Crop Profile for Field Corn in Minnesota

Prepared Dec, 2001

General Production Information

Nationally, Minnesota is ranked #4 in average annual production (0.86 billion bushels), planted and harvested acres, and raw product value, at $1.72 billion (Table 1). Although the raw product value only represents 9.2% of the U.S. production, this reflects a significant component of Minnesota's $9.0 billion agricultural industry. As with most commodity estimates, it is important to note that this value does not include the numerous additional value-added corn products processed in the state, or more recent industrial applications such as ethanol production or specialty corn hybrids.

The most productive counties are concentrated in the south-central to southwest regions of the state, where corn is produced on gently rolling glacial till soils (Figure 1; Table 2). Corn is also grown on Loess soil in southeast and extreme southwest Minnesota. South central, central and southwest Minnesota corn is primarily rotated with soybean and grown in association with confinement hog production and/or poultry production. Southeast Minnesota topography is characterized by greater relief and has a greater portion of acres in continuous corn, corn/alfalfa rotations and dairy production.

As shown in Table 2, soybean is one of the most common rotational crops throughout southern Minnesota. As in many growing regions in the U.S. and globally, corn in Minnesota is susceptible to many insect, pathogen and weed pests. In this profile, we highlight the most consistent and economically damaging pests, current control options and potential impacts of FQPA.

Table 1. Corn production data for the twelve North Central states, 1997. Ranked by bushel produced, and value.

State	Production (billion bu)	Planted (million ac.)	Harvested (million ac.)	Ave. Yield (bu/ac.)	% of US production	Value* $ (billion)
Iowa	1.656	12.2	12.0	138	17.7	3.31
Illinois	1.425	11.2	11.05	129	15.2	2.85
Nebraska	1.151	9.0	8.73	132	12.3	2.3
Minnesota	**0.858**	**7.0**	**6.45**	**133**	**9.2**	**1.72**
Indiana	0.720	6.0	5.85	123	7.7	1.44
Ohio	0.462	3.6	3.45	134	4.9	0.92
Wisconsin	0.403	3.8	3.05	132	4.3	0.81
Kansas	0.386	2.85	2.7	143	4.1	0.77
South Dakota	0.333	3.8	3.4	98	3.6	0.66
Missouri	0.333	2.95	2.87	116	3.6	0.66
Michigan	0.263	2.6	2.25	117	3.2	0.53
North Dakota	0.06	0.8	0.61	99	0.6	0.12
North-Central States	8.05	65.8	62.41	125	86.4	16.09
U.S. Total	9.365	80.23	73.7	127	100.0	18.73

*@ $2.00/bu

Production Regions

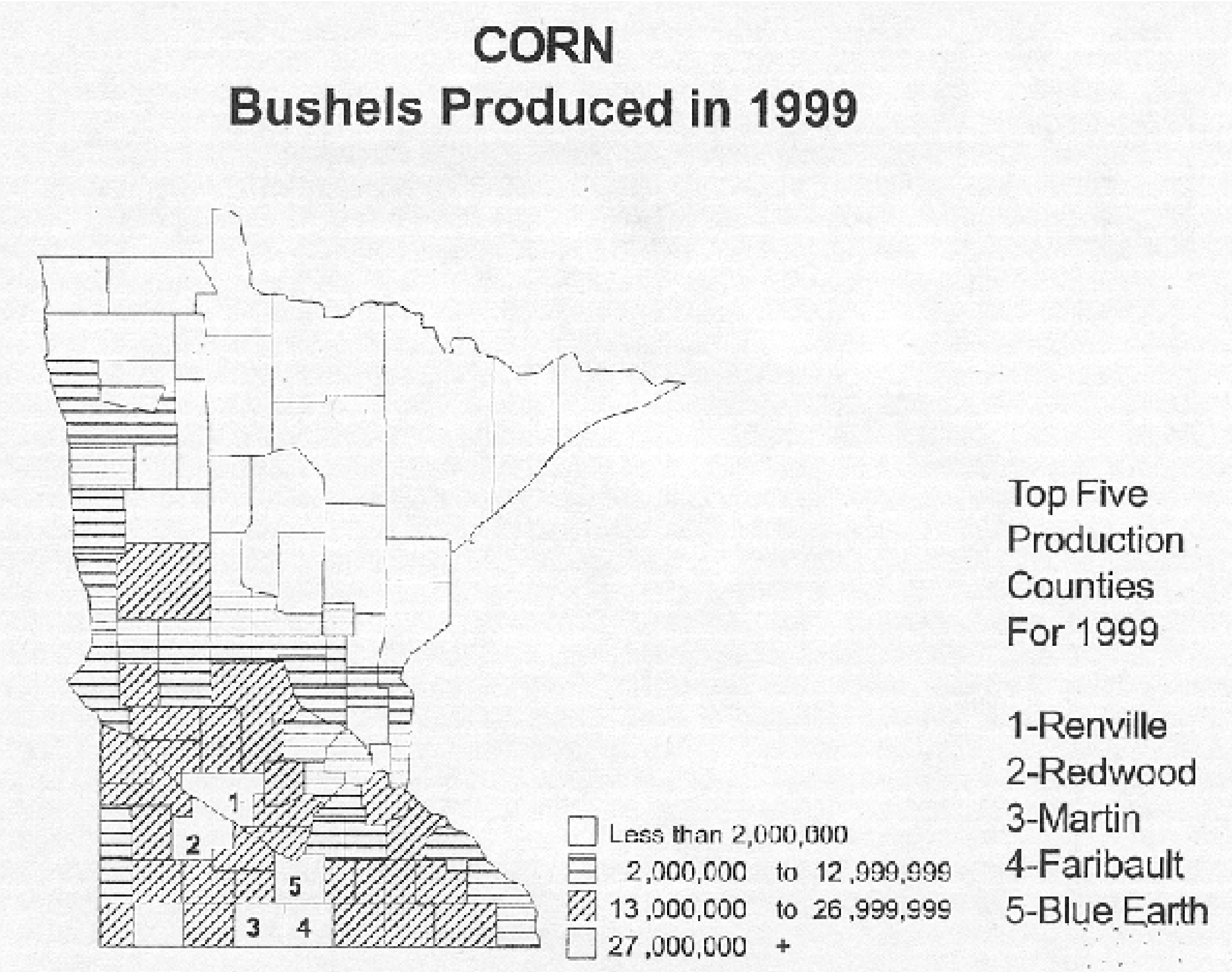

Figure 1. Minnesota corn production by county (MN Agricultural Statistics 2000).

Table 2. Major corn production areas in Minnesota.

Production Region	Predominant Soil Type	Crop Maturity	Main Rotational Crops	Livestock Production
Southeast	Loess over bedrock	Late I – Early II	Corn, alfalfa, soybean, processing crops	Dairy, Beef cattle

Southwest, Western and West-central	Glacial till, Loess over till in extreme SW	Early I – Early II	Corn, soybean, some sugarbeet	Confinement Hogs Beef cattle
South-central, Central and West-central	Glacial till	Early I (north) Mid I - Early II (South)	Corn, soybean, processing crops, sugarbeet	Confinement Hogs, poultry
Northwest	Lacustrian	Early 0 – Early I	Corn, small grains, sugarbeet	--

Climate and Stand Establishment:

Climatic conditions vary widely for Minnesota corn production. Average annual precipitation ranges from 20 inches in the northwest to 31 inches in the southeast. The average frost-free dates (>32 degrees F) vary by >35 days through the portions of Minnesota where corn is grown. Corn days-to-maturity ranges from 80-day hybrids in the north to 110-day hybrids in the south. In general, soils are neutral to alkaline and have relatively high water holding capacity.

Nearly all corn and soybean acreage is planted in a 6-week period in the mid-spring (Fig. 2). Planting begins once the soil temperature approaches 50° F, typically in the third week of April, and it is completed by the third week in May—if weather is favorable. Crop development in the southern third of Minnesota typically leads the northern third by as much as a week and a half during the growing season because of warmer temperatures.

