flushes. Nonresidual nature of Liberty will allow any crop to be planted the following year. Liberty can be applied with spray grade AMS fertilizer. Refer to label for weeds controlled, application information and timing, tankmix options, restriction. application information, and other restrictions.

Sethoxydim Resistant (SR) Corn

Poast (sethoxydim) at 0.5 to 1.5 pt/A applied only to Poast (Sethoxydim) Resistant (SR) Corn varieties will control annual including barnyardgrass, field sandbur, foxtails, wild proso millet, and suppress quackgrass. Apply POST with oil additive at 1 qt/A to actively growing grasses 2 to 6 inches tall. Drift and off-site movement may cause injury or death to grass weeds and crops.

Restrictions on Feeding and Grazing of Corn Treated with Herbicides

Bladex, Dual, Eradicane, Lasso, Lorox, Prowl, Ramrod, Scorpion III, Sutan +:
No restrictions.

Accent, Basis, Buctril, Permit:
Do not feed or graze for 30 days after application.

Atrazine, Basagran:
Do not feed or graze for 21 days after application.

Banvel, Clarity:
Do not graze or harvest for feed prior to ensilage (milk) stage of crop.

Sencor:
Do not feed or graze for 60 days after application.

Stinger:
Do not feed or graze for 40 days after application.

Tough:
Do not feed or graze for 68 days after application.

2,4-D:
Do not feed or graze for 7 days after application.

Rotation Restrictions for Corn

Herbicide	Months after Application
Ally	22a
Amber	22
Assert	NCS
Broadstrike + Treflan	8
Buckle	16
Curtail	1
Exceed	f
Far-Go	NCS
Finesse	f
Lexone	4[p]
Lightning	8.5
Peak	1
Prowl	0[q]
Pursuit	8.5
Sencor	4[p]
Sonalan	NCS
Tordon (<1.5 oz)	SCS[r]
Treflan/Trifluralin	NCS[s]

NCS = Next cropping season after herbicide application.

SCS = Second cropping season after herbicide application.

[a] Do not use on soil with pH greater than 7.9. Requires 22 months and 22 inches of precipitation west of Hwy 1 or 34 months and 34 inches of precipitation east of Hwy 1.

[f] Do not plant until field bioassay indicates it is safe.

[h] Buckle is labeled as a fall treatment in durum wheat and spring PPI application for durum and HRSW (some varieties excluded).

[p] Must add 2 months if soil pH is 7.5 or above. Wheat and barley can be planted 4 months after application following lentils or soybeans.

[q] Corn can be planted only if Prowl is applied PRE. DO NOT APPLY PPI.

[r] 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.

[s] Oats, sorghum, and annual or perennial grass crops may be planted at least 12 months after application in areas that received 20 inches or more of precipitation during the growing season.

Relative Herbicide Effectiveness on Weeds and Persistence in Soil

This table gives a general rating of relative herbicide effectiveness to weeds listed and persistance of herbicides in soil. Under favorable weather conditions, control may be better than indicated. Under unfavorable conditions, some herbicides rated as good or fair may give erratic and unacceptable results. Also, dry and/or cool weather increases herbicide persistence while wet and/or warm weather reduces herbicide persistence.

Weed control ratings in this section are based on the following scale:

E = Excellent = 90 to 99% Control
G = Good = 80 to 90% Control
F = Fair = 65 to 80% Control
P = Poor = 40 to 65% Control
N = None = No Control

Herbicide persistence ratings are for residues present 12 months after application:

O = Often
S = Seldom
N = None

SOIL APPLIED HERBICIDES	Barnyardgrass	Field Sandbur	Foxtail, Green	Foxtail, Yellow	Quackgrass	Volunteer Cereals	Wild Oat	Wild Proso Millet	Herbicide Persistence
Atrazine (PPI)	G	F	F-G	G	P-F	E	E	P-F	O
Atrazine (PRE)	G	F	F-G	G	P	E	G-E	P	O
Bladex/Cy-Pro (PPI)	F	F	G	G	P-F	E	F	P-F	S
Bladex/Cy-Pro (PRE)	P-F	F	F-G	F-G	P	G-E	P-F	P-F	S
Broadstrike (PPI)	N	N	N	N	N	N	N	N	N
Broadstrike (PRE)	N	N	N	N	N	N	N	N	N
DoublePlay (PPI)	E	G-E	E	E	F-G	G-E	G-E	F-G	N
Dual (PRE)	G-E	P	G-E	G-E	N	F-G	G	P	N
Dual (PPI)	F-G	P	G	G	N	F	P	N	N
Eradicane (PPI)	E	G-E	E	E	F-G	G-E	G-E	F-G	N
Frontier (PPI)	G-E	G	G-E	G-E	N	G	F	F	N
Frontier (PRE)	F-G	G	G-E	G-E	N	F	F	F	N
Harness/Surpass (PPI)	E	G-E	G-E	G-E	N	G	G	F-G	N

	Barnyardgrass	Field Sandbur	Foxtail, Green	Foxtail, Yellow	Quackgrass	Volunteer Cereals	Wild Oat	Wild Proso Millet	Herbicide Persistence
Harness/Surpass (PRE)	E	G	G-E	G-E	N	G	G	F-G	N
Hornet (PPI/PRE)	N	N	N	N	N	N	N	N	O
Lasso/generics (PPI)	G-E	F	G-E	G-E	N	F-G	F-G	P-F	N
Lasso/generics PRE	F-G	P	G	G	N	F-G	P	P	N
Sencor (PPI)	F	F-G	F	F	F	G	N	P	S
Sencor (PRE)	P-F	F	P-F	P-F	N	F-G	P	P	S
Prowl/Pentagon (PPI)	E	G	E[1]	E[1]	N	G	G	P-F	S
Prowl Pentagon (PRE)	E	F	G-E[1]	G-E[1]	N	F-G	P-F	PF	S
Ramrod (PRE)	E	F-G	G-E	G-E	N	G-E	P	P	N
Sutan (PPI)	G-E	G	E	E	P-F	E	G	P-F	N
TopNotch (PPI)	E	G-E	G-E	G-E	N	G	G	F-G	N
TopNotch (PRE)	E	G	G-E	G-E	N	G	G	F-G	N

PPI = Preplant Incorporated, PRE = Preemergence
[1] Except where resistant populations have developed.

SOIL APPLIED HERBICIDES	Buckwheat, Wild	Cocklebur, Common	Flixweed	Kochia	Lambsquarters, Common	Lanceleaf Sage	Mallow, Venice	Marshelder	Mustard, Wild	Nightshade, Black	Pigweed, Redroot	Prickly Lettuce	Ragweed, Common	Smartweed, Annual	Sunflower	Thistle, Russian	Thistle, Canada
Atrazine (PPI)	E	G	E	E	E	-	G	-	E	E	E	E	E	E	G-E	E	F
Atrazine (PRE)	G-E	F-G	E	G-E	G-E	-	G	-	E	G-E	G-E	E	E	E	F-G	G-E	P-F
Bladex/Cy-Pro (PPI)	G	F	E	G-E	G-E	-	G	-	E	F	F	E	E	E	F-E	E	N
Bladex/Cy-Pro (PRE)	F-G	F	E	G	G-E	-	G	E	G-E	P-F	P-F	E	E	E	P-F	G-E	N
Broadstrike (PPI)	G-E	F-G	E	E[1]	E	G-E	E	E	E	G-E	E	E	G	E	G-E	G-E[1]	F
Broadstrike (PRE)	G	F	E	E	E	G-E	E	E	E	G-E	E	E	F-G	E	G	G[1]	P-F
DoublePlay (PPI)	F	P	P	G-E	E	N	N	P	F	G-E	E	P	G-E	P	P	F	N
Dual (PPI)	P	N	-	F	F	N	N	-	P	G	G-E	P	P-F	P	N	F	N
Dual (PRE)	P	N	-	P-F	P-F	N	N	-	P	G	F-G	P	P-F	P	N	P-F	N
Eradicane (PPI)	F	P	P	F	F	N	N	P	P	F-G	G	P	F	P	N	P	N
Frontier (PPI)	P	N	-	F	F	N	-	-	P-F	G-E	E	-	P	P	N	P-F	N
Frontier (PRE)	P	N	-	P-F	F	N	-	-	P-F	G	G-E	-	P	P	N	P	N
Harness/Surpass (PPI)	P	P	-	G-E	G-E	N	-	-	F	G-E	E	-	G-E	P	P	F	N
Harness/Surpass (PRE)	P	P	-	G	G	N	-	-	F	G	G-E	-	G	P	N	F	N

	Buckwheat, Wild	Cocklebur, Common	Flixweed	Kochia	Lambsquarters, Common	Lanceleaf Sage	Mallow, Venice	Marshelder	Mustard, Wild	Nightshade, Black	Pigweed, Redroot	Prickly Lettuce	Ragweed, Common	Smartweed, Annual	Sunflower	Thistle, Russian	Thistle, Canada
Hornet (PPI/PRE)	E	G-E	E	E[1]	E	G-E	E	E	E	E	E	E	E	E	E	E[1]	F-G
Lasso/generics (PPI)	P	N	-	F	F	N	N	-	P	G	G-E	P	P	P	N	F	N
Lasso/generics (PRE)	P	N	-	P-F	P-F	N	N	-	P	G	F-G	P	P	P	N	P-F	N
Sencor (PPI)	F	F	E	G	F	F-G	G-E	E	E	P	E	E	E	G	P-F	E	N
Sencor (PRE)	F	P-F	G-E	F-G	P-F	F-G	G	E	G-E	P	G-E	E	G-E	G	P	G-E	N
Prowl/Pentagon (PPI)	P-F	N	P	G-E	E	N	F-G	N	N	P	E	N	F	P	N	G	N
Prowl/Pentagon (PRE)	P	N	P	F-G	G	N	F	-	N	N	G	N	P	P	N	F-G	N
Ramrod (PRE)	F	P	P	G	F	N	N	N	P	-	E	P	P	P	N	P	N
Sutan + (PPI)	P	P	P	-	P	N	N	-	P	F	F	P	F	P	N	P	N
TopNotch (PPI)	P	P	-	G-E	G-E	N	-	-	F	G-E	E	-	G-E	P	N	F	N
TopNotch (PRE)	P	P	-	G	G	N	-	-	F	G	G-E	-	G	P	N	F	N

PPI = Preplant Incorporated, PRE = Preemergence

[1] Except where resistant populations have developed.

POST APPLIED HERBICIDES	Barnyardgrass	Field Sandbur	Foxtail, Green	Foxtail, Yellow	Quackgrass	Volunteer Cereals	Wild Oat	Wild Proso Millet	Herbicide Persistence
Accent	E	G-E	E	G-E	G-E	G-E	E	G-E	O
Atrazine + oil	G	F	G	G-E	P-F	F-G	G-E	F	S
Banvel/SGF/Clarity	N	N	N	N	N	N	N	N	S
Banvel/SGF + MCPA	N	N	N	N	N	N	N	N	S
Basagran	N	N	N	N	N	N	N	N	N
Basis	G-E	F-G	G-E	G	F-G	F-G	F-G	F	S
Basis Gold	E	G	E	E	E	G	E	G-E	O
Bladex/Cy-Pro + oil	G	F-G	G	G	N	G-E	F-G	P-F	N
Blazer	N	P	P-F	P-F	N	N	N	P	N
Bronate/Bison/others	N	N	N	N	N	N	N	N	N
Buctril/Bromox/others	N	N	N	N	N	N	N	N	N
Gramoxone Extra/Cyclone	G	G	G	G	P	F-G	G	F-G	N
Hornet	N	N	N	N	N	N	N	N	O
Lexone	G	G	G	G	P	P	P	P	O

	Barnyardgrass	Field Sandbur	Foxtail, Green	Foxtail, Yellow	Quackgrass	Volunteer Cereals	Wild Oat	Wild Proso Millet	Herbicide Persistence
Liberty	E	-	E	E	P	F-G	E	E	N
Lightning	E	E	E	E	P	-	G-E	G-E	O
Permit	N	N	N	N	N	N	N	N	O
Poast/Plus	E	E	E	E	F-G	E	G-E[1]	E	N
Pursuit	G	P-F	G	F-G	N	G	F	P-F	O
Roundup Ultra/RT/Glyphos	E	E	E	E	E	E	G-E	E	N
Scorpion III	N	N	N	N	N	N	N	N	S
Sencor	F	-	F	F	P	P	-	-	O
Sencor + Banvel/Buctril	P	N	P	P	N	N	N	N	N
Stinger	N	N	N	N	N	N	N	N	S
Touchdown	E	E	E	E	E	E	G-E[1]	E	N
Tough	N	N	N	N	N	N	N	N	N
2,4-D	N	N	N	N	N	N	N	N	N

[1] Herbicides will not control resistant biotypes.