Most corn is grown under conventional and reduced tillage systems. Poorly drained soils and a short growing season limit the number of acres of no-till corn planted. Additional acres are planted under ridge and strip-till systems. Most fields are chisel plowed and receive herbicide treatments in the fall.

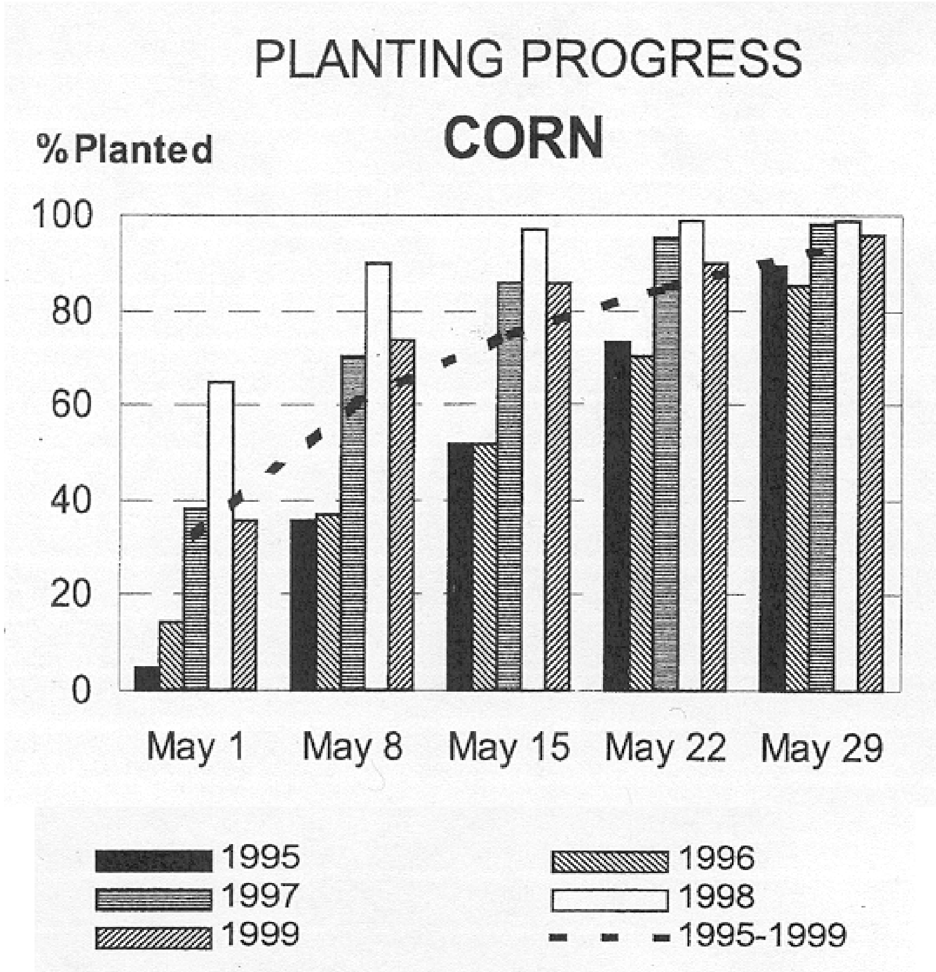

Figure 2. Average planting date for corn (MN Agricultural Statistics 2000)

Insect Pests

There are four major insect pests of corn in Minnesota and a number of secondary pests. The insect species that occur are listed below chronologically according to stage of corn development with brief narrative detailing their effects and management. Pesticide classes are indicated as follows: 1.) Organophosphate, 2) Biological, 3) Carbamate, 4) Organochlorine, 5) Pyrethroid, and 6) other.

Germination, emergence:
Seedcorn maggot is the larva of a small fly. The flies are attracted to fields where relatively fresh manure and other organic material is present. The maggots feed on germinating soybean and corn seeds and eat the germ, killing the plant.

True white grub, *Phylophaga sp.;* wireworm, *Melanotus sp.;* seedcorn beetle, and slender seedcorn beetle are all insects that attack the germinating corn seed. There are no rescue treatments for control of these insects. Generally, infestations occur in patchy areas of fields with damage likely to recur in successive years. There are no rescue treatments available for control of these pests so most treatments are made as preventative, at planting, or in replant situations.

Chemical controls: At planting treatments (no rescue treatments)

- 1,4 Agrox DL Plus as a seed box treatment.
- 4 DB Green as a seed box treatment.
- 1 Diazinon 50W as a seed box treatment.
- 4 Enhance Plus as a seed box treatment.
- 1,4 Germate Plus as a seed box treatment.
- 4 Grain Guard Plus as a seed box treatment.
- 1,4 Kernel Guard as a seed box treatment.
- 1 Lorsban 50SL as a seed box treatment.
- 4, Sorghum Guard as a seed box treatment.
- 6 Prescribe as a seed treatment.
- 5 Proshield as a seed treatment.
- 1,5 Aztec 2.1G @ 6.7 ounces per 1,000 ft. of row.
- 5 Capture 2EC @ 0.3 fluid ounces per 1,000 ft of row.
- 1 Counter 15G @ 8 ounces per 1,000 ft. of row.
- 1 Counter CR @ 6 ounces per 1,000 ft. of row.
- 5 Force 1.5G @ 8 ounces per 1,000 ft. of row.
- 5 Force 3G @ 4 ounces per 1,000 ft. of row.
- 3 Furadan 4F @ 2 pints per acre – broadcast post- (at cultivation).
- 1 Lorsban 15G @ 8 ounces per 1,000 ft. of row.
- 1 Lorsban 4E @ 6 pints per acre – broadcast PPI.
- 6 Regent 4SC @ 0.24 fluid ounces per 1,000 ft of row.
- 1 Thimet 20G @ 6 ounces per 1,000 ft. of row.

Vegetative stages:
Western and northern corn rootworm (CRW) beetles, *Diarotica sp.,* are the most significant insect pests of corn in the Midwestern U.S. from the standpoint of insecticide use. Adults lay eggs in the late summer and fall that hatch in early June. Corn rootworm larvae feed on a narrow range of host species. Corn-soybean rotations generally disrupt the beetles' life cycle and constitute the most effective management tool available for farmers. Some populations of northern CRW have shown a life cycle adaptation called extended diapause. This occurs when some of the eggs rest through the next summer and hatch the following spring. With extended diapause, insect management using a corn-soybean rotation is defeated. Recently, populations of western CRW have been found in a neighboring state with adults that lay eggs into soybean fields, but this phenomenon is not widespread to date. Soil-applied insecticide treatments are a standard practice in corn following corn—targeting CRW larvae. Corn rootworm adults occasionally cause economic levels when they feed on emerging corn silks. If silk feeding is severe, pollination suffers with a resulting yield loss. Some producers scout for significant populations of adults in mid to late summer and treat for adults to reduce egg density and the need for spring soil-insecticide applications.

Available chemical treatments:

Seed treatments for larval control:

6 Prescribe as a seed treatment.
5 Proshield as a seed treatment.

Soil-applied for larval control:

- 1,5 Aztec 2.1G @ 6.7 ounces per 1,000 ft. of row
- 5 Capture 2EC @ 0.3 fluid ounces per 1,000 ft of row
- 1 Counter 15G @ 8 ounces per 1,000 ft. of row
- 1 Counter CR @ 6 ounces per 1,000 ft. of row
- 5 Force 1.5G @ 8 ounces per 1,000 ft. of row
- 5 Force 3G @ 4 ounces per 1,000 ft. of row
- 3 Furadan 4F @ 2 pints per acre – broadcast post- (at cultivation)
- 1 Lorsban 15G @ 8 ounces per 1,000 ft. of row
- 1 Lorsban 4E @ 6 pints per acre – broadcast PPI
- 6 Regent 4SC @ 0.24 fluid ounces per 1,000 ft of row.
- 1 Thimet 20G @ 6 ounces per 1,000 ft. of row.