POST APPLIED HERBICIDES	Buckwheat, Wild	Cocklebur, Common	Flixweed	Kochia	Lambsquarters, C.	Lanceleaf Sage	Mallow, Venice	Marshelder	Mustard, Wild	Nightshade, Black	Redroot Pigweed	Prickly Lettuce	Ragweed, Common	Smartweed, Annual	Sunflower	Thistle, Russian	Thistle, Canada
Accent	P-F	P	-	F	P	-	P	-	E	N	E	-	P	G-E	P	P	N
Atrazine + oil	G	G	E	E	E	-	-	E	E	G	E	E	E	E	G	E	P
Avenge	N	N	P	N	N	N	N	N	N	N	N	N	N	N	N	N	N
Banvel/SGF/Clarity[1]	E	E	P-F	E	G	P-F	F	E	G	E	G	G-E	E	E	G-E	G	F-G
Banvel/SGF + MCPA[1]	G-E	E	F-G	G-E	E	G-E	G	G-E	E	E	G	E	E	E	E	G	F
Basagran	F-G	G-E	E	F-G	F-G	P	E	G-E	E	F	F	E	G	E	E	F	F-G
Basis	F	P	-	F-G[2]	G	P	F	G	E	P	E	-	P	E	F-G	G[2]	P
Basis Gold	G	F-G	E	E[2]	E	-	-	E	E	F	E	E	G-E	E	G	E	P-F
Bladex + oil	G	G	F-G	G	G	-	-	E	E	G	F-G	G	E	E	E	G	P
Buctril	E	E	F-G	G-E	G	E	G-E	E	F-G	E	F-G	E	E	G-E	G-E	E	F
Gramoxone Extra/Cyclone	F	F-G	G	G-E	E	E	G	G	E	G-E	E	E	G-E	E	E	E	P
Hornet	F-G	E	E	E	P-F	-	E	-	E	G-E	E	-	E	F-G	E	F-G	G-E
Liberty	E	E	-	E	E	-	E	E	E	E	E	-	E	E	E	G-E	P-F
Lightning	E	G	E	E	E	-	G	E	E	E	E	-	G	E	G	E	P-F

	Buckwheat, Wild	Cocklebur, Common	Flixweed	Kochia	Lambsquarters, C.	Lanceleaf Sage	Mallow, Venice	Marshelder	Mustard, Wild	Nightshade, Black	Redroot Pigweed	Prickly Lettuce	Ragweed, Common	Smartweed, Annual	Sunflower	Thistle, Russian	Thistle, Canada
Permit	P	E	E	F[2]	P-F	P	E	G-E	E	P	F-G	-	G-E	F-G	E	-	N
Poast/Plus	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
Pursuit	F-G	G	E	E[2]	F-G	E	P	E	E	E	E	E	P-F	G	G-E	G-E	N
Raptor	F-G	G-E	E	E[2]	G	E	P	E	E	E	E	-	G	G-E	E	-	N
Roundup Ultra/ RT/Glyphos	P-F	G-E	G-E	F-E	G-E	E	E	G-E	G-E	F-G	G-E	E	E	E	G	F-G	G
Scorpion III	G-E	E	G	G-E[2]	E	-	E	E	E	G-E	G-E	-	G	G	E	G-E	F-G
Sencor	G	P	E	F-G	E	-	-	-	E	P	G	-	E	E	-	-	P
Sencor + Banvel/Buctril	E	E	G-E	E	E	G-E	G-E	E	G-E	G-E	E	G-E	E	E	G-E	E	P-F
Stinger	F-G	E	P	N	P-F	F	G	E	P	F-G	P	E	G-E	G-E	G-E	P-F	G-E
Touchdown	P-F	G-E	G-E	F-E	G-E	E	E	G-E	G-E	F-G	G-E	E	E	E	G	F-G	G
Tough	P	G	P	E	E	P-F	P-F	-	P	E	E	P	P	P	F-G	E	N
2,4-D	P-F	G-E	F-G	F-G	E	P-F	G-E	E	E	P-F	G	E	G-E	F-G	E	G	F-G

[1] Herbicides will not control resistant biotypes.

Insect Management in Corn

Corn Leaf Aphid

The corn leaf aphid is a bluish green color with black legs, cornicles, and antennae. The populations can build up very rapidly on corn, especially on the tassles. Infestations on corn are seldom economically important, except in late seeded crops or crops growing under drought stress.

Threshold

The critical period for injury by corn leaf aphid is during tassel emergence through pollination. Treatment is suggested only when 50% of the corn plants have 100+ aphids per plant during tassel emergence and plants are drought stressed.

Natural controls

Lady beetles, Aphid lions, Syrphid fly, and parasitic wasps play a major role in reducing aphid populations. When natural enemies are present in large numbers, and the crop is well developed, farmers are discouraged from spraying fields.

CORN LEAF APHID

Insecticide	Dosage in LB AI per Acre	Product Rate per Acre	Remarks
Dimethoate (Cygon 400,	0.33 to 0.5	0.66 to 1 pt	Do not harvest, feed, or graze within 14 days of last application. Do not make more than three applications per season. Do not apply to corn during the pollen-shed period.
Di-Syston*	0.5 to 1	8 to 16 fl oz	Aerial application only. Do not apply within 28 days of corn harvest.
Ethyl parathion 4E*	0.25	8 fl oz	Aerial application only. Do not apply within 12 days of corn harvest. Do not enter treated fields within 3 days after application. Fields must be posted.
Lorsban 4E	0.5 to 1	1 to 2 pts	Do not apply within 14 days of corn silage harvest nor 35 days of corn grain harvest. Apply by air, ground or chemigation (treatment through irrigation systems) in sufficient water for adequate coverage.
Lannate LV*	0.225 to 0.45	0.75 to 1.5 pts	Do not harvest within 21 days or feed treated forage within 3 days of application. Field re-entry interval is 2 days.
Methyl parathion 4 EC*	0.25	8 fl oz	Aerial application only. Do not use within 12 days of corn harvest. .Do not enter treated fields within 48 hours after application. Fields must be posted. Do not apply during pollen shed.
Penncap-M*	0.5 to 0.75	2 to 3 pts	Do not apply within 12 days of harvest or grazing. To avoid injury to bees, do not apply during pollen shed if bees are visiting the areas to be treated during foraging hours. Do not enter treated fields within 48 hours after application. Fields must be posted.

* EPA restricted use pesticide

Armyworms

Armyworm outbreaks in North Dakota can occur when large migrations of moths from southern states occur in late spring and early summer. Moths prefer to lay eggs in moist, shady areas where small grains or grasses have lodged or been damaged by hail or wind. Armyworms feed at night and hide under vegetation or in loose soil during the day. To scout for armyworms in grains, part the plants and inspect the soil for fecal pellets. If pellets or feeding damage are found, look for larvae under plant trash, soil clods or in soil cracks.

Threshold

Treat when 25 to 30% of the plants have two or more worms **or** 75% of the plants have one worm.

Migrating armyworms

Treat a couple of swaths ahead of the infestation in the direction of movement to form a barrier strip.

ARMYWORMS

Insecticide	Dosage in LB AI per Acre	Product Rate per Acre	Remarks
permethrin (Ambush* and Pounce*)	0.1 to 0.2	Ambush: 6.4 to 12.8 fl oz Pounce: 4 to 8 fl oz	Apply prior to brown silk. Apply a minimum of 1 gallon of finished spray per acre by air and 10 gallons per acre by ground equipment. Do not apply within 30 days of harvest.
Asana XL*	0.03 to 0.05	5.8 to 9.6 fl oz	Do not apply within 21 days of harvest.
Carbaryl (Sevin)	1 to 2	rate varies by formulation	Do not apply within 0 days of harvest.
Ethyl parathion 4E*	0.375	12 fl oz	Aerial application only. Do not apply within 12 days of harvest. Do not enter treated fields within 3 days after application. Fields must be posted.
Lannate LV*	0.225 to 0.45	0.75 to 1.5 pts	Do not harvest within 21 days or feed treated forage within 3 days of application. Field re-entry interval is 2 days .
Lorsban 4E	0.5 to 1	1 to 2 pts	Do not apply within 35 days of harvest. Do not apply more than 15 pints by postemergence application/season. Do not allow livestock to graze in treated areas within 14 days or feed treated corn silage, fodder or grain to meat or dairy animals within 35 days after treatment.
Methyl parathion 4EC*	0.25	8 fl oz	Aerial application only. Do not apply within 12 days of corn harvest. Do not enter treated fields within 48 hours or application. Fields must be posted.
Penncap-M*	0.5 to 0.75	2 to 3 pts	Do not apply within 12 days of harvest. Do not enter treated fields within 48 hours after application. Fields must be posted.
Warrior*	0.02 to 0.03	2.56 to 3.84 fl oz	Do not apply within 21 days of harvest. When applying by air, apply in a minimum of 2 gallons of water per acre. For control of first and second instar only.

* EPA restricted use pesticide

Cutworms

Management in corn

Some criteria that may help predict cutworm problems are: 1) field history of cutworm damage; 2) surface crop residue from reduced or minimum tillage; 3) bottom land or low spots in field; 4) fair to poor drainage; 5) near shelterbelts with grassy ground cover. Eggs of the important cutworms are laid during late summer in North Dakota. Soil moisture at this time is important for survival. Growers should be cautious when planting corn following pasture, alfalfa, or clover sites where survival may be greater.

Threshold

Begin scouting for cutworms when corn is up to a stand and continue until mid June. Treat when 3 to 6% of the plants are cut and small larvae (<3/4 inch) are present. Application rate of 15 to 20 gallons of water per acre by ground application is suggested.

CUTWORMS

Insecticide	Dosage in LB AI per Acre	Product Rate per Acre	Remarks
permethrin (Ambush* and Pounce*)	0.1 to 0.2	Ambush: 6.4 to 12.8 fl oz Pounce: 4 to 8 fl oz	Apply prior to brown silk. Apply a minimum of 1 gallon of finished spray per acre by air and 10 gallons per acre by ground equipment. Do not apply within 30 days of harvest.
Asana XL*	0.03 to 0.05	5.8 to 9.6 fl oz	Do not apply within 21 days of harvest.
Carbaryl (Sevin)	2 to 3	rate varies by formulation	Spray in 12-inch band over the row. No limitation on forage.
Sevin 5% bait	1 to 2	20 to 40 lbs	Broadcast treatment. No limitation on forage. Do not incorporate bait.
Lorsban 4E	0.5 to 1.0	1 to 2 pts	Do not apply more than 15 pints by postemergence application per season. Postemergence broadcast treatments should be with sufficient water to provide good coverage. If soil is dry, rotary hoeing can improve control if no rainfall occurs. Do not allow livestock to graze in treated areas within 14 days or feed corn silage, fodder or grain to meat or dairy animals within 35 days after treatment.
Warrior*	0.015 to 0.025	1.92 to 3.2 fl oz	In corn, may be applied before, during, or after planting for cutworm control. Do not apply within 21 days of harvest. When applying by air, apply in a minimum of 2 gallons of water per acre.

* EPA restricted use pesticide

Corn Rootworm Larvae

Rootworm larvae injure the root system of the corn plant. Yield potential may be reduced and/or lodging of plants may occur. Annual crop rotation from corn should prevent serious damage and losses. Early planting of corn allows for better root development prior to the late June hatch of rootworm eggs.

Threshold

The decision to rotate from corn or to use an insecticide may be based on field scouting for adult beetles during a three week period after pollination. Record the number of corn rootworm beetles on the foliage and silk of 100 plants. When the adult population averages one beetle per plant in continuous corn or 0.5 beetles per plant in first year corn fields, the potential for larval root damage the next summer is sufficient to rotate from corn or to apply an insecticide.

CORN ROOTWORM LARVAE

Insecticide	Dosage in LB AI per Acre	Product Rate per Acre	Remarks
Aztec 2.1 G*	varies by row spacing	6.7 oz/1,000 ft of row	May be applied at planting as band, T-band, or in furrow treatment. Cover or incorporate spills (including end row spillage). Do not use on other crops grown for food or forage.
Counter 15 G*	varies by row spacing	8 oz/1,000 ft of row	May be applied in a 7-inch band at planting or in the seed furrow behind the planter shoe. Do not exceed 8.7 lbs of product per acre. Do not apply Accent or Beacon herbicide to corn treated with Counter 15 G.
Dyfonate 15 G	varies by row spacing	8 oz/1,000 ft of row	Application at planting: Incorporate into the top 0.5 to 1 inch of soil by dragging a short length of chain behind the press wheels. Application at cultivation: Cover the treated band with 2 to 3 inches of soil by making application immediately ahead of disc tillers or cultivation equipment. Do not apply within 30 days of harvest. Do not exceed 27 lbs of product per acre.
Force 1.5 G* and 3 G*	varies by row spacing	1.5G: 8 to 10 oz/1,000 ft; 3G: 4 to 5 oz/1,000 ft of row	Apply in a 7-inch band or in-furrow behind the planter shoe in front of the press wheel. Do not rotate to another crop within 30 days after application.

* EPA restricted use pesticide

CORN ROOTWARM LARVAE - continued

Fortress 2.5 G* and 5 G*	varies by row spacing	2.5 G: 6 oz/1,000 ft of row 5 G: 3 oz/1,000 ft of row	Apply as a T-band or in-furrow at planting. Do not apply as a surface band behind the press wheel. Granules exposed on the soil surface must be incorporated. Crop rotational intervals: corn – anytime; other crops – 30 days.
Lorsban 15 G	varies by row spacing	8 oz/1,000 ft of row	Apply in a T-band or in-furrow in front of press wheels at planting time or at time of cultivation. Not more than 1 application per season. Incorporate into top 0.5 to 1 inch of soil using chains or tines behind press wheel.
Phorate 20 G*	varies by row spacing	6 oz /1,000 ft of row	Apply in a 7-inch band over the row directly behind the planter shoe in front of the press wheel or at the time of cultivation in a band at base of plants and cover with soil. Do not apply in direct contact with soil.
Thimet 20 G*	varies by row spacing	6 oz /1,000 ft of row (minimum 30 inch row spacing)	Place granules in a 7-inch band over the row behind the press wheel and lightly incorporate. Do not use in-furrow application. Do not use more than 6.7 lbs of product per acre.

* EPA restricted use pesticide

Corn Rootworm Adults

Rootworm beetles feed on the leaves, silk and pollen of corn. Occasionally, the beetles congregate and feed on silks during early pollen shed. If silks are chewed back to the tips of ears (less than 1/2 inch of silks protruding) during the period of maximum pollen shed, poor pollination and grain set can occur. Adult injury very seldom occurs in North Dakota.

Threshold

When an average of five or more beetles per silk mass are found during the first week of pollen shed, control may be necessary. Another management threshold uses silk clipping. When silk clipping is occurring on 25 to 50% of the plants during pollen shed, control would be justified.

Egg laying suppression programs

Compel and Slam are two new products used for egg laying suppression. Both products contain Curcurbitacin, a rootworm feeding stimulant. The use of these "bait" products is still in the experimental and promotional phase. Research trials in Midwest states have not provided consistent results at this point.

Insecticide	Dosage in LB AI per Acre	Product Rate per Acre	Remarks
Asana XL*	0.03 to 0.05	5.8 to 9.6 fl oz	Do not apply within 21 days of harvest.
Carbaryl (Sevin)	1 to 2	rate varies by formulation	No preharvest interval.
Lorsban 4E	0.5 to 1	1 to 2 pts	Do not apply within 35 days of harvest. Apply by air, ground or chemigation.
Malathion 8EC	1 to 1.25	1 to 1.25 pts	Do not apply within 5 days of harvest.
Malathion (ULV)	0.3	4 oz	Do not apply within 5 days of harvest.
Penncap-M*	0.25 to 0.5	1 to 2 pts	Do not harvest, cut for forage, or graze within 12 days of application. See bee precautions on label. Do not enter treated fields within 48 hours after application. Fields must be posted.
Warrior*	0.02 to 0.03	2.56 to 3.84 fl oz	Do not apply within 21 days of harvest. When applying by air, apply in a minimum of 2 gallons of water per acre.

* EPA restricted use pesticide

European Corn Borer

Managing corn borer in North Dakota is a challenge due to the lengthy emergence interval of the moths from overwintering. In North Dakota, borers have the potential for one or two generations during the season. The two generation borers are present in the southeastern quarter and of the state. They begin emerging in early June and represent the first flush of larval feeding. The single generation borer is present throughout North Dakota, emerging from mid June and beyond. The challenge of the crop manager is to distinguish when egg laying and larval populations can be tolerated or they need to be controlled. Corn should be **monitored** weekly for **at least five weeks** once plants exceed an extended leaf height of 17 inches. At this point, corn borer larvae will be able to survive on the plant. Inspect plants for the presence of egg masses, whorl feeding, and active larvae. Observing moth activity around field margins or within the field may alert you to developing infestations. Recent corn borer infestations in North Dakota developed in mid to late July and August as a result of the late emergence of the numerous single generation type borers. In other years, the two generation borers emerging first may contribute more to significant infestations.

Field scouting for corn borers

Whorl stage corn — Pull the whorls from 10 plants at five locations across the field. Select whorls at random, avoiding damaged plants. Unwrap the whorl leaves; count and record the number of live larvae found.

Tassel stage or older corn — Examine the underside of the middle 7 leaves (3 leaves above and 3 leaves below the ear leaf) on 20 plants from 5 locations in the field. Multiply the number of egg masses found by 1.1 (correction factor for eggs on other leaves). Complete worksheet to determine the need for treatment.

Worksheet for whorl stage corn — you fill in the blanks

1.	_____% of plants infested	x	_____ Avg no. borers/plant	=	_____	Borers per plant
2.	_____ borers per plant	x	_____ percent yield loss per borer*	=	_____	percent yield loss
3.	_____ percent yield loss	x	_____ expected yield (bu. per acre)	=	_____	bushels / acre loss
4.	_____ bushel loss per acre	x	_____ price per bushel	=	$_____	loss per acre
5.	_____ loss per acre	x	_____ percent control**	=	$_____	preventable loss/a
6.	_____ preventable loss/acre	–	_____ cost of control per acre	=	$_____	profit (loss)/acre

* 5% for corn in the early whorl stage; 4% for late whorl; 6% for pretassel
** 80% for granules; 70% for sprays.

Worksheet for tassel stage or older corn — you fill in the blanks

1.	_____ egg masses per plant*	x	4.5 borers per egg mass	=	_____	borers per plant
2.	_____ borers per plant	x	_____ percent yield loss per borer**	=	_____	% yield loss
3.	_____ percent yield loss	x	_____ expected yield (bu. per acre)	=	_____	bushels / acre loss
4.	_____ bushel loss per acre	x	_____ price per bushel	=	$_____	loss per acre
5.	_____ loss per acre	x	80 percent control	=	$_____	preventable loss/a
6.	_____ preventable loss/acre	–	_____ cost of control per acre	=	$_____	profit (loss) / acre

* Cumulative counts taken five to seven days later can be added here
** Use 0.04 for pollen-shedding corn, 0.03 if kernels are initiated

EUROPEAN CORN BORER

Insecticide	Dosage in LB AI per acre	Product Rate per Acre	Remarks
permethrin (Ambush* and Pounce*)	0.1 to 0.2	Ambush: 6.4 to 12.8 fl oz Pounce: 4 to 8 fl oz	Apply prior to brown silk. Apply a minimum of 1 gallon of finished spray per acre by air and 10 gallons per acre by ground equipment. Do not apply within 30 days of harvest.
Asana XL*	0.04 to 0.05	7.8 to 9.6 fl oz	Do not apply within 21 days of harvest.
Carbaryl (Sevin)	1.5 to 2	rate varies by formulation	No preharvest interval.
Bacillus thuringiensis	see specific labels for rate recommendations		No preharvest interval. Non-toxic to man or wildlife. Application to newly hatched larvae critical for best performance. Products currently labeled are: Agree®, Biobit®, Condor G®, Dipel®, Javelin®, M-Peril®, MVP®.
Dyfonate 15 G	rate varies by application	Band: 4 to 8 oz/ 1,000 ft of row Broadcast: 5 to 6.75 lbs	Apply granules over the whorl. Do not apply within 30 days of harvest nor feed or graze livestock within 30 days of treatment.
Furadan 4F*	0.75 to 1	1.5 to 2 pts	Do not make more than two applications per season at this rate. Do not apply within 30 days of harvest. Do not apply to seed corn less than 14 days prior to detasseling or rogueing. If prolonged intimate contact will result, do not re-enter treated fields within 14 days of application without wearing proper protective clothing.

* EPA restricted use pesticide

EUROPEAN CORN BORER - continued

Lorsban 4E	0.75 to 1 0.5 to 1 (chemigation)	1.5 to 2 pts 1 to 2 pts	Apply in at least 2 to 5 gallons water per acre by air. For ground application to control 2nd generation use +10 GPA if directed spray or +15 GPA if broadcast. For best results when chemigating, add 2 pts/acre non-emulsifiable crop oil. May be applied by center pivot irrigation according to label restrictions. Do not allow livestock to graze in treated areas within 14 days or feed treated corn silage, fodder or grain to meat or dairy animals within 35 days after treatment.
Lorsban 15 G	0.66 to 1	3.5 to 8 oz/ 1,000 ft of row directed into the whorl	Restrictions same as above. May be broadcast aerially or banded with suitable ground application equipment prior to tassel emergence. Use high rate (6.5 lb product per acre) when applying broadcast.
Penncap-M*	0.5 to 1	2 to 4 pts	Apply when first eggs begin to hatch. May be applied by center pivot irrigation according to label restrictions. Observe label precautions for bees. Do not harvest, cut for forage, or graze within 12 days of application. Do not enter treated fields within 48 hours after application. Fields must be posted.
Pounce 1.5 G*	0.1 to 0.2	6.7 to 13.3 lbs	Apply prior to brown silk stage.
Warrior*	0.02 to 0.03	2.56 to 3.84 fl oz	Do not apply within 21 days of harvest. When applying by air, apply in a minimum of 2 gallons of water per acre.

* EPA restricted use pesticide

Grasshoppers

In the northern plains, grasshopper egg hatch normally begins in late April to early May. Peak hatch occurs about mid June. Heavy infestations typically occur in areas of low rainfall or during drought years. Outbreaks are usually preceded by several years of hot, dry summers and warm falls. Cool, wet weather increases disease occurrence and delays development of grasshoppers, reducing the overall population.

Cultural Control Methods

Early seeding allows for early establishment and vigorous growth of plants.

Crop rotation avoid planting in areas of high egg deposits. Fields with late maturing crops or green plant cover attract adults which then lay eggs.

Tillage Summer fallow will act as a trap crop, attracting females for egg laying. Spring tillage of these sites will reduce successful emergence of nymphs.

Grasshopper Thresholds

Infestation Ratings

	Nymphs (young hoppers)		Adults	
Rating	**Margin**	**Field**	**Margin**	**Field**
	per square yard			
Light	25-35	15-23	10-20	3-7
Threatening	50-75	30-45	21-40	8-14
Severe	100-150	60-90	41-80	15-28
Very Severe	200+	120	80+	28+

GRASSHOPPERS

Insecticide	Dosage in LB AI per Acre	Product Rate per Acre	Remarks
Asana*	0.03 to 0.05	5.8 to 9.6 fl oz	Do not apply within 21 days of harvest.
Dimethoate (Cygon 400, Dimethoate 400)	0.5	1 pt	Do not apply within 14 days of harvest, feeding, or grazing. Do not make more than three applications per season. Do not apply during pollen-shed period.
Carbaryl (Sevin)	0.5 to 1.5	Rate varies by formulation	Do not apply within 21 days of grain harvest. Do not make more than 2 applications after the boot stage. No limitations on forage. The lower rate (0.5 lb) is suggested for nymphs on small plants or sparse vegetation. The higher rate is suggested for mature grasshoppers or when material is applied to crops requiring greater coverage.
Ethyl parathion 4E*	0.375	12 oz	Aerial application. Do not apply within 12 days of corn harvest. Do not enter treated fields within 3 days after application. Fields must be posted.
Furadan 4F*	0.125 to 0.25	4 to 8 fl oz	Do not forage cut or harvest within 30 days of last application. Use a minimum of 10 gal of finished spray/acre with ground equipment and 2 gal/acre with aerial equipment.