Adult beetles:

- 5 Ambush 2EC @ 6.4-12.8 ounces per acre – at brown silk stage
- 5 Asana XL 0,66 EC @ 5.8-9.6 ounces per acre, 21 day pre harvest interval (PHI)
- 3 Furadan 4F @ 0.25-0.5 pints per acre, 30 day PHI
- 1 Lorsban 4E @ 1-2 pints per acre, 21 day PHI
- 1 Penncap-M @ 1-2 pints per acre, 12 day PHI
- 5 Pounce 3.2EC @ 4-8 ounces per acre – prior to brown silk stage
- 3 Sevin XL+ @ 2-4 pints per acre, no PHI
- 5 Warrior 1E @ 1.92-3.2 fluid ounces per acre
- 3 SLAM – semiochemical treatments
- 3 Sevin 80WSP @ 1.25-2.5 pounds per acre; Classified as a bee hazard. 48 days PHI

European corn borer:
European corn borer, *Ostrinia nubilalis* (Hubner), or ECB, pressure is responsible for the second most insecticide applications to corn. ECB overwinter as larvae within corn stubble. The insects pupate once the temperature warms sufficiently in the spring. Moths emerge from pupae in June, adults mate, and females oviposit egg masses containing 15-25 eggs on the underside of leaves. Once larvae hatch, they feed on leaf tissue. These larvae mature, pupate, and emerge as the second generation of moths in late July-August. Second-generation ECB prefer younger corn for oviposition. Newly hatched second generation larvae feed lightly on leaves, but soon bore into leaf midribs, stalks and ear shanks. Economic thresholds for second generation corn borer are difficult to determine. There are predictive models available that help growers scout and plan treatments, if needed.

Chemical treatments:

- 5 Ambush 2EC @ 6.4-12.8 ounces per acre – at brown silk stage
- 5 Asana XL 0,66 EC @ 5.8-9.6 ounces per acre, 21 day pre harvest interval (PHI)
- 5 Capture 2EC @ 2.1-6.4 ounces per acre 30 day PHI
- 3 Furadan 4F @ 0.25-0.5 pints per acre, 30 day PHI
- 1 Lorsban 15G @ 5-6.5 pounds per acre
- 1 Penncap-M @ 1-2 pints per acre (Minnesota bee law applies)
- 5 Pounce 1.5G @ 6.7-13.3 ounces per acre
- 5 Pounce 3.2EC @ 4-8 ounces per acre – prior to brown silk stage
- 6 Regent 2 CS @ 0.24 fluid ounces per 1000 ft of row at planting
- 2 Bacillus thuringiensis (several trade names): See individual labels for rates
- 5 Warrior 1E @ 2.56-3.84 fluid ounces per acre

Black cutworm:

Black cutworm, *Agrotis ipsilon* (Hufnagel), is an insect that causes stand losses to young corn in the first month of growth. BCW does not overwinter in the north central states, instead, it moves northward, aided by southerly winds carrying moths from overwintering areas along the Gulf of Mexico. Moths prefer barren fields littered with weeds or plant residue on which to lay their eggs. Prophylactic treatment is not recommended, because of the sporadic nature of the infestation patterns and intensities. Scouting is based on monitoring degree-day accumulations following significant moth flights are detected in an area.

Chemical treatments:

- 1,5 Aztec 2.1G @ 6.7 ounces per 1,000 ft. of row
- 5 Capture 2EC @ 0.3 fluid ounces per 1,000 ft of row
- 5 Force 1.5G @ 8 ounces per 1,000 ft. of row
- 5 Force 3G @ 4 ounces per 1,000 ft. of row
- 1 Lorsban 15G @ 5-6.5 pounds per acre
- 5 Ambush 2EC @ 6.4-12.8 ounces per acre – at brown silk stage
- 5 Asana XL 0,66 EC @ 5.8-9.6 ounces per acre, 21 day pre harvest interval (PHI)
- 3 Furadan 4F @ 0.25-0.5 pints per acre, 30 day PHI
- 1 Lorsban 15G @ 5-6.5 pounds per acre
- 1 Penncap-M @ 1-2 pints per acre (Minnesota bee law applies)
- 5 Pounce 1.5G @ 6.7-13.3 ounces per acre
- 5 Pounce 3.2EC @ 4-8 ounces per acre – prior to brown silk stage
- 2 Bacillus thuringiensis (several trade names): See individual labels for rates
- 5 Warrior 1E @ 1.92-3.2 fluid ounces

Common stalk borer:

Common stalk borer, *Papaipema nebris*, is a native insect which causes damage to corn by tunneling into plants and destroying growing points. Damage is typically confined to field areas which are adjacent to borders of perennial grasses, including road ditches, terrace back slopes, and grass waterways. Large broadleaf weeds, especially hemp, *Cannabis sativa*, and giant ragweed, A*mbrosia trifida*, can be favored oviposition sites in the fall, and if these weeds are disseminated throughout the field, widespread damage can occur. Typically, stalk borer damage is limited to border rows, and treatments can be targeted to those specific areas.

Chemical treatments:

- 5 Ambush 2EC @ 6.4-12.8 ounces per acre – at brown silk stage
- 5 Asana XL 0,66 EC @ 5.8-9.6 ounces per acre, 21 day pre harvest interval (PHI)
- 1 Lorsban 15G @ 5-6.5 pounds per acre
- 1 Penncap-M @ 1-2 pints per acre (Minnesota bee law applies)
- 5 Pounce 1.5G @ 6.7-13.3 ounces per acre
- 5 Pounce 3.2EC @ 4-8 ounces per acre – prior to brown silk stage
- 6 Regent 2 CS @ 0.24 fluid ounces per 1000 ft of row at planting
- 2 *Bacillus thuringiensis* (several trade names): See individual labels for rates
- 5 Warrior 1E @ 2.56-3.84 fluid ounces per acre

<u>Corn leaf aphids</u>:
Corn leaf aphids, *Rophalosiphum maidis*, are colonial sucking insects that can rapidly increase population to cover the emerging tassels and youngest leaves of stage R1 corn plants. Although corn leaf aphid populations approaching 400 per plant are necessary to warrant treatment, such populations do occasionally occur under favorable (dry) weather conditions. The primary damage from large populations is physiological, but secretion of honeydew can cause tassels to gum up and can reduce the effective dissemination of pollen. Scouting is most critical under drought conditions, and seed corn producers must pay special attention to protect pollen availability from inbred lines.

Chemical treatments:

- 5 Ambush 2EC @ 6.4-12.8 ounces per acre – at brown silk stage
- 5 Asana XL 0,66 EC @ 5.8-9.6 ounces per acre, 21 day pre harvest interval (PHI)
- 5 Capture 2EC @ 2.1-6.4 ounces per acre 30 day PHI
- 5 Warrior 1E @ 2.56-3.84 fluid ounces per acre

<u>Corn flea beetles</u>:

Corn flea beetles, *Chaetocnema pulicaria* (Melsheimer), are small insects that feed on corn leaf surfaces where they abrade the surface tissue and cause minor loss of leaf photosynthetic area. Flea beetles play a major role in overwintering and transmission of Stewart's wilt, a bacterial disease of corn. The incidence of Stewart's wilt is generally tied to winter conditions that favor winter survival of corn flea beetles. A model has been developed that predicts damage potential based on temperature. When the average air temperatures (in degrees F) for December, January and February are added and the total is >95, Stewart's wilt is of potential concern, when <95, the risk is relatively small.

Chemical treatments:

- Counter 15G @ 8 ounces per 1,000 ft. of row
- Counter CR @ 6 ounces per 1,000 ft. of row
- 5 Capture 2EC @ 2.1-6.4 ounces per acre 30 day PHI
- 3 Furadan 4F @ 0.25-0.5 pints per acre, 30 day PHI

Sod webworm:
Sod webworm, *Crambus sp.*, is an occasional pest of corn and treatments are rarely required

Chemical treatments:

- 5 Capture 2EC @ 2.1-6.4 ounces per acre 30 day PHI
- *Bacillus thuringiensis* (several trade names): See individual labels for rates

Hop-vine borer:
Hop-vine borer is the larva of a weak-flying moth and is found predominantly in the southeast quadrant of Minnesota. Hop vine borer larvae are soil dwelling and feed into the base of young corn plants where they destroy the growing points. Localized infestations can be intense.