* EPA restricted use pesticide

GRASSHOPPERS – continued

Insecticide	Dosage in LB AI per Acre	Product Rate per Acre	Remarks
Lorsban 4E	0.25 to 0.5	0.5 to 1 pt	Do not allow livestock to graze in treated areas within 14 days nor feed treated corn silage, fodder or grain to meat or dairy animals within 35 days after treatment.
Malathion 8 EC	1 to 1.25	1 to 1.25 pts	Wait 5 days before grain harvest.
Malathion (ULV)	0.6	8 fl oz	Do not harvest for 5 days.
Methyl parathion 4EC*	0.5	1 pt	Aerial application only. Do not apply within 15 days of small grains harvest or within 12 days of corn harvest. Do not enter treated fields within 48 hours after application. Fields must be posted.
Penncap-M*	0.5 to 0.75	2 to 3 pts	Do not apply within 12 days of harvest. Do not enter treated fields within 48 hours after application. Fields must be posted.
Warrior*	0.02 to 0.03	2.56 to 3.84 fl oz	Do not apply within 21 days of harvest. When applying by air, apply in a minimum of 2 gallons of water per acre.

* EPA restricted use pesticide

Wireworms

Wireworms are the immature stage of click beetles (Family: Elateridae). The larvae are hard, brownish-orange, shiny, slender worms. They bear six short, thin legs behind the head. The last body segment is forked or notched. Mature larvae are about ¾ to 1 inch long. Wireworms are most likely to be problems when corn follows pasture or grassland. Continuous corn has developed problems in the past, also. Infestations often are found in coarse textured soils (sandy loam) where moisture is abundant, perhaps in low spots of fields.

Threshold

There is no easy way to estimate wireworm infestations. Two methods are currently used.

Soil Sampling — Sample 20 well spaced, 1 square foot sites to a depth of 4 to 6 inches for every 40 acres being planted. If an average of one wireworm per square foot is found, treatment would be justified.

Solar Baiting — In September, establish bait stations for two to three weeks before freeze. Place bait stations randomly through the field, but representing all areas of the field. There should be 10 - 12 stations per 40 acre field. Place one cup wheat and one cup shelled corn in a 4 to 6 inch deep hole. Cover grain with soil and then an 18 inch square piece of clear plastic. Dig up the grain. If an average of one or more wireworm larvae are found per station, treatment would be justified

WIREWORMS

Insecticide	Dosage in LB AI per acre	Product Rate per Acre	Remarks
Aztec 2.1 G*	varies by row spacing	6.7 oz/1,000 ft of row	May be applied at planting as band, T-band, or in furrow treatment. Cover or incorporate spills (including end row spillage). Do not use on other crops grown for food or forage.
Counter 15 G*	varies by row spacing	8 oz/1,000 ft or row	Apply in a 7-inch band or in-furrow at planting. Do not exceed 8.7 lbs of product per acre. Do not apply Accent or Beacon herbicide to corn treated with Counter 15 G.
Dyfonate 15 G	varies by row spacing	8 oz/1,000 ft of row	Apply in a 7-inch band at planting. Do not apply in contact with seed. Do not exceed 27 lbs of product per acre. Dyfonate aids in the suppression of wireworms.
Force 1.5 G* and 3 G*	varies by row spacing	1.5G: 8 to10 oz / 1,000 ft of row and 3G: 4 to 5 oz/1,000 ft of row	Apply in a 7-inch band or in-furrow behind the planter shoe in front of the press wheel. Do not rotate to another crop within 30 days after application.

* EPA restricted use pesticide

Fortress 2.5 G* and 5 G*	varies by row spacing	2.5 G: 6 oz/ 1,000 ft of row; 5 G: 3 oz/1,000 ft of row	Apply as a T-band or in-furrow at planting. Do not apply as a surface band behind the press wheel. Granules exposed on the soil surface must be incorporated. Crop rotational intervals: corn – anytime; other crops – 30 days. For wireworms, the in-furrow application provides optimal control.
Lorsban 15 G	varies by row spacing	8 to 16 oz/1,000 ft of row	T-Band or in-furrow at planting. If high wireworm numbers are anticipated, add insecticide seed treatment to planter box to augment control
Lorsban 4E	2	4 pts	Broadcast ppi in sufficient water to the soil surface and incorporate into the soil.
Mocap 20 G*	varies by row spacing	6 oz/1,000 ft of row	Apply in a 7-inch band at planting. Do not apply in contact with seed.
Thimet 20 G*	varies by row spacing	6 oz/1,000 ft of row	Place granules in a 7-inch band over the row directly behind the planter shoe in front of the press wheel. Do not use in-furrow application.

* EPA restricted use pesticide

White Grubs

White grubs that are destructive to field crops in North Dakota have a three year life cycle. In southeastern North Dakota, the most common white grub pest occurs in continuous cropping situations at sites where willow and cottonwood trees are present. In other areas of the state, white grubs are most likely to be found when rotation from grassland, pasture, or grassy weed sites occur. Most root feeding occurs in the second year of the life cycle. In most cases, the number of second year grubs will only be great enough to justify control once every three years.

Threshold

Treatment is recommended when sampling indicates an average of one or more white grubs per square foot are found. The following sampling procedure provides treatment decisions based on this guideline.

Soil sampling — Sampling in late summer or early fall, before a freeze, provides a more reliable estimate of populations than spring sampling just before planting. Take soil samples, 1 square foot in size to a depth of 8 inches. Begin taking samples 45 yards from shelterbelts. A total of 30 samples per field, randomly spaced along the shelterbelts are necessary. If at least a single grub is found in less than 40% of the samples, treatment may be required only out 20 yards from the tree line. If 40 to 60% of the samples are infested, treatment is needed to this distance and maybe as far as 65 yards. If greater than 60% of the samples are infested, treatment may be needed out to 90 yards from the tree line.

WHITE GRUBS

Insecticide	Dosage in LB AI per acre	Product Rate per Acre	Remarks
Aztec 2.1 G*	varies by row spacing	6.7 oz/1,000 ft of row	May be applied at planting as band, T-band, or in furrow treatment. Cover or incorporate spills (including end row spillage). Do not use on other crops grown for food or forage.
Counter 15 G*	varies by row spacing	8 to16 oz/1,000 ft of row spacing	Apply in a 7-inch band (1 to 2 lb rate). Do not exceed 8.7 lbs of product per acre. Do not apply Accent or Beacon herbicide to corn treated with Counter 15 G.
Force 1.5 G* and 3 G*	varies by row spacing	1.5G: 8 to 10 oz / 1,000 ft of row and 3G: 4 to 5 oz/1,000 ft of row	Apply in a 7-inch band or in-furrow behind the planter shoe in front of the press wheel. Do not rotate to another crop within 30 days after application.
Fortress 2.5 G* and 5 G*	varies by row spacing	2.5 G: 6 oz/1,000 ft of row 5 G: 3 oz/1,000 ft of row	Apply as a T-band or in-furrow at planting. Do not apply as a surface band behind the press wheel. Granules exposed on the soil surface must be incorporated. Crop rotational intervals: corn – anytime; other crops – 30 days. For white grubs, the in-furrow application provides optimal control.
Lorsban 15 G	varies by row spacing	8 to 16 oz/1,000 ft of row	Apply in-furrow at planting time. (NDSU research indicates that Lorsban aids in white grub suppression. With heavy white grub infestation, some stand reduction may still occur.)

* EPA restricted use pesticide

Bt-Corn and European Corn Borer

Seed companies are now marketing *Bt*-corn hybrids. These hybrids produce an insecticidal protein from a bacterium, *Bacillus thuringiensis*, inside the corn plant to provide insect control. The use of *Bt*-corn has the potential to provide unique, easier, more consistent control of the European corn borer (ECB).

What is *Bt*?

Bacillus thuringiensis is a naturally occurring soil-borne bacterium found worldwide. *Bt* produces a crystal-like protein that kills specific groups of insects. These crystals are stomach poisons that must be ingested to provide effective control. The toxic proteins disrupt the intestinal membranes of the larvae, leading to their death.

There are several strains of *Bt*, each with different spectrums of activity. The first *Bt*-corn hybrids contain Cry1Ab or Cry1Ac *Bt* proteins. These have activity against ECB.

The Creation of *Bt*-corn and Its Impact on Corn Insect Pests

The DNA portion responsible for producing the toxin is extracted from the *Bt* bacterium. This DNA is inserted into the corn plant's DNA. The DNA is inserted as a genetic package which includes the *Bt* protein gene, a genetic marker (allows for identification of successful transfer), and a promoter (controls where the toxin is produced in the plant). The transformation, or event, is observed for toxin production levels and the absence of detrimental impacts on yield or other important agronomic traits.

The level of control of ECB is dependent on the *Bt* event. Currently, there are three unique events that have been registered by EPA for commercial use. The three events are: 176 (Ciba Seeds, and Mycogen), MON810 (Monsanto), and Bt-11 (Northrup King). Event 176 is trademarked as "Maximizer" by Ciba Seeds and "NatureGard" by Mycogen. Both the Monsanto and Northrup King events are trademarked as "YieldGard".

An important difference between event 176 and the Bt-11 and MON810 plant material is that the *Bt* toxin expressed in the 176 hybrids is limited to green tissues, while YieldGard hybrids express *Bt* in many of the reproductive tissues, such as tassel and silk, as well as green tissues. YieldGard hybrids have the potential to provide higher control levels of late-season ECB. Early field trials in neighboring states have shown that despite higher numbers of late-season ECB surviving on the 176 hybrids, final yield data is still favorable.

Regardless of the *Bt* event, growers should still select corn hybrids based on overall yield performance in their region. Selecting a *Bt*-hybrid only for ECB control will not guarantee higher yields compared with other conventional hybrids. The *Bt* gene can only enhance the yield potential of a hybrid when ECB are present.

Current *Bt*-corn hybrids have no activity on aphids, spider mites, corn rootworms, cutworms, grasshoppers, or stalk borer. Field studies evaluating the hybrids impact on armyworms is limited.

Performance of *Bt*-corn

General observations made on performance of these hybrids found that the *Bt* hybrids dramatically reduce first generation ECB. Hybrids differed in the levels of control of late-season or second generation ECB; some survival and tunneling were observed in those hybrids with the 176 event. Yields varied; the presence of the *Bt* gene was not a guarantee of higher yields. Some unprotected, non-*Bt* hybrids yielded better than *Bt* hybrids. However, the *Bt* hybrids out yielded their unprotected counterparts.

Before deciding to use a *Bt* hybrid, compare yield results from corn hybrid performance trials in your area. *Bt* hybrids suitable for use in North Dakota and surrounding regions are currently being developed and evaluated.

Diseases in Corn

Seed Rots and Seedling Blights (various fungi)

Description: Seed may rot before germination or shortly after, resulting in no seedling emergence, or seedlings may emerge and turn yellow and wilt. Aggravated by poorly drained soils, cold and wet soils, compacted soils, deep planting, and quality of seed.

Management: Injury-free seed of high quality and germination percentage should be planted. Seed treatments will reduce the risk of seedling blight and seed rot. Most corn seed is sold pre-treated with fungicides. However, further information on corn seed treatments registered in North Dakota may be found in NDSU Extension publication PP-622, Field Crop Fungicide Guide. Good cultural practices and seedbed preparation reduce the risk.

Common Leaf Diseases

Eyespot *(Kabatiella zeae)*

Description: Very small (1/16 to 1/8 inch), translucent circular to oval spots with yellow halos. Initial spots water-soaked; spots later develop brown or purple border.

Management: Crop rotation away from corn; tillage to bury residue.

Northern Corn Leaf Blight *(Helminthosporium turcicum)*

Description: Large elliptic water soaked lesions on leaves which soon turn straw colored to dark brown.

Management: Choose hybrids with good resistance. Use crop rotation and tillage to bury residue.

Common Rust *(Puccinia sorghi)*

Description: Red eruptions (pustules) on leaf surface contain thousands of rust spores.

Management: Hybrids vary in resistance; rarely serious enough to warrant additional control.

Gray Leaf Spot *(Cercospora zeae-maydis)*

Description: Disease occurs in warm to hot, humid seasons. Lesions are pale brown or gray to tan, long (½ to 2 inches), narrow and rectangular, characteristically restricted by the veins. Losses have been severe in some Corn Belt states in recent years. Fungus survives in corn residue.

Management: Variation in hybrid susceptibility exists. Fungicide protection may be warranted for high value fields under severe disease pressure.

Holcus Spot *(Psuedomonas syringae)*

Description: Small, irregular shaped spots, with a water-soaked appearance at first, followed by spots turning a creamy white to tan, resembling parchment paper. Favored by warm, wet weather and winds.

Management: Crop rotation reduces overwintering of bacteria. Seldom serious as weather turns too hot or dry to be favorable for continued infection.

Maize Dwarf Mosaic (Maize Dwarf Mosaic Virus)

Description: Light green mottle or mosaic forms on upper leaves. Upper portion of plant may be stunted.

Management: Hybrids may vary in susceptibility. Rare in Northern climates. Transmitted by aphids that must move into area from states farther south.

Stalk and Ear Diseases

Common Smut *(Ustilago maydis)*

Description: Leaves, stalks, ear, or tassels may be replaced by black spore mass which is covered by a persistent grayish membrane. "Boils" or irregular growths common.

Management: Trace of smut usually found in every field. Hybrids vary in susceptibility. Hail damage or various stresses increase risk of smut.

Head Smut *(Sphacelotheca reiliana)*

Description: Spores infect plant systemically while in seedling stage, causing possible stunting, but only tassels and ears are smutted. Black spore masses covered with only a thin membrane which easily breaks up (in contrast to common smut). Thread-like strands occur in the spore masses.

Management: Crop rotation reduces risk of infection. Most hybrids resistant.

Ear Rots (various fungi)

Description: Kernels of ears turn pink to red to black with associated mold growths. Often associated with insect injuries or with other injuries and very wet weather.

Management: Hybrids vary in resistance to ear molds. Crop rotation reduces risk of exposure to fungi. Reducing insect damage may also reduce ear mold damage.

Stalk Rots (various fungi)

Description: Stalks are weak; the pith is shredded and discolored, often pink to red. Lodging frequently occurs. Yield losses occur due to poor filling of ears, early ear drop, and stalk breakage.

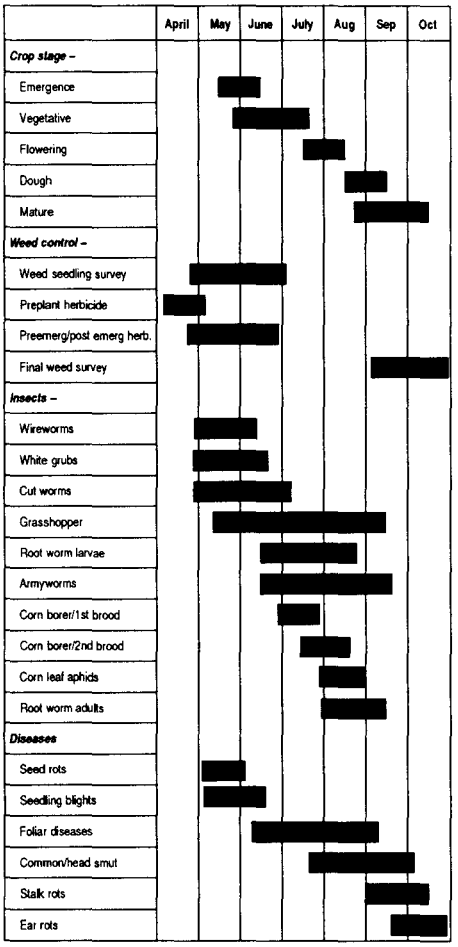
Management: Crop rotation to non-cereal crops is beneficial. Proper management of soil fertility reduces stalk rots. Hybrids vary in resistance to stalk rot as well. If stalk rot present, harvesting early reduces ear loss.

Integrated Pest Management (IPM) for Corn

Timely field scouting is the key to any successful pest management program. Regular scouting of fields reveals the growth stage of the crop, the condition of the crop, the identity of the pests present, and the extent and severity of the pest. This information is used to determine if a growing season control measure is needed, the appropriate timing for such a measure, or if another management step is needed at harvest or following harvest.

One of the tools that may help in timely field scouting is the use of a pest management calendar. An example of a **corn pest management calendar** is given. These calendars have been developed for many crops to indicate when certain pests are most likely to be observed in a field, according to calendar date and crop growth stage. For example, cutworms in corn in North Dakota should be scouted for between May 1 and June 30, while armyworms attack corn later and should be scouted for between June 15 and September 15. Keep in mind that these dates are general guidelines and may vary slightly each year, depending on planting dates and growing season weather conditions.

Corn Pest Management Calendar



Preparations of Samples for Plant Diagnostic Lab

Samples of diseased or injured plants and corn insect pests may be sent for diagnosis to:

Plant Pest Diagnostic Laboratory
Box 5012
North Dakota State University
Fargo, ND, 58105.

Mailing instructions: INSECTS: Send small ones in vial of alcohol; never in envelope. Pack large insects such as moths in cotton. Insects should be dead. PLANTS: Collect as much of plant as possible, several entire plants if feasible. May be placed in a plastic bag which is folded over loosely, but not sealed tightly. DO NOT add moist towels as specimen will decompose. If possible, place some leaves flat in paper envelope and rest of plant and leaves in plastic bag.

A fee ($8-$10) is charged for diagnosis; additional fees charged if special tests are required or requested.

Corn Rotations

For purposes of disease management, corn should follow a broadleaf crop whenever possible. Corn does not have any diseases in common with broadleaf crops such as drybean, soybean, or potatoes. Use of corn in rotation with these crops helps break the disease cycle of organisms that attack corn and those that attack the broadleaf crops.

Corn has some important and damaging diseases in common with other cereal crops, such as wheat, barley, oats, millet or sorghum. The *Gibberella (Fusarium graminearum)* stalk rot of corn is caused by the same fungus that causes head scab in wheat, barley and other small grains. This scab fungus survives very well in corn residue, and planting wheat or barley back into corn ground results in a high risk of head scab in the small grain crops, if wet weather should occur during the flowering period of the small grain crops. Corn following small grains is not as severe a disease risk as wheat/barley/oats following corn, although corn and small grains do have some root rot disease organisms in common.

Leaf diseases, such as northern corn leaf blight and grey leaf spot, are caused by fungi that survive in corn residue. Sorghum and sudangrass are hosts of several corn diseases. Crop rotation to breadleaf crops reduces the potential for corn leaf diseases that survive in corn debris.

Corn Fertility

Corn is a high user of nutrients. Corn in the Northern Plains is responsive to application of nitrogen (N), phosphorus (P), potassium (K), sulfur (S) and zinc (Zn) if soil test levels indicate less than adequate levels. Soil testing is recommended to predict the probability of response of corn to soil nutrient levels. Soil test cores should be taken at 0-6 inch and 6-24 inch levels. N and S should be analyzed on both core depths. P, K and Zn is analyzed on the surface depth. Salt levels may be analyzed on both depths if salt problems are anticipated.

Nitrogen

Nitrogen deficiency of corn is characterized by yellowing of the lower leaves in a pattern that begins at the leaf tip and extends down the midrib until the entire leaf turns yellow, then brown in extreme deficiency situations.

Nitrogen recommendations for corn are based on the formula:

N recommended = 1.2 X Yield Goal (bu/acre) - STN - SDA - PCC

where STN is soil test N to 2 ft.
SDA is sampling date adjustment of 1/2 lb N/day if sampled before September 15.
PCC is previous crop credit, usually from a legume

Nitrogen for corn may be applied preplant or sidedressed before or after emergence. Some N may be applied at planting, but banded rates are restricted by the sensitivity of corn to salt/ammonia damage and no more than 10 lb/acre of N + K_2O with the seed. If higher levels of banded fertilizer are desired, than the fertilizer and seed must be separated. A band 2 inches beside and 2 inches below the seed is often

used to apply higher rates of fertilizer. A total fertilizer program can be applied in a separated band, but when fertilizer N rates exceed about 50 lb N/acre, corn roots have difficulty taking up P for several weeks. It is therefore recommended to apply less than 50 lb/acre N in a banded application and apply the rest of the N in a separate application.

High levels of N increase protein content of the kernel somewhat but also increase susceptibility to green snap during periods of rapid growth potential. Over-fertilization with N is therefore discouraged, although adequate levels of N are important for yield.

Phosphorus

Phosphorus deficiency symptoms are characterized by purpling of lower leaves, especially early in the season. Purpling may not always be related to low soil P levels but may be related to decreased ability of the plant to take up P due to root growth restrictions, including cold soil temperatures, wet soils or compaction. Some corn varieties are also more likely to display purpling than others.

Recommended rates of broadcast P fertilizer are shown in Table 1. Banded rates of P may be reduced by 1/3 if soil test levels are low or very low, because these rates include additional P for buildup. Reducing P levels may be economical in the short-term but will not buildup levels over the long-term. Sustaining high levels of production is most likely if soil test levels are built to at least medium P levels.

Fallow syndrome is a condition thought to be caused by reduced populations of soil fungi called mycorrhiza. After black fallow, or following sugarbeet, mycorrhiza levels are reduced. Mycorrhiza aid corn plants by infecting roots and acting as root hairs to facilitate the uptake of nutrients, expecially P, into the plant. In return, the corn plant supplies the fungi with organic nutrients. This relationship is called symbiosis- a relationship that is mutually beneficial to both organisms. In most rotations, such as soybean-corn-wheat, mycorrhiza levels are maintained. However, when soil remains bare, or after sugarbeet, myccorhiza levels are lowered. High rates of P are required for corn following fallow or sugarbeet.

Potassium

Recommended rates of broadcast K are shown in Table 2. Although many of the soils in the region are high in K, low K soils are common in some areas. Sandy soils on uplands are especially low in K. K deficiency may be observed as yellowing on the lower leaf margins, gradually moving inward toward the midrib of the leaf, and up the plant. Both younger and older plants may display K deficiency. Plant K levels may be reduced in high K soils when soils are droughty or are drier due to ridge-till. In these soils, some K may be helpful in a 2 by 2 inch banded application, or in a deep band method of application in moister soils to supply K in a more concentrated form.

Sulfur

Sulfur deficiency of corn is not common but may sometime be seen in coarser soils with lower organic matter levels.Sulfur deficiency is seen as yellowing of the upper leaves. Sulfur soil test levels of 16 lb/acre S in the surface 2 ft. would be considered likely to respond to S applications. Fertilizers with available sulfate, such as ammonium sulfate or ammonium thiosulfate would be expected to perform more efficiently as an S source than some other elemental forms.

Zinc

Zinc deficiency is common in some areas because of low native soil zinc levels. Crops in soils with zinc levels of 0.6 ppm or lower may be expected to respond to Zn. Zinc deficiency symptoms include yellowing or whitening of the leaf tissue between the leaf margins and midrib. The symptoms are usually greatest on younger leaves. Foliar sprays of zinc sulfate, zinc chelate or ammoniated zinc solutions are helpful early in the season. Deficiency symptoms may be avoided by applying 3-5 lb/acre actual Zn as zinc sulfate preplant incorporated, or by adding zinc chelate or other zinc fertilizers in the planter banded treatment.

Chloride

Recent research in the eastern US has reported yield responses and lowered stalk lodging when chloride was applied to low chloride soils. This research has not been attempted in North Dakota, but it is curious that despite locally high levels of K, stalk rot damage is still a considerable problem in the region. Perhaps lower stalk rot reported in the lower midwest with K application is not just a response to K, but to application of K plus chloride in the 0-0-60-49Cl usually applied in such trials. For producers with chloride levels below 30 lb/acre in the surface 2 ft., application of chloride may be tried on a trial basis. Again, no North Dakota research has been attempted yet to verify these early reports.

Salts

Corn is moderately susceptible to salt damage. Certain varieties show more susceptibility to damage than others. Check with your seed supplier for information on susceptibility. Because salts are not a normal occurance in the lower midwest, evaluations are only available locally. Encourage your seed company to screen for this problem wherever possible.

Table 1. Phosphate recommendations for grain corn.

		Soil Test Phosphorus, ppm				
Yield Goal	Bray PI Olsen	VL 0-5 0-3	L 6-10 4-7	M 11-15 8-11	H 16-20 12-15	VH 21+ 16+
bu/A		lb P_2O_5/Acre				
50		30	25	15	0	0
100		65	45	25	10	0
150		95	70	40	15	0
300		125	90	55	20	0

Table 2. Potassium recommendations for grain corn.

	Soil Test Potassium, ppm				
Yield Goal	VL 0-40	L 41-80	M 81-110	H 121-160	VH 161+
lb/A	lb K_2O/Acre				
50	50	35	20	10	0
100	100	75	45	15	0
150	155	110	65	20	0
200	205	145	85	25	0

Irrigation Management

Corn needs between 18 to 22 inches of soil moisture during most growing seasons to achieve maximum yield potential. In North Dakota, irrigation is used to supplement rain to maintain optimum soil moisture for growth. Under these conditions, corn is capable of producing 8 to 14 bushels of grain corn and 1.25 to 1.75 tons of silage for each inch of additional applied water. Corn variety maturity length will affect seasonal water use. For example, water use during a particular growing season will be greater for 90 day corn than for 80 day corn.

The water that evaporates from the soil near a corn plant plus the soil water used by the corn is called evapotranspiration (ET) or simply water use. The frequency and amount of irrigation depends on the growth stage of the corn (which determines the daily water use), the water-holding capacity of the soil in the root zone and the prevailing weather conditions.