Chemical treatments:

- 5 Pounce 3.2EC @ 4-8 ounces per acre, 30 day PHI

True Armyworm:
True Armyworm, *Pseudaletia unipuncta* (Haworth), damage is characterized by ragged feeding and large amounts of frass on affected plants. The most severe damage occurs on no-till cornfields put into grass. Grass is a favored oviposition site for adults that arrive from the gulf-coast states on strong southerly winds, similar to black cutworm. Damage to young corn can appear suddenly if the grass supply is consumed or when it is killed with a herbicide treatment. No-till fields must be observed closely, and treatments should be based on the presence of small larvae feeding on grass.

Chemical treatments:

- 5 Ambush 2EC @ 6.4-12.8 ounces per acre – at brown silk stage
- 5 Asana XL 0,66 EC @ 5.8-9.6 ounces per acre, 21 day pre harvest interval (PHI)
- 5 Capture 2EC @ 2.1-6.4 ounces per acre 30 day PHI
- 3 Lannate LV @ 0.75-1.5 pints per acre, 21 day PHI
- 1 Lorsban 15G @ 5-6.5 pounds per acre
- 1 Penncap-M @ 1-2 pints per acre (Minnesota bee law applies)
- 5 Pounce 1.5G @ 6.7-13.3 ounces per acre
- 5 Pounce 3.2EC @ 4-8 ounces per acre – prior to brown silk stage
- 2 Bacillus thuringiensis (several trade names): See individual labels for rates

<u>Two-spotted spider mites</u>:
Two-spotted spider mites, *Tetranychus urticae* (Koch), are not normally pests of corn in Minnesota. They are controlled during most years in Minnesota by a naturally occurring disease, however, when there are prolonged periods of low humidity, the fungus is suppressed allowing the spider mite population to proliferate. If adverse weather conditions continue, treatment may be warranted.

Chemical controls: spot treatments are recommended; re-infestation is possible.

- 5 Capture 2EC @ 2.1-6.4 ounces per acre 30 day PHI
- 1 Cygon 400 @ 1 pt. per acre, pre harvest interval (PHI) of 21 days. Do not use for forage or straw.
- 1 Lorsban 4E @ 0 .5-1 pint per acre, PHI of 28 days. Do not use for forage or straw.
- 1 Dimethoate @ labeled rates (24C registration)

<u>Grasshopper</u>:
Grasshopper (predominantly 3 species: differential, *Melanoplus differentialis* (Thomas); two-striped, *Melanoplus bivittatus* (Say); and red-legged *Melanoplus femurrubrum* (DeGeer), are common mid-late-summer pests of corn in Minnesota. Grasshoppers hatch in grassy field edges where they begin to feed and gradually spread into fields. Grasshopper presence in border areas is not necessarily a cause of alarm; greatest yield losses are caused by the loss of leaf area during tassel and silking stages. A 20% loss of leaf area during this time will result in about 7% loss in yield. Scouting is important because it is important to only treat when populations reach economic thresholds. Adults are most easily controlled with pyrethroid or carbamate insecticides.

Chemical treatments:

- 5 Ambush 2EC @ 6.4-12.8 ounces per acre – at brown silk stage
- 5 Asana XL 0,66 EC @ 5.8-9.6 ounces per acre, 21 day pre harvest interval (PHI)
- 5 Capture 2EC @ 2.1-6.4 ounces per acre 30 day PHI
- 3 Furadan 4F @ 0.25-0.5 pints per acre, 30 day PHI
- 1 Lorsban 15G @ 5-6.5 pounds per acre
- 1 Penncap-M @ 1-2 pints per acre (Minnesota bee law applies)
- 5 Pounce 1.5G @ 6.7-13.3 ounces per acre
- 5 Pounce 3.2EC @ 4-8 ounces per acre – prior to brown silk stage
- 2 *Bacillus thuringiensis* (several trade names): See individual labels for rates

Diseases

Diseases reduce yields to some extent every year in corn production. Diseases also are responsible for reductions in grain and seed quality. Disease losses vary from year to year, and their occurrence is strongly influenced by weather conditions. Some diseases occur commonly but may not cause much damage; some have the potential to be very serious.

Seed Decay and Seedling Blight:
These diseases are generally caused by soil-inhabiting fungi such as Pythium, Fusarium, Diplodia Rhizoctonia, and Penicillium. These fungi also may be seedborne, except for Pythium. Seeds may be rotted before germination or the seed may germinate and the seedling infected and blighted (damping-off). This can occur as either pre-emergence damping-off or post-emergence damping-off. Damping-off is favored by cool, wet soils, so it is more common in low-lying or poorly drained areas or in fields planted too early in the spring. Heavy residue on the soil surface can favor damping-off by suppressing soil temperature and drying. Other factors that delay germination and emergence such as herbicide damage, compaction, crusting, or planting too deep, can result in more seedling blight.

Damping-off is generally controlled by seed treatment with a fungicide such as fludioxonil, captan, or metalaxyl, standard on almost all seed corn. This is sufficient in most cases, but not under severe conditions. Plant corn when the soil temperature is above 50°F and soil moisture is not excessive. Seeds should not be planted too deep; about 1 1/2 to 2 inches is best, depending on soil conditions.

Root Rots:
Root rots of corn are very common, and can be caused by a number of fungal pathogens including Pythium graminicola, Fusarium graminearum and other Fusarium species, and Exserohilum pedicellatum. Losses to root rots vary substantially from year to year, and are difficult to estimate. Root rots occur to some extent in every field. But under wet conditions, root rots cause economic losses. Wet soil conditions predispose plants to root rots because of oxygen deficiency, and the root rot fungi thrive under these conditions. Highly compacted or otherwise poorly drained soils are particularly prone to root rots. Many of the stalk rot pathogens enter through the roots and cause a root rot in advance of the stalk rot.

Under good growing conditions losses to root rots are negligible, and control measures are not necessary. Most hybrids are tolerant to some degree of root rot. Some hybrids are more resistant than others, but high levels of root rot resistance are not available. Improved drainage reduces the risk of root rots when wet conditions occur. Soil drying can be enhanced through a reduction in surface residue or cultivation, but the value of these practices in reducing root rot has not been demonstrated.

Foliage and Aboveground Diseases:

Eyespot:
Eyespot is caused by the fungus *Aureobasidium zeae*, previously known as *Kabatiella zeae*. This fungus overwinters in corn residue and in wet conditions produces conidia that are spread by splashing water and wind. The disease is much more common when corn follows corn. Eyespot may appear early in the season on lower leaves and again near the end of the season on upper leaves. It is more prevalent in the northern part of the Corn Belt.

Resistant hybrids are available. Inoculum can be reduced by crop rotation or reducing surface residue through tillage. In reduced tillage systems, resistance and rotation are very important control measures. Fungicides can be used to control leaf diseases in corn, but usually they are economical only in seed corn, popcorn, or sweet corn production. Registered fungicides include mancozeb, propiconazole, chlorothalonil, and others. Check fungicide labels for specific diseases controlled, and check with your extension specialist for current information on available fungicides. To be effective, a fungicide program must be started when the disease is at very low levels (1 percent or less of leaf area affected). More than one application is necessary when conditions are favorable for disease.

Common smut:
Common smut is caused by the fungus *Ustilago zeae*, previously known as *Ustilago maydis*, which overwinters in corn residue or soil. This fungus produces black teliospores that are resistant to environmental conditions, so that they can survive well in soil. These teliospores germinate during the spring and summer, with each teliospore then producing four smaller spores, called sporidia. These are spread by wind and water. All above ground plant parts are susceptible, especially the actively growing meristematic tissue. Sporidia can infect through unwounded cells, but wounds caused by insects, detasseling, cultivation, hail, or blowing soil are important infection sites as well. Disease is favored by excess nitrogen, excess manure or herbicide injury, and relatively dry, warm weather.