Corn Rooting Depth and Water Use

Corn is a relatively deep rooted crop. Typically, in deep soils, roots grow laterally 12 to 18 inches from the stalk and downward to a depth of 4 feet or more. About 90 percent of the roots will be found in the top 3 feet, which is considered the effective rooting depth for irrigation purposes. Over the course of a growing season, about 40% of the water used by corn will come from the first foot of soil, 30% from the second foot and 20% from the third foot. Less than 10 percent will be obtained from the soil below 3 feet.

Average corn water use will increase from about 0.03 inches per day soon after emergence to over 0.27 inches per day during ear formation (Figure 1). However, during July and August, hot, windy days can push water use to over 0.35 inches per day. The water use is given as a

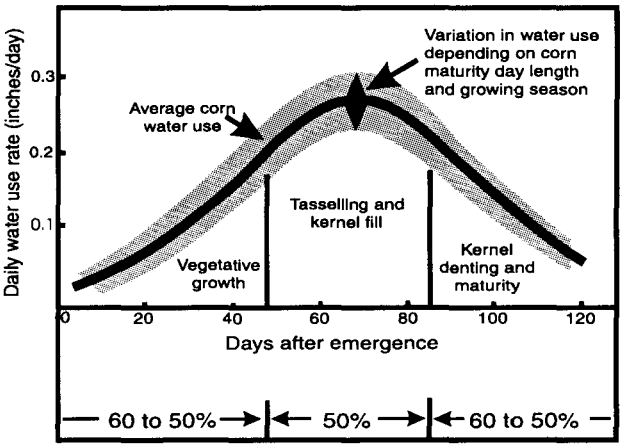


Figure 1. Corn water use and soil moisture management criteria.

depth measurement because it is assumed that corn removes soil water from under every square foot of soil surface in the field.

Water Holding Capacities of Soil

The depth and water holding capacity of soil has a great influence over when and how often irrigations are required. Soil texture determines the amount of available water it will hold (Table 1). Note that the greater the water holding capacity of the soil in the root zone, the less frequent the irrigations should be. It is important to know the soil texture and water holding capacity of the dominant soil type in a corn field and use that information for making irrigation decisions.

Table 1. Approximate available soil water holding capacities for various soil textural classifications.

Soil Texture	Available Moisture	
	Inches/Inch	Inches/Foot
Coarse sand and gravel	0.02 to 0.06	0.2 to 0.7
Sand	0.04 to 0.09	0.5 to 1.1
Loamy sand	0.06 to 0.12	0.7 to 1.4
Sandy loam	0.11 to 0.15	1.3 to 1.8
Fine sandy loam	0.14 to 0.18	1.7 to 2.2
Loam and silt loam	0.17 to 0.23	2.0 to 2.8
Clay loam and silty clay loam	0.14 to 0.21	1.7 to 2.5
Silty clay and clay	0.13 to 0.18	1.6 to 2.2

Irrigation Water Management

It is desirable to have a soil profile that is near field capacity at planting. Most years this will happen naturally with normal winter snow and spring rainfall. Less than a full soil moisture profile to a depth of at least 3 feet at planting could hinder root development later in the season. Also, stored soil moisture in the root zone serves as a supplement during high water use periods.

From emergence to the onset of tassels (about 40 days), corn is relatively drought tolerant. It can withstand up to 60 percent soil water depletion in the root zone without a significant impact on yields (Figure 1). However, from the onset of tasseling to the blister kernel stage (40 to 80 days after emergence), soil moisture levels in the root zone should not be depleted more than 50 percent to achieve maximum yields. After blister kernel development, corn can again withstand 60 percent soil water depletion without much impact on yields.

The period of greatest water stress sensitivity coincides with the time of highest water use demands (July and August). Corn water use will average around 7 to 8 inches in July and 6 to 7 inches in August. With temperatures in the 80s, corn will use about 1.75 inches per week (net). Temperatures in the 90s will increase the water demand to around 2.1 inches per week (net).

Most center pivots are set to apply from 0.5 to 1 inch of water per revolution. For a center pivot system covering 128 acres with 800 gallons per minute (gpm) of capacity, it will take about three days to put on 1 inch (net) of irrigation water. Therefore, when the corn begins to tassel it is critical that the soil moisture profile be monitored frequently, or it may be difficult to keep up with corn water use during periods of high temperatures and wind. Scheduling of irrigations during these periods is extremely important.

Corn planted on relatively deep soil where the full 3-foot root zone can develop should receive at least 1.0 inches (net) of water each irrigation during the period of highest water use.

Corn planted on shallow soils (12 to 24 inches of top soil) underlain by coarse sand and gravel can pose irrigation management problems. The roots will be concentrated only where there is top soil, thus this becomes the management root zone. A shallow root zone means there is less available water. For this situation, applying less water (0.5 to 0.7 inches) more frequently would be produce better results than applying a larger amount less frequently.

For corn grain, the last irrigation of the season is determined by the maturity of the corn kernels. Corn should be irrigated until sufficient soil moisture is available to ensure the milk layer in the kernel moves down to the tip of the kernel or black layer formation. This generally occurs about 55 days after 75% of the plants have visible silks on the ears. Yellow dent corn is usually well dented at maturity.

Irrigation Scheduling

Determining when to start and stop an irrigation system is a very important part of irrigation water management. Since irrigation is used to supplement rain, it is extremely important to have at least two rain gages for each irrigated field. They should be located on opposite sides of the field to provide an accurate estimate of the amount received over the entire field. They should be located so that they measure only rain, not applied irrigation water.

Soil in the root zone is the reservoir that stores the water for use by corn. Soil moisture levels in the root zone determine the criteria for when to start and stop irrigations. There are several soil moisture monitoring tools available to determine the soil moisture level at a particular time and place.

Direct soil moisture measurement can be done several ways. The "soil feel" method is the most widely used. It involves using a soil probe to obtain a soil sample from a certain depth in the root zone, then determining the amount of soil moisture by squeezing the soil in the palm of your hand. For corn, soil samples should be checked at 1 and 2 feet below the soil surface. To be accurate, using the soil feel method requires considerable experience with a variety of soil textures.

Soil moisture can also be measured with mechanical devices such as tensiometers and soil moisture blocks. When these are used, one or more of these devices are buried at different levels in the root zone and at several locations in the field. For corn, the root zone soil moisture should be monitored at 1 and 2 feet below soil surface. The amount of soil moisture is determined by either reading a gage or using a portable meter. These devices only indicate the soil moisture status at that particular location. Electronic methods which measure soil moisture levels based on the changes in measurable electronic properties of the soil are also available.

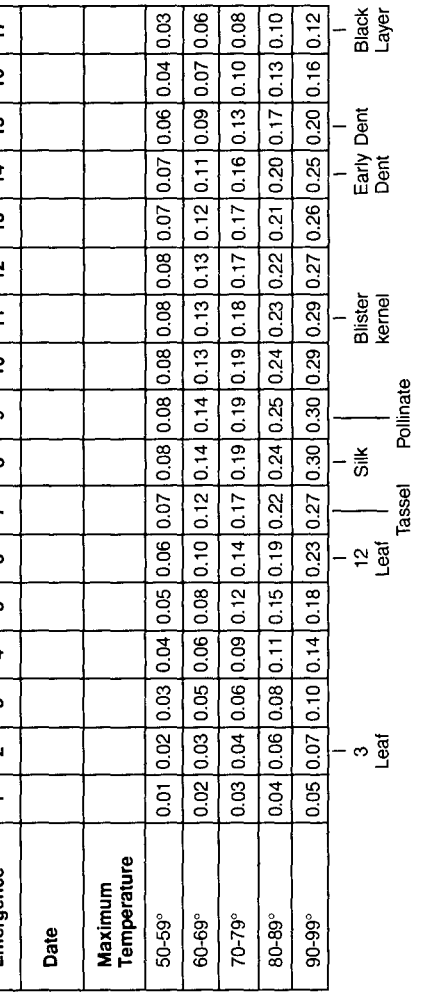
Using just soil moisture measurement for irrigation scheduling can create more work during the growing season for the irrigation manager. Soil moisture measurements must be made two or three times during the week and at several locations in the field. It is important to sample the most common soil types in the field. Consulting the county soil survey will show where these soils are located in the field.

Another form of irrigation scheduling is to use estimated corn water use values. This method, sometimes called the "crop water use replacement method," is based on obtaining daily estimates of corn water use and accurately measuring the amount of rain received on the field. Irrigations are scheduled to replace the amount of soil moisture used by the corn minus the amount of rain received since the last irrigation. Estimations of water use for corn based on maximum daily temperature are shown in Table 2.

The best choice of tools for irrigation scheduling is a combination of in-field soil moisture measurement and a recorded daily soil water accounting procedure. This method, called the "checkbook" method, has also been used successfully for many years in Minnesota and North Dakota. The checkbook method is a soil moisture accounting method which uses daily corn water use values and the soil water-holding capacity to predict the time and amount of water needed to replenish what has been removed from the root zone since the last irrigation or rain. A circular on irrigating using the checkbook method is available from any county extension office in Minnesota and North Dakota.

Table 2. Average corn water use based on maximum daily air temperature, week after emergence and growth stage (inches/day).

Week After Emergence	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Date																	
Maximum Temperature																	
50-59°	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.08	0.08	0.08	0.08	0.07	0.07	0.06	0.04	0.03
60-69°	0.02	0.03	0.05	0.06	0.08	0.10	0.12	0.14	0.14	0.13	0.13	0.13	0.12	0.11	0.09	0.07	0.06
70-79°	0.03	0.04	0.06	0.09	0.12	0.14	0.17	0.19	0.19	0.19	0.18	0.17	0.17	0.16	0.13	0.10	0.08
80-89°	0.04	0.06	0.08	0.11	0.15	0.19	0.22	0.24	0.25	0.24	0.23	0.22	0.21	0.20	0.17	0.13	0.10
90-99°	0.05	0.07	0.10	0.14	0.18	0.23	0.27	0.30	0.30	0.29	0.29	0.27	0.26	0.25	0.20	0.16	0.12



Estimation of Pre-harvest Corn Yields

There are several techniques for estimating corn grain yield prior to harvest. This version was developed by ag. engineering at the University of Illinois and is the one most commonly used. A numerical constant for kernel weight is figured into the equation in order to calculate grain yield. Since weight per kernel will vary depending on hybrid and environment, the yield equation should only be used to **estimate relative grain yield.** For example, yield will be overestimated in a year with poor grain fill conditions, while it will be underestimated in a year with good grain fill conditions.

Step 1. Count the number of harvestable ears per 1/1000th acre (Table 4).

Step 2. Count the number of kernel rows per ear on every fifth ear. Calculate the average.

Step 3. Count the number of kernels per row on each of the same ears, but do not count kernels on either the butt or tip that are less than half size. Calculate the average.

Step 4. Yield (bushels per acre) equals:

$$\frac{\text{(ear \#) X (avg. row \#) X (kernel \#)}}{90}$$

Green Snap Damage

Green snap or "brittle corn" are terms often used to describe the breakage of corn stalks caused by high winds primarily during the elongation (rapid growth) period of vegetative growth.

Green snap can occur at most any vegetative stage after the growing point reaches the soil surface (8 inches tall), but corn usually is most susceptible from the 14-leaf to tassel stages. Rapidly growing plants adequately supplied with water and nutrients are predisposed to green snap. Cells at each node site are rapidly dividing. The new cells push-up and elongate to form internodes, thus increasing plant height and leaf exposure. These rapidly growing cells will be thin-walled at first with little strength tissue or fiber. Therefore they become quite vulnerable to breakage by wind, cultivation, anhydrous application or any physical activity that bends the stalk. At night they are extremely vulnerable since the plants are turgid (full of water). During mid-day they are less susceptible as the cells are less full of water and stalks are more flexible.

Corn being grown under the best conditions of plentiful moisture, high N rates, warm temperatures and optimum plant populations are vulnerable to green snap. Usually breakage occurs just below the primary ear node site. Some hybrids appear to have a longer time period when the stalks are susceptible to breakage. Most corn seed companies test/screen using artificial green snap tests to eliminate those corn lines that tend to have weaker stalks.

Hail Damage

Prior to and for some time after emergence, the corn plant is relatively immune to hail damage. At emergence, the plant's growing point is below the soil surface and remains there for about three weeks, until five or six leaves have fully emerged. Because the growing point is in the leaf whorl and below ground level, plant damage due to hail at these early stages rarely results in any significant yield loss.

Approximately three weeks after emergence, all nodes and internodes are developed, and the growing point is elevated above the soil surface.