Some hybrids are less susceptible than others. Rotation and tillage will not affect the occurrence of smut, since the teliospores survive well in the soil. Avoiding mechanical damage through cultivation can reduce the risk of disease. Maintenance of balanced fertility and avoiding herbicide injury also will reduce the risk of disease.

Northern Corn Leaf Blight:
Northern leaf blight is caused by the fungus *Exserohilum turcicum*, previously called Helminthosporium turcicum. This has traditionally been the most consistently damaging leaf disease of field corn in the northern Corn Belt, but its severity has decreased due to improvements in resistance. It occurs throughout the eastern half of the United States, as far west as eastern Nebraska. The fungus overwinters as mycelium and spores in corn residue. Spores are dispersed by wind and splashing water. Disease development is favored by extended periods of leaf wetness (rain or dew) and moderate temperatures (64-81°F). There are at least four races of the fungus.

Northern leaf blight can be controlled by two types of resistance, monogenic or polygenic. The monogenic Ht resistance does not confer resistance to all races of the fungus. Hybrids with an Ht gene may become susceptible if new races appear in the area. Polygenic resistance confers resistance to all races, but the resistance is not as absolute as Ht resistance. The level of polygenic resistance varies among hybrids. Inoculum can be reduced by crop rotation or reducing surface residue through tillage. In reduced tillage systems, resistance and rotation are very important control measures. Fungicides can be used to control leaf diseases in corn, but usually they are economical only in seed corn popcorn, or sweet corn production. Registered fungicides include mancozeb, propiconazole, chlorothalonil, and others. To be effective, a fungicide program must be started when the disease is at very low levels (1 percent or less of leaf area affected). More than one application is necessary when conditions are favorable for disease.

Helminthosporium leaf spot:
Helminthosporium leaf spot or northern leaf spot is caused by the fungus *Bipolaris zeicola*, previously known as *Helminthosporium carbonum*. There are five known races of this fungus with different virulence characteristics and symptoms. Race 0 is nearly avirulent to corn, and race 1 is virulent on only a few

genotypes. Races 2 and 3 are the most common races in the Midwest. Race 2 is not specific for corn genotypes, while race 3 is only a problem on certain susceptible lines. A fifth race has been reported recently. *B. zeicola* overwinters as mycelium and spores in corn residue, and the spores are dispersed by wind and splashing water. It is favored by high humidity and moderate temperatures.

Resistant hybrids and inbreds are available. Inoculum can be reduced by crop rotation or reducing surface residue through tillage. In reduced tillage systems, resistance and rotation are very important control measures. Fungicides can be used to control leaf diseases in corn, but usually they are economical only in seed corn, popcorn, or sweet corn production. Registered fungicides include mancozeb, propiconazole, chlorothalonil and others. To be effective, start a fungicide program when the disease is at very low levels (1 percent or less of leaf area affected). More than one application is necessary when conditions are favorable for disease.

Anthracnose leaf blight:
Anthracnose leaf blight is caused by the fungus *Colletotrichum graminicola*, the same fungus that causes anthracnose stalk rot (see page 16). It overwinters as mycelium or sclerotia in corn residue or seed. Several weed species also are hosts and may act as inoculum sources. Spores are spread primarily by splashing water. Disease development is favored by wet weather with moderately warm temperatures. Anthracnose is much more common where corn follows corn. Anthracnose is usually more severe in the eastern corn states, but its importance in the Midwestern states is increasing.

Resistant hybrids are available, but resistance to anthracnose leaf blight and anthracnose stalk rot are not necessarily found in the same hybrid. Inoculum can be reduced by crop rotation or reducing surface residue through tillage. In reduced tillage systems, resistance and rotation are very important control measures. Fungicides can be used to control leaf diseases in corn, but usually they are economical only in seed corn, popcorn, or sweet corn production. Registered fungicides include mancozeb, propiconazole, chlorothalonil, and others. To be effective, a fungicide program must be started when the disease is at very low levels (1 percent or less of leaf area affected). More than one application is necessary when conditions are favorable for disease.

Gray leaf spot:
Gray leaf spot is caused by the fungus *Cercospora zeae-maydis*. This disease is a problem in the eastern United States, and it has grown in importance in the western Corn Belt as far west as central Nebraska. In Minnesota, gray leaf spot is occasionally observed in the southern half of the state. It is more of a problem when corn follows corn. The fungus survives as mycelium in corn residue, and spores are dispersed by wind and splashing water. Sporulation and disease development are favored by warm, humid weather.

Some hybrids are more resistant to gray leaf spot, but control may no t be adequate in some areas. Inoculum can be reduced by crop rotation or reducing surface residue through tillage. In reduced tillage systems, resistance and rotation are very important control measures. Fungicides can be used to control leaf diseases in corn, but usually they are economical only on very susceptible hybrids or in seed corn, popcorn, or sweet corn production. Registered fungicides include mancozeb, propiconazole, chlorothalonil and others. Check fungicide labels for specific diseases controlled. To be effective, a fungicide program must be started when the disease is at very low levels (1 percent or less of leaf area affected). More than one application is necessary when conditions are favorable for disease. For more information see ISU Extension publication Corn Gray Leaf Spot, IPM-49. Each year corn hybrids entered in the Minnesota Crop Performance Test are evaluated for gray leaf spot severity.

Stewart's Disease:
This disease, also called Stewart's wilt or bacterial wilt, is caused by the *bacterium Erwinia stewartii*, which overwinters in the gut of the corn flea beetle. The occurrence of this disease is strongly linked to the winter survival rate of the corn flea beetle (Figure 24), because the beetle introduces the pathogen into the corn plants as it feeds and carries the bacterium from plant to plant. The beetles survive in high numbers following a mild winter, resulting in high disease levels. If the sum of the mean monthly temperatures for December, January and February is 90°F or more, the beetles will survive and the threat of Stewart's wilt is high. This disease is more common in the southern and eastern parts of the Corn Belt. Dent corn is not very susceptible except for a few inbred lines, but sweet corn can be very susceptible.

The disease can be spread by insects other than the flea beetle, but they are not as important. Stewart's disease is also seedborn, but seed transmission is very rare. Most cultural practices do not influence Stewart's disease because the pathogen survives in the flea beetle. Weed control may have some effect because the insects prefer grassy weeds and damage to corn is highest in weedy fields. Most hybrids are resistant enough that no further management is required. If flea beetle numbers are extremely high, and insecticide applications can reduce the beetle population and the disease spread. This will occur only after a very mild winter. In seed production with susceptible inbred lines, an insecticide may be justified more often.

Stalk Rots:
Stalk rots are a consistent problem in corn production, causing yield losses through premature plant death and/or lodging. When plants die prematurely, the result is poor yields and low test weight grain. If a plant with severe stalk rot survives to maturity, yield may not be greatly affected. However, rotted stalks will easily lodge, making harvest impossible. Stalk rots are caused by several different fungi that infect plants through the roots or through wounds in the stalk. The major stalk rot pathogens are *Gibberella zeae*, *Fusarium* species, and *Colletotrichum graminicola* (anthracnose). The occurrence of stalk rots is strongly affected by stresses on the corn plant during the grain filling stage of development. Any conditions that reduce photosynthesis and the production of sugars can predispose the plant to severe stalk rot. Such stresses include severe leaf diseases or hail damage, drought or soil saturation, lack of sunlight, extended cool weather, low potassium in relation to nitrogen, and insect damage. Insects such as the European corn borer cause stress to the plant as well as providing wounds for entrance of the stalk rot fungi. Many stalk rot infections can be traced back to stalk boring insect wounds. Early maturing hybrids sometimes suffer more stalk rot damage than full-season hybrids.

In general, losses to stalk rots can be reduced by scouting fields 40 to 60 days after pollination and looking for symptoms or pinching stalks. If more than 10 to 15 percent of stalks are rotted, the field should be scheduled for the earliest possible harvest. Severe stalk rot can be avoided by reducing the stresses that predispose plaints. This means balanced fertilization, appropriate plant population and adapted hybrids, insect and weed control, avoidance of root and stalk injury, good drainage, proper irrigation (where applicable), and using hybrids that are resistant to foliar diseases. Resistance is available for some stalk rots, and some hybrids are tolerant of stalk rots (will not lodge even if rotted).

Ear and Kernel Rots:

Fusarium Rots:
Fusarium ear and kernel rot is the most common ear disease in the Midwest. It is caused by several fungi in the genus *Fusarium*, but *F. moniliforme* is considered to be the primary species on corn in the Midwest. *Fusarium* ear rot occurs under a wide range of weather conditions. The fungus causes a stalk rot and can colonize any part of the corn plant, overwintering in the corn residue and on dead grassy weeds. *F. moniliforme* also is commonly found in corn seed. *Fusarium* spores are spread by wind and splashing rain to the silks, which are most susceptible for the first 5 days after they appear. Infections also occur through wounds made by insects or other types of wounds in the kernels. There is some evidence that insects act as vectors of *Fusarium*. *Fusarium. moniliforme* can grow throughout the corn plant, and some ear infections may be the result of the fungus entering the ear through the shank. Several of the *Fusarium* species causing corn ear rot can produce harmful mycotoxins, so caution should be used in feeding molded corn. *Fusarium* species usually do their damage in the field, but they can be a problem in storage if grain moisture is 18 percent or above.

Gibberella ear rot:
This ear rot is common throughout the Midwest. It is caused by the fungus *Gibberella zeae* which is the sexual reproductive stage of *Fusarium graminearum*. This fungus also causes a stalk rot, and overwinters in corn residue. The spores are spread by splashing rain and wind infecting ears through the silks. Silks are most susceptible 2 to 6 days after emergence. The disease is favored by cool, wet weather after silking. This is the most consistently important mycotoxigenic fungus in the northern corn belt, producing vomitoxin, zearalenone, and other toxins. *Fusarium* species usually do their damage in the field, but they can be a problem in storage if grain moisture is 18 percent or above.

Diplodia ear rot:
Diplodia ear rot is caused by the fungus *Diplodia maydis* (Stenocarpella maydis), which also causes Diplodia stalk rot. This disease is not typically as common as Fusarium or Gibberella ear rots, but it can be destructive when it occurs. The fungus overwinters as mycelium, spores, and pycnidia on corn residue or seed. The spores are spread primarily by splashing rain. The infection process for this disease is poorly understood, but infections first appear at the base of the ear. Corn borer damage in the shank can provide an entry wound for the pathogen. Diplodia is rot is favored by cool, wet weather during grain fill. Rainfall during August, September, and October is correlated with Diplodia ear rot incidence. D. maydis is not known to produce harmful mycotoxins. Diplodia maydis usually does its damage in the field, but it can be a problem m storage if grain moisture is 20 percent or above.

Control of ear and kernel rots:
Control of the various ear and kernels rots can be achieved by similar practices. Prevention of their occurrence is difficult because of their dependence on weather and the limited affects of cultural practices. Control of these diseases places an emphasis on harvest and grain handling.

Plant more resistant hybrids. Resistance to the ear rots varies among hybrids, although complete resistance is not available. Hybrids with tight husk coverage and ears that do not remain erect after maturity tend to suffer less damage. Crop rotation can reduce the occurrence of some ear rots, such as Diplodia. Others may not be affected much because of the movement of spores from neighboring fields. Insect control may reduce ear rots to some extent. Scout fields as the corn begins to dent and identify areas with mold problems. Harvest these areas as soon as possible to prevent further mold development. Properly adjusted combines will reduce kernel damage. Damaged kernels are more susceptible to mold development. Combine adjustments also can be used to help discard light weight, moldy kernels during combining. Cleaning grain before drying will remove fine particles which are often the moldiest and most toxic component of grain. Moldy grain should be dried immediately and rapidly to 15 percent or less (13-14 percent for long-term storage). Holding this grain for even a short time can result in substantial mold and toxin development. Grain that does not have obvious mold problems also should be dried immediately. There may be more economical options to rapid, high-temperature drying including: cooling the grain after drying, cleaning bins prior to storing new grain, aerating and stirring stored grain; periodically checking for condensation and mold growth and controlling stored-product insects. Antifungal agents such as propionic acid can retard mold growth in storage, but they do not kill fungi already present or destroy toxins that are already formed. These compounds have some disadvantages in Test molded grain for mycotoxins prior to feeding.

Fungicide information:

Mancozeb:

Trade name and formulation: Dithane (M-45, DF, F-45 formulations), Penncozeb 75DF and 80WP,
Use rates: 1.13 lb a.i./A
Application timing: start applications at onset of symptoms and, depending on severity, continue on a 4 to 14 day schedule.
Pre-harvest interval: 40 days
REI: 24 hours
Component of other products: Ridomil Gold MZ, Ridomil MZ
Primary use: helminthosporium leaf blights, common rust

Propiconazole:

Trade name and formulation: Tilt
Use rates: 0.05-0.1 lb a.i./A
Application timing: apply at onset of symptoms and continue on a 7 to 14 day schedule.
Pre-harvest interval: 30 days. Do not apply after corn silking stage.
REI: 24 hour
Component of other products: none
Primary use: helminthosporium leaf blights, gray leaf spot, common rust

Captan:

Trade name and formulation: various
Use rates: 0.62-1.18 oz/100 lbs. seed
Application timing: seed treatment
REI:

Primary use: seed treatment for seed rots and seedling blights

Carboxin:

Trade name and formulation: Vitavax 34
Use rates: 0.8-0.16 oz a.i./100 lbs seed
Application timing: seed treatment
REI:
Primary use: seed treatment for seedling diseases and seedborne head smut

Chlorothalonil:

Trade name and formulation: Bravo 500, Bravo 720
Use rates: 2.25-3 lb a.i./A
Application timing: postemergence at onset of symtpoms at 4-7 day intervals.
Pre-harvest interval: 14 days
Application timing: seed treatment
REI: 24 hours
Primary use: rust, helminthosporium leaf blights

Fludioxonil:

Trade name and formulation: Maxim 4FS
Use rates: 0.04 oz a.i./100 lbs seed
Application timing: seed treatment
REI:
Primary use: seed treatment for seed rots and seedling blights

Mefonoxam:

Trade name and formulation: Apron XL
Use rates: 0.016-0.032 oz a.i./100 lbs
Application timing: seed treatment
REI:
Primary use: seed treatment for pythium
Component of other products: Maxim XL

Metalaxyl:

Trade name and formulation: Apron 50W, Ridomil
Use rates: 0.032-0.5 oz a.i./100 lbs seed
Application timing: seed treatment
REI: 12 hours
Primary use: seed treatment for seed rots and seedling blights

Thiram:

Trade name and formulation: 42-S Thiram
Use rates: 0.75 oz a.i./bu
Application timing: seed treatment
REI:--
Primary use: seed treatment

Nematodes

Every cornfield in Minnesota contains nematodes actively feed on plants. Nematodes that attack corn are microscopic roundworms, approximately 3/10-3/64 inch long. The presence of nematodes depends on the soil type and its properties, other soil microorganisms, cropping history, climatic factors such as temperature and rainfall, tillage practices, and the use of pesticides.

There are many species of nematodes that feed on corn in Minnesota. Dagger and spiral nematodes may be the most common and widespread nematodes that feed on corn in Minnesota. Needle nematode probably is the most damaging, but is not widespread throughout the state. The most important species that is a parasite on corn in Minnesota probably is the lesion nematode.