For the next four to five weeks, the plant grows rapidly and becomes more and more susceptible to hail damage up through tasseling — the most critical period. Once past tasseling, hail has progressively less effect on yield loss.

Estimating total yield loss

Total corn yield loss from hail damage is estimated by adding the expected yield loss caused by stand reduction, the expected loss caused by defoliation, and the expected loss caused by direct ear damage. Remember, however, that this is only an estimate of the percent yield loss. As with undamaged corn, extremely favorable weather during the rest of the growing season can cause actual yields to be higher than expected. Similarly, unfavorable weather can cause greater-than-anticipated reductions.

Estimated % corn grain yield loss due to defoliation at various growth stages[1].

	% Leaf Defoliation																		
Growth Stage[2]	**10**	**15**	**20**	**25**	**30**	**35**	**40**	**45**	**50**	**55**	**60**	**65**	**70**	**75**	**80**	**85**	**90**	**95**	**100**
	% Yield loss																		
7 leaf	0	0	0	0	0	0	1	1	2	3	4	4	5	5	6	7	8	9	9
8 leaf	0	0	0	0	0	1	1	2	3	4	5	5	6	6	7	8	9	10	11
9 leaf	0	0	0	1	1	2	2	3	4	5	6	6	7	7	9	10	11	12	13
10 leaf	0	0	0	1	2	3	4	5	6	7	8	8	9	9	11	13	14	15	16
11 leaf	0	0	1	1	2	3	5	6	7	8	9	10	11	12	14	16	18	20	22
12 leaf	0	0	1	2	3	4	5	7	9	10	11	13	15	16	18	20	23	26	28
13 leaf	0	1	1	2	3	4	6	8	10	11	13	15	17	19	22	25	28	31	34
14 leaf	0	1	2	3	4	6	8	10	13	15	17	20	22	25	28	32	36	40	44
15 leaf	1	1	2	3	5	7	9	12	15	17	20	23	26	30	34	38	42	46	51
16 leaf	1	2	3	4	6	8	11	14	18	20	23	27	31	36	40	44	49	55	61
17 leaf	2	3	4	5	7	9	13'	17	21	24	28	32	37	43	48	53	59	65	72
18 leaf	2	3	5	7	9	11	15	19	24	28	33	38	44	50	56	62	69	76	84
19-21 leaf	3	4	6	8	11	14	18	22	27	32	38	43	51	57	64	71	79	87	96
Tassel	3	5	7	9	13	17	21	26	31	36	42	48	55	62	68	75	83	91	100
Silked	3	5	7	9	12	16	20	24	29	34	39	45	51	58	65	72	80	88	97
Silks brown	2	4	6	8	11	15	18	22	27	31	36	41	47	54	60	66	74	81	90
Pre-blister	2	3	5	7	10	13	16	20	24	28	32	37	43	49	54	60	66	73	81
Blister	2	3	5	7	10	13	16	19	22	26	30	34	39	45	50	55	60	66	73
Early milk	2	3	4	6	8	11	14	17	20	24	28	32	36	41	45	50	55	60	66
Milk	1	2	3	5	7	9	12	15	18	21	24	28	32	37	41	45	49	54	59
Late milk	1	2	3	4	6	8	10	12	15	18	21	24	28	32	35	38	42	46	50
Soft dough	1	1	2	2	4	6	8	10	12	14	17	20	23	26	29	32	35	38	41
Early dent	0	0	1	1	2	3	5	7	9	11	13	15	18	21	23	25	27	29	32
Dent	0	0	0	1	2	3	4	6	7	8	10	12	14	15	17	19	20	21	23
Late dent	0	0	0	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Nearly mature	0	0	0	0	0	0	0	0	1	2	3	4	5	5	6	6	7	7	8
Mature	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

[1] Adapted from the National Crop Insurance Association's "Corn Loss Instruction" (Rev. 1984).

[2] As determined by counting fully expanded leaves (i.e., those with 40-50% of leaf exposed from whorl and whose tip points below the horizontal.)

Frost Damage

Early Season – When early frost kills corn leaf tissue, producers worry about whether or not corn plants will recover. The key to assessing corn seedling viability is to find and observe the "growing point." The growing point is where all new tissue originates and is protected below ground until the plants reach the V-5 stage. Removal or death of leaf tissue above the growing point has only a small effect on corn growth and yield at these early stages.

The growing point can be found by pulling the entire corn plant, including roots and splitting the entire plant lengthwise. If the growing point was below ground and white or creamy in appearance, then injury didn't occur. Observations of frost damage are best made by waiting at least two or three days after frost occurred. If the growing point appears healthy and is white to light yellow color several days after frost, full plant recovery is likely. Plants with extensive leaf tissue damage will likely recover if the growing point is not injured by early frost. New leaves should appear within three to four days if growing point is uninjured.

Late Season – If a killing frost occurs before grain fill is complete, yield potential and quality could be affected. A killing frost can occur when the temperature in the crop canopy drops from 32°F to 28°F for a short time (5-10 minutes) or if the canopy temperature stays at 32°F for four to five hours. This is adequate to kill the entire plant. A lighter frost of 30-32°F lasting an hour or two could kill leaves but not the stalk or ear shank. When only a portion of the leaves are killed, those not killed can continue to function and contribute to grain yield if good growing conditions follow frost. The effects of late season frost on killing leaves at various growth stages are shown below:

Corn Grain Yield Reduction by Frost

Development Stage	Days after Pollination	Percent of Total Yield	PERCENT Yield LOSS
Early Dent	35	68	32
Dent	40	77	23
Late Dent	45	85	15
Half Milk Line	50	92	8
Mature	55	100	0

Source: University of Minnesota

USDA market grades of shelled corn

GRADE	Minimum	Maximum limits of —		
GRADE	Test Weight per Bushel	Heat-Damaged Kernels	Total Damaged Kernels	Broken Corn and Foreign Material
	(lbs.)	(%)	(%)	(%)
U.S. No. 1	56	0.1	3	2
U.S. No. 2	54	0.2	5	3
U.S. No. 3	52	0.5	7	4
U.S. No. 4	49	1.0	10	5
U.S. No. 5	46	3.0	15	7

U.S. Sample grade:

U.S. Sample grade is corn that:

(a) Does not meet the requirements for the grades U.S. Nos. 1, 2, 3, 4, or 5; or

(b) Contains 8 or more stones which have an aggregate weight in excess of 0.1 percent of the sample weight, 2 or more pieces of glass, 3 or more crotalaria seeds (Crotalaria spp.), 2 or more castor beans (Ricinus communis L.), 4 or more particles of an unknown foreign substance(s), 8 or more cockleburs (Xanthium spp.) or similar seeds singly or in combination, or animal filth in excess of 0.20 percent in 1,000 grams; or

(c) Has a musty, sour, or commercially objectionable foreign odor; or

(d) Is heating or otherwise of distinctly low quality.

Note: Moisture content is not considered in USDA Grade determinations.

Corn Planting

Planting a crop is probably the most important part of the corn production cycle. Typically, the crop must be planted early into a warm, moist and firm seedbed. To maximize yield, the seed needs to be placed at a uniform depth and be evenly spaced in the row. Commercially available row crop planters are capable of doing a good job, but traveling too fast in the field can reduce planting accuracy.

Studies at NDSU found that planters are at their peak performance at low speeds under 5 mph. At speeds above 5 mph, planting accuracy starts dropping off. At 7 mph, seed spacing accuracy dropped off 10 to 15% compared to speeds of 5 mph. Seeding accuracy is a trade-off between speed, plant spacing and number of seeds planted. As your planting speed goes up, potential yield loss goes up.

Seed size does not affect most newer planters ability to meter seeds as long as the correct plates or discs are used along with the correct air flow or vacuum depending on planter design.

Corn Harvesting

Every bushel of corn left in the field represents a loss in profit. Combine losses cannot be reduced to zero, but skillful operators usually can reduce losses to an acceptable level without affecting the rate of harvest.

Corn is mature when the grain has about 30 to 32% moisture. The best time to harvest depends upon the individual's harvest and storage system. Early harvest has several advantages:

- Less lodging from stalk rot and severe storms.
- Less chance of water logged fields which delay or prevent harvest.

- Less ear droppage.
- Less grain is shelled when the ears hit the snapping rolls.

The following chart shows the relationship between field losses and delayed harvesting:

Averages from tests in Illinois, Indiana, Iowa, and Nebraska over several seasons.

	October % Loss	November % Loss	December % Loss
Machine loss	4.6	7.0	11.8
Total loss	5.0	8.4	18.4

The drawback to early harvest is that it can require more energy for drying. But, the extra corn saved can often more than cover the cost.

To keep harvesting losses low, you need to know where losses occur, how to measure them, what reasonable loss levels are, and what machine adjustments and operating practices will reduce losses.

Where Losses Occur

Preharvest losses are ears that drop from the stalk before harvesting begins. These losses are not caused by the combine, but they can be reduced by harvesting early.

Corn harvest losses can be separated into four types. Gathering losses occur at the front of the combine and consist of ears missed or dropped by the machine and loose kernels shelled by the snapping rolls in the cornhead. Cylinder and separating losses will be found on the ground behind the combine. **Cylinder losses** are kernels attached

to pieces of cob that were not shelled by the combine cylinder. **Separating losses** are loose kernels that were not shaken out of the cobs and husks and were lost out the rear of the combine.

How to Measure Losses

Ear losses can be measured from an area equal to 1/100 acre. Each 3/4-pound ear (or its equivalent in smaller ears) found in this area is approximately equal to a loss of 1 bushel per acre. The length of row for 1/100 acre depends on your row width and the number of rows being harvested. (See Table 1.)

Table 1. Length of row (feet) for 1/100 acre for measuring ear losses.

Row width	2	3	4	6	8
(inches)					
20	130.7	87.1	65.3	43.6	32.7
28	93.3	62.2	46.7	31.1	23.3
30	87.1	58.1	43.6	29.0	21.8
32	81.7	54.4	40.8	27.2	20.4
36	72.6	48.4	36.3	24.2	18.2
38	68.8	45.9	34.4	22.9	17.2
40	65.3	43.6	32.7	21.8	16.3

The easiest way to measure loose kernel losses is to use a rectangular frame enclosing 10 square feet. Every 20 kernels of corn found within the frame is approximately equal to 1 bushel per acre loss. Make the frame out of heavy wire or 1/8 inch rod. The width of the frame should be the same width as your corn rows. The length of the frame is listed in table 2.

Table 2. Dimensions of a rectangular frame enclosing 10 square feet for measuring loose kernel losses.

Width	Length
(inches)	(inches)
20	Use frame for 40-inch rows and place over 2 rows at a time
28	51.4
30	48
32	45
36	40
38	37.9
40	36

To measure losses, stop your combine a few rows in from the edge of the field. Disengage the header, raise the header, and back up 15 to 20 feet. Measure off an area of 1/100 acre on the harvested rows behind your combine, gather all missed ears of corn within this area, and count the number of equivalent ¾-pound ears to determine total ear loss.

If total ear loss is high, mark off an area of 1/100 acre in the standing corn in front of the combine, gather all missed ears, and count the number of equivalent ¾-pound ears to determine preharvest loss. Subtract preharvest loss from the total ear loss to find machine ear loss.

To measure kernel losses, place the rectangular frame over the first harvested row behind the combine. Remove the stalks, husks, and leaves, and count the kernels attached to pieces of cob and the loose kernels within the frame. Record each count separately. Then move the frame over onto the next row and count the kernels. After kernels are counted from all the rows being harvested, divide the total number of kernels attached to cobs by the number of rows, and then divide the answer by 20 to find **cylinder loss**. Divide the total number of loose kernels by the number of rows, and then divide the answer by 20 to find the **total loose kernel loss**. This will be the sum of snapping roll shelling and separating loss.

Next, place the frame over the first harvested row in front of the combine header. Be sure to measure between the standing corn and the residue dropped from the rear of the combine. Remove the stalks and leaves, count all loose kernels within the frame, and divide by 20 to find snapping roll shelling loss for that row. Move the frame over and count the kernels in the next row. Record the count for each row separately, because only one row on the cornhead may be out of adjustment and may be shelling more corn than the others. After counting losses for all rows, add them and divide by the number of rows to find an average snapping roll loss. Subtract this average loss from the total loose kernel loss found behind the combine to determine separating loss.

What are reasonable loss levels?

Iowa extension personnel checked 84 central Iowa corn combines, and the average loss for the top 10% and average operators are listed in Table 3. Machine ear loss and snapping roll shelling were the most frequent causes of high field losses. Harvest losses were lowest when kernel moisture was between 19 and 23 percent. Losses increased as lodging increased and were the highest in weedy fields.