In general, damage to corn from plant-parasitic nematodes results in poor or uneven stands if high nematode densities occur early in the season. Symptoms also include yellowing or chlorosis of foliage, unevenness in the height of the corn plants, and small or poorly filled ears during mid- to late-season. The symptoms and damage caused by plant-parasitic nematodes can occur in distinct patches or "hot-spots" that often elongate in corn fields in the direction of tillage operations. Damaged corn roots will be stunted, discolored, swollen, and lacking fine roots, and may contain dark brown or black lesions. However, other factors also can cause these types of above-ground and below-ground symptoms, so nematode damage easily can be misdiagnosed. Nematode damage to corn roots may look similar to herbicide damage.

Corn nematodes can feed without causing appreciable yield loss if nematode numbers are low and/or the environmental conditions are such that the corn crop is not stressed. Much is still unknown about the nematode population densities needed to cause damage to the many corn hybrids grown throughout Minnesota, and about the environmental and host factors involved in the build-up of nematode densities.

Management options for control of nematodes on corn are limited. Many effective nematicides have been removed from the market and very few new nematicides are being developed, but a few compounds (including some soil insecticides) are still labeled for control of plant-parasitic nematodes on field corn. Cultural control strategies such as crop rotation, delayed planting, and alternative tillage have little effect on corn nematode densities and nematode-resistant corn hybrids are lacking.

Weeds

CORN: Frequency and Extent of Chemical Usage by Active Ingredient, Minnesota, 1999 1/

Active Ingredient	Area Applied 1/	Applications	Rate per Application	Rate per Year	Total Applied
	Percent	Number	Pounds	Pounds	1,000 Pounds
HERBICIDES:					
2,4-D	11	1.4	0.43	0.61	481
Acetochlor	32	1.0	1.61	1.61	3,614
Alachlor	2	1.0	1.71	1.71	265
Atrazine	24	1.0	0.61	0.61	1,017
Bromoxynil	6	1.0	0.24	0.24	103
Clopyralid	28	1.0	0.08	0.08	163
Dicamba	27	1.0	0.27	0.27	520
Dimethenamid	18	1.0	1.35	1.35	1,706
Glyphosate	7	1.0	0.70	0.70	337
Metolachlor	10	1.0	2.31	2.31	1,564
INSECTICIDES:					
Tefluthrin	7	1.0	0.11	0.11	50

1/ Planted areas in 1999 for Minnesota were 7.10 million acres.

Table 4. Herbicide use on Minnesota corn, 1999 (1,3).

Annual weed species comprise a majority of the weed control problems in Minnesota corn production. Many of the primary weed species are introduced rather than native. The most troublesome weeds are those adapted to the two-crop rotation system primarily used in Minnesota. Weeds that are able to germinate in the spring following primary tillage, compete with the crop, and produce seed before frost or harvest are the most common. However, as the amount of tillage in Minnesota row-crop production decreases, there has been an increase in the frequency of perennial and biennial weed problems.

Weeds reduce corn yield primarily by competing for water, sunlight and nutrients, thus diminishing total corn yield potential. Heavy weed infestations can also affect harvest efficiency by increasing grain moisture content at harvest and increasing foreign material levels in harvested grain, both resulting in added cost to the producer.

Annual grasses:
Annual grasses infest virtually all corn acres in Minnesota. Many of these are controlled with pre-emergence herbicide applications and tillage. While not as competitive as broadleaf weed species, annual grasses can reduce crop yields when significant populations are present. In most weed management programs, control of grasses is of secondary concern to control of broadleaf weed species. Of the many species present, three of the most prevalent are discussed below.

Foxtails:
There are three important foxtail species in Minnesota: giant foxtail, *Setaria faberi*, yellow foxtail, *Setaria*

glauca, and green foxtail, *Setaria viridis*. At least one of these species infests nearly 100 percent of the corn acres in Minnesota. Low population densities do not result in adverse crop competition, however, due to the volume of seed production, unchecked foxtail populations can quickly become a severe problem. None of these species is native to Minnesota.

A primary control method for foxtail species is the application of pre-emergence grass herbicides. These provide early season control, reducing early season competition with the corn.

Yellow foxtail, *Setaria glauca*, is the most challenging foxtail species to control. It germinates later in the spring and has shown a higher tolerance to ALS herbicides. All three species of foxtail have developed ALS herbicide resistant biotypes in Minnesota.

Woolly cupgrass:
Woolly cupgrass, *Eriochloa villosa* [Thunb.] Kunth, is a relatively new and potentially serious weed problem in Minnesota. Woolly cupgrass populations have increased rapidly in the last decade and the distribution has spread widely.

This annual grass weed demonstrates biological, biochemical, and morphological characteristics that make it economically damaging and adds to the difficulty in developing effective management strategies. Woolly cupgrass is a prolific seed producer. This seed tends to germinate earlier and at higher populations than other annual grass weeds. Woolly cupgrass has demonstrated tolerance to most herbicides commonly used for control of annual grasses in corn. In addition, woolly cupgrass serves as an egg laying site for hopvine borer, a lepidopteran pest in corn.

Wild proso millet, *Panicum miliaceum*, is a serious annual grass problem in Minnesota. The problem seems to be more severe in areas where canary crops are grown, especially sweetcorn. Wild proso millet is a prolific seed producer Wild proso millet typically germinates later than most grass species. Wild proso millet is not easily control with preemergence corn herbicides.

Other annual grasses of economic importance in corn include: barnyardgrass, *Echinochloa crusgalli*; fall panicum, *Panicum dichotomiflorum*; and wild proso millet, *Panicum miliaceum*.

Perennial grasses:
Perennial grasses were once a severe problem in Minnesota corn production prior to herbicides and when pasture was a standard part of the crop rotation. With the introduction of effective herbicides and decline in pasture rotations, many perennial grasses have declined in importance.

Quackgrass:
Quackgrass, *Agropyron repens*, is a perennial grass that spreads by rhizomes. These rhizomes are effectively spread by tillage, increasing the scope of the population in a field. While quackgrass can be found in nearly every county in Minnesota, it is more common in small grains and lawn areas than in corn production. Tillage is an effective control by depleting food reserves and bringing rhizomes to the surface. Atrazine is also provides excellent control.

Wirestem muhly:
Wirestem muhly, *Muhlenbergia frondosa*, is a perennial grass that reproduces by seeds and underground rhizomes. It is native to Minnesota. It was not considered a common row crop weed until the 1950's when serious infestations developed in cultivated fields. Wirestem muhly is most common as a weed of cultivated fields in northeast and east central Minnesota. Delayed seedbed preparation will help control wirestem muhly in corn by bringing rhizomes to the soil surface to dry out.

Annual broadleaves:
Annual broadleaf weed species are the main weed management target in Minnesota corn production. Velvetleaf, *Abutilon theophrasti*; lambsquarter, *Chenopodium album*; common cocklebur, *Xanthium strumarium*, and giant ragweed, *Ambrosia trifida*, are some of the most common broadleaf weeds found in Minnesota. These weeds can provide significant crop yield reduction because of their aggressive growth habit, canopy structure, and competitiveness.

Waterhemp:
Common waterhemp is a relatively new weed problem in Minnesota. However, common waterhemp is a native species that has been identified by botanists in the historic taxonomic records. Currently, common waterhemp is a serious weed problem throughout Minnesota. There have been changes in agricultural practices that have favored this weed. These changes include reductions in tillage, herbicide selection, simplified crop rotations, and recent weather patterns that have resulted in the relatively rapid rise in importance of common waterhemp to Minnesota agriculture. Because waterhemp is a relatively new weed problem, there has been little research conducted. Most of the research has focused on the relationship of this weed complex with herbicides. Specifically, there have been many studies documenting difficulties in controlling common waterhemp with herbicides that inhibit acetolactate synthase (ALS) activity.

There are many factors that have contributed to the increase in common waterhemp populations in Minnesota. Studies have shown the common waterhemp emerges late in the growing season when compared to other annual broadleaves such as velvetleaf (Abutilon theophrasti). Over the past few years, a common pattern of waterhemp emergence has been emergence approximately two weeks after velvetleaf and continuing for two months. Velvetleaf demonstrated a relatively short germination period of three weeks. In many weeds, late emergence is not a major management issue because the crop canopy effectively competes with the weed. However, common waterhemp is able to emergence late and grow through the crop canopy. The survival of emerged waterhemp is highly dependent on environmental conditions. Abundant rainfall during the growing season will promote high waterhemp populations.