If your losses are greater than the average values in Table 3, stop and find out why. Your goal should be to reduce your losses to the levels shown for the top 10 percent of the combines in the survey.

Table 3. Harvesting losses for 84 randomly selected combines harvesting corn in central Iowa.

	Average	Top 10%
	-------- bu/acre --------	
Machine ear loss	1.5	0.0
Stalk roll shelling	0.9	0.3
Cylinder loss	0.6	0.0
Separating loss	0.7	0.2
Total harvesting loss	3.7	0.5
Preharvest dropped ears	2.1	1.0
Total loss	5.8	1.5

Adjustments and Operating Practices to Keep Losses Low

Keep your combine in good repair. Keep chains properly adjusted and belts tight. Lubricate bearings and roller chains when they're warm to get better lubricant penetration.

Properly governed engine speed is essential for proper separator action. The recommended speed for the engine and the cylinder is in your **operator's manual**. Check these speeds when the engine is at operating temperature.

Adjust snapping roll speed and spacing to snap ears about one-half to two-thirds of the way up the snapping bars. Snapping bars should be spaced narrower in front than in back to prevent wedging. A spacing of 1-1/4 inches in front and 1-3/8 inches at the back will be satisfactory under most conditions. If a wider spacing is used, small ears will wedge between the snapping bars and shelling losses will increase. Be sure snapping roll spacing and snapping bar spacing are the same on all rows.

Adjust gathering chains so the flights are opposite each other and extend about 1/4 inch beyond the snapping bars.

Gathering snouts should just touch the ground under normal field conditions. If corn is badly lodged, slow down and let the snouts float on the ground. Under good field conditions, maintain a field speed of 2.5 to 3 miles per hour. If separating losses are high, slow down.

Adjust cylinder-concave clearance according to your **operator's manual** and adjust cylinder speed to fit corn conditions. For conventional combines with transverse cylinders, clearance is usually 7/8 to 1¼ inches in front and 1/2 to 7/8 inch at rear. It is best to adjust cylinder or rotor speed to recommendations as listed in your **operator's manual**. This is due to the wide range of cylinder and rotor diameters. Diameters range from 17 to 30 inches. Cylinder bar travel speed in feet per minute is similar for all combines whether conventional cylinder or rotary type. Excess cylinder speeds often cause severe crop damage. If cob breakage is severe, increase the rear cylinder-concave spacing 1/8 inch and then increase cylinder speed to improve shelling.

Corn Drying and Storage

Corn must be harvested at moisture contents above that acceptable for storage to increase harvest efficiency, minimize harvest losses, minimize damage to the corn kernels, and due to uncertain weather conditions.

There are many acceptable methods of drying corn. Each has its advantages and limitations, so each situation must be evaluated to select an appropriate method.

In-bin dryers can be grouped as natural air, low temperature, and high temperature. Natural air drying is economical and there is no "bottle-neck" at harvest, since bins are filled at the harvest rate. Corn at 21% moisture content can be dried to 15% in about 36 days during October using an airflow rate of 1.25 cfm/bu. Because the temperature is about 20° cooler in November, the drying time increases to about 70 days and the final corn moisture content will be about 18%.

Low temperature drying is defined as a natural air system with the air heated 5-10°F which permits drying during periods of higher humidity and slightly reduces drying time. Adding enough heat in October to warm the air by 5° will reduce the drying time a little, but will also dry the corn to about 14%. Warming the air by 5° during an average November permits drying the corn to 15% in about 52 days using an airflow rate of 1.25 cfm/bu. Warming the air by 10° in November would further reduce the final moisture content and slightly reduce the drying time.

Layer drying using a natural air or low temperature (NA/LT) system permits harvesting limited amounts of grain at higher moisture contents than could be dried in a full bin.

Fans warm the air that passes through them. The amount the air is warmed depends on operating static pressure, fan type, and fan efficiency. Temperature increases of 2-4°F have

been measured at 4 inches of static pressure and 4-6°F at 6 inches of static pressure. This temperature increase needs to be included in designing and managing a NA/LT drying system.

Airflow moving from bottom to top of a bin is recommended for NA/LT drying, so the last grain to be dried is at the top of the bin where it can be monitored and for ease in determining when the grain is dry. NA/LT drying fans should operate during the night to provide the most corn drying hours. The decision to stop natural air drying fans during wet weather needs to be made after evaluating the grain allowable storage time, expected drying period, and corn equilibrium moisture content for a 24 to 48 hour period.

There is no single best fan for all applications. The fan selected must deliver the most airflow at the expected operating static pressure. Vane-axial fans will typically deliver the most airflow at low static pressures. Low speed centrifugal fans will generally deliver the most airflow at moderate static pressures. In-line centrifugal fans will deliver the most airflow at moderate to high static pressures. High speed centrifugal fans deliver the most airflow at high static pressures.

Combination drying utilizes a high temperature dryer to remove some of the moisture, then uses a NA/LT dryer to complete the drying. This increase the high temperature drying capacity by two to three times and results in high quality grain.

High temperature bin drying permits efficiently drying higher moisture content grain in a bin faster and under conditions that would not be possible with a NA/LT drying system. High temperature bin batch dryers are simple, but it is difficult to determine the appropriate time to stop drying so the overdried grain on the bottom of the bin mixes with the wet grain at the top to achieve the desired average moisture content after the bin has been unloaded. Stirring devices are recommended to mix the grain during drying

to achieve a uniform moisture content when the drying air is heated more than 10°. A high temperature continuous flow bin dryer removes dry grain from the bottom of the bin as it reaches the desired moisture content. It is an efficient dryer, but the disadvantage is that the hottest air contacts the driest grain, which can damage grain quality if excessive temperatures are used.

High temperature column dryers are categorized by the drying process as batch, recirculating batch, automatic batch, and continuous flow. The batch dryer sequences through fill, dry, cool and unload. In a continuous flow dryer these steps occur simultaneously. High temperature dryers are also categorized by the airflow pattern in the dryer as cross-flow, counter-flow, concurrent-flow, and mixed flow. The cross-flow dryer is the most common type.

Germination rates drop rapidly as kernel temperatures exceed 120°F. Therefore, maximum recommended drying air temperature is 110°F for seed. Maximum recommended drying air temperature for commercial corn in the various types of dryers are: continuous flow and recirculating batch, 200°; column batch, 180°, and bin batch 120°. Corn kernel temperature should not exceed 140° on corn for wet milling. There is normally about a 40° difference between plenum air temperature and average kernel temperature in a cross-flow dryer. Therefore, a 180° plenum temperature should be an acceptable maximum recommended temperature for drying corn for wet milling. Remember that corn moisture and temperature varies across a high temperature drying column.

High temperature drying is effective during periods of high humidity and cold temperatures. Air that has a very high relative humidity will have a very low relative humidity after it has been heated. Air that is 40° and 90% relative humidity will have a relative humidity of only 1% after being heated to 180°. The energy required to heat air to 180° from -20° will be 1.4 times greater than heating it from 40°. The amount of

energy required to heat the air can be calculated using the formula: Btu/hr=cfm x 1.1 x temperature increase. Partial air recirculation should be considered on corn dryers to reduce energy costs.

Dryeration is the process of allowing hot grain from a high temperature dryer to steep in a bin without airflow for about six hours, followed by cooling which removes about 0.25 percentage point of moisture for each 10°F the grain is cooled. Grain must be moved to a storage bin to mix grain wet by condensation next to the bin wall on the top during steeping with dry grain. Dryeration increases the drying rate about 60%, increases energy efficiency, and reduces kernel stress cracks.

Cooling grain in the bin increases drying rate about 30 percent. An airflow rate of 12 cfm/bu-hr cools the grain at the fill rate and is required to rapidly cool the grain to minimize condensation near the bin wall.

Grain moisture content needs to be measured accurately for proper drying and storage. Since moisture content varies, it is important that the sample measured is truly representative of the whole. Most moisture meters are influenced more by kernel surface moisture than internal moisture. If moisture is not uniform through the kernel, the sample should be placed in a plastic bag or other moisture tight container for about 12 hours prior to measuring the moisture content. Kernel temperature affects the measured value. An adjustment should be made manually or automatically to the measured moisture content to adjust for temperature. It is best to estimate the amount of error in measuring the moisture content of corn coming from a high temperature dryer by measuring the measure content, placing the sample in a sealed plastic bag for 12 hours, then checking the moisture content again. Growing conditions affect the composition of grain and therefore its moisture measurement. Measurements can vary by almost a percentage point for differing growing conditions. The moisture content of numerous

samples should be taken to assure the most accuracy in measurement.

Grain storage management requires monitoring the grain including probing, checking the temperature and moisture content at various locations within the storage, using insect traps and screens. The grain should be checked every two weeks until a storage history is developed and the grain has been cooled for winter storage. The grain should be checked at least monthly during the winter. Keep records of the grain condition each time the grain is checked.

Grain stores best when it is cool and dry. Optimum conditions for both insect activity and mold growth is at about 80°F. Insects are dormant at temperatures below about 50°F and are killed at temperatures below freezing. Grain should be cooled to about 25°F for winter storage.

Previous recommendations indicated that grain should be warmed in the spring. Since grain stores better at lower temperatures, current recommendations are to aerate to create a uniform grain temperature of about 40°F for summer storage. Moisture migration during the spring and summer causes a moisture content increase of 0.5 to 1.0 percentage point about 2-3 ft below the top center grain surface. Warming the grain to summer temperatures would increase the moisture content of all the grain by 0.5 to 1.0 percentage point.

The amount of dockage varies within a truck load and across the grain stream from the end-gate of a truck. Therefore, the sampling method must collect grain from the entire grain stream to truly represent a cross-section of the grain in the truck. Samples should not be collected from the first or last portion of a load because this is not a true cross-section of the load. The grain must be handled so its condition does not change. For example, the grain should be placed in a sealed container to prevent the moisture content from changing prior to measuring the moisture content.

Resource Publications

North Dakota State University:

- Fertilizing Corn Grain and Silage (SF-722)
- Agricultural Weed Control Guide (current year) (W-253)
- Field Crop Fungicide Guide (current year) (PP-622)
- North Dakota Hybrid Corn Performance Testing (current year) (A-793)
- European Corn Borer Development and Management (NCR 327)
- Uneven Emergence in Corn (NCR 344)
- Herbicide Symptoms in Corn (NCR 94)
- White Grub Management (E-901)
- Corn Insects in North Dakota (E-631)
- Silage Production and Management (R-846)
- Grain Drying (AE-701)
- Crop Storage Management (AE-791)
- Crop Dryeration and In-Storage Cooling (AE-808)
- Energy Conservation and Alternative Energy Sources for Corn Drying (NCH-14)
- Grain Moisture Content Effects and Management (AE905)
- Calculating Grain Drying Cost (AE923)
- Maintaining Corn Quality for Wet Milling (AE119)
- Natural Air & Low Temperature Crop Drying (EB35)

University of Minnesota

- Corn Growth and Development & Management Information for Replant Decisions (FO-5700)
- Corn Insects-Above Ground (MI-0569)
- Corn Insects-Below Ground (MI-3289)
- European Corn Borer Development and Management (BU-2322)
- Fertilizer Management for Corn Planted in Ridge-Till or No-Till Systems (FO-6074)
- Fertilizing Corn in Minnesota (FO-3790)
- Managing Nitrogen for Corn Production on Irrigated Sandy Soils (FO-2392)
- Natural-Air Corn Drying in the Upper Midwest (BU-6577)
- Setting Realistic Crop Yield Goals (FS-3873)
- Soil Nitrogen Test Option for N Recommendations With Corn, A (FO-6514)
- Some Important Insect Larvae Affecting Corn (FS-0581)
- Understanding Nitrogen in Soils (FO-3770)
- Cultural and Chemical Weed Control in Field Crops (BU-3157)

South Dakota State University

- Gerwing, J. and R. Gelderman. 1996. EC750 — Fertilizer Recommendations Guide SDSU/CES.
- Hall, R.G. C253-1996 South Dakota Corn Performance Trials, SDSU/AES.
- McLeod, M.J. Insecticide Recommendations for South Dakota Corn and Sorghum, 1997. SDCES FS 888 CD.
- McLeod, M.J. 1996. Economic Thresholds for First Generation Corn Borers. SDCES EXEX 8125.

- McLeod, M.J. 1992. First generation European corn borer management. SDCES EXEX 8079.
- McLeod, M.J. 1992. Second generation European corn borer management. SDCES EXEX 8080.
- McLeod, M.J. 1992. Scouting adult corn rootworms. SDCES EXEX 8082.
- Wrage, L. Weed Control in Corn, FS 525C.

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1997

January

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