Other biological characteristics that contribute to the rapid increase in common waterhemp populations are high seed production and an ability to germinate from shallow soil depths. Small-seeded annual weeds like common waterhemp must be near the soil surface to successfully germinate and emerge. Reduced and no tillage systems which have increased in the Midwest favor the establishment and success of common waterhemp populations.

Control of common waterhemp has become increasingly difficult to manage due to resistance to ALS-inhibiting herbicides. Waterhemp has demonstrated cross-resistance to all herbicides with this mode of action.

Other broadleaf weeds of economic significance in Minnesota corn production:

redroot pigweed (Amaranthus retroflexus)

lambsquarter (Chenopodium album)

Pennsylvania smartweed (Polygonum pensylvanicum)

common ragweed (Ambrosia artemisiifolia) and giant ragweed (Ambrosia trifida)

Perennial broadleaves:
The occurrence of perennial broadleaf weeds is highly dependent on the tillage regime used in corn production. Since most perennial broadleaf weeds do not tolerate tillage, the following weeds are more of a problem in reduced tillage and no-till operations: Canada thistle, *Cirsium arvense*; hemp dogbane, *Apocynum cannabinum*; common milkweed, *Asclepias syriaca*; swamp smartweed, *Polygonum coccineum*; and smooth groundcherry, *Physalis subglabrata*.

Herbicides continue to be the primary strategy used for corn weed management in Minnesota. Ninety-nine percent of Minnesota corn acres were treated with at least one herbicide in 1995. Atrazine continues to be the most widely used herbicide on corn. The percentage acres treated with atrazine increased even with new restrictions placed on its use in 1993. In 1995, 67% of the acres were treated with atrazine, compared to 61% in 1990 and 49% in 1985. The continued growth in atrazine use is largely due to its popularity as a tank-mix partner with other postemergence products. This practice allows atrazine to be used at rates <1 lb./ac, thereby reducing the risk of carryover that has limited atrazine use in many areas of Minnesota.

There has been a large change in herbicides used for controlling grasses in corn. Alachlor (Lasso) was used on 22% of the corn acres in 1990 but dropped to 2% in 1995. The two thiocarbamate herbicides, EPTC (Eradicane) and butylate (Sutan+) decreased from use on 14% of the acres in 1990 to 4% in 1995. In 1979 these three herbicides were used on over 70% of the corn acres. Acetochlor, introduced in 1993, was used on 26% of the acres in 1995.

Postemergence herbicides have increased in importance. In 1979, approximately 30% of the corn acres were treated postemergence for weed control. It is estimated that over 70% of the corn acres were treated after crop and weed emergence in 1995. The leading postemergence products include dicamba (36%), bromoxynil (15%), and nicosulfuron (14%). A significant percentage of these products would have been applied in combination with atrazine.

Nearly four times as much herbicide was applied to corn as that applied to soybeans. The primary reason for this is differences in specific activity of the major herbicides used in the two crops. For example, metolachlor and trifluralin are the leading herbicides for grass control used in corn and soybeans, respectively. A typical use rate for metolachlor in Minnesota is 2.5 lb per acre, whereas a typical rate of trifluralin would be 0.8 lb./ac. Although there was little change in the percentage of corn and soybean acres treated with herbicides, the total amount of product applied in the state continues to decline. This is largely due to the increasing popularity of new herbicides that are used at very low rates (< 0.1 lb./ac) rather than changes in weed management systems that allow reductions in herbicide use.

The following is a review of the primary herbicide active ingredients currently used in Minnesota corn production. Herbicides are grouped according to primary mode of action. Many times herbicides within a mode of action will control a similar spectrum of weeds and have similar use properties. Products that are package mixes are listed under the primary active ingredient with other ingredients noted. Information on acreage treated, if available, is from the 1995 Survey of Pesticide Use in Minnesota. For products or active ingredients introduced since the 1995 survey, no use data is provided. The following classes of herbicides are grouped together: ALS-inhibitors and amino acid derivatives PSII inhibitors (non-mobile), shoot inhibitors, root inhibitors, growth regulators, pigment synthesis inhibitors, and unclassified.

ALS-inhibitors and amino acid derivatives

Flumetsulam:

Trade name and formulation: Python 80WDG
Use rates: 0.6-1.1 oz a.i./A
Application timing: can be applied preplant incorporated, preemerge or postemerge. Python can be applied from 30 days prior to planting until corn spike stage. Hornet can be applied from 30 days prior to planting until corn is 20 inches high. Scorpion III can be applied postemerge prior to the V4 growth stage or 8 inches.
Pre-harvest interval: 85 days
REI: 12 hours (Python)
Component of other products: Broadstrike+Dual, Hornet, Scorpion III, Accent Gold
Comments: Primary activity is on broadleaf species. Shows good to excellent control of pigweed species (non-resistant), velvetleaf and smartweed.

Halosulfuron:

Trade name and formulation: Permit 75WDG
Use rates: 0.03-0.06 lb a.i./A
Application timing: postemergence from spike stage to layby
Pre-harvest interval: following application to foliage allow 30 days before grazing domestic livestock, harvesting forage or harvesting silage
REI: 12 hours
Component of other products: none

Imazapyr:

Trade name and formulation: Lightning 70DF
Use rates: 1.28 oz product/A

Application timing:postemergence - apply before weeds are 4 inches in height and before corn is 12 inches tall
Pre-harvest interval: do not harvest or graze treated corn or fodder for at least 45 days after application. Do not harvest for grain for 45 days after application.
REI: 12 hours
Component of other products: none

Imazethapyr:

Trade name and formulation: Pursuit 2AS, Pursuit 70DG
Use rates: 0.0625lb a.i./A
Application timing: postemergence - apply to weeds less than 3 inches in height or before corn exceeds the 8-leaf stage
Pre-harvest interval: apply prior to 45 of harvest
REI: 4 hours
Component of other products: Lightning 70DF

Nicosulfuron:

Trade name and formulation: Accent 75DF
Use rates: 0.5 oz a.i./A
Application timing: Broadcast over top of corn up to 20 inches tall or 6 visible leaf collars. Applications on corn 20 - 36 inches tall are allowed with drop-nozzles.
Pre-harvest interval: 30 day restriction on grazing or feeding harvested grain or silage following application
REI: 4 hours
Component of other products: Accent Gold, Basis Gold, Celebrity, Celebrity Plus, Steadfast
Comments: Nicosulfuron is the primary postemergence of grass control in corn. Selected broadleaf weeds such as pigweed spp., morningglory, and smartweed, are also controlled at the 1-4 inch stage.

Primisulfuron:

Trade name and formulation: Beacon 75DF
Use rates: 0.29-0.57 oz a.i./A
Application timing: over top on corn 4 - 20 inches tall. From 20 inches to pretassel apply with drop nozzles.
Pre-harvest interval: Do not graze or feed forage to livestock within 30 days. Do not harvest silage within 45 days. Do not harvest grain within 60 days.
REI: 12 hours
Component of other products: Exceed 57WG, NorthStar, Spirit 57WG
Comments: Provides good to excellent control of numerous broadleaves including pigweed, Jimsonweed, sunflower, velvetleaf, cocklebur and smartweed.

Rimsulfuron:

Trade name and formulation: no products containing rimsulfuron as only active ingredient
Percent crop treated: no current data
Use rates:
Application timing:
Pre-harvest interval:
REI:
Component of other products: Accent Gold, Basis Gold, Steadfast

PSII inhibitors (non-mobile)

Bentazon:

Trade name and formulation: Basagran 4S
Use rates: 0.75-1.0 lb a.i./A
Application timing: Postemerge when weeds are small and actively growing. Generally corresponds to 1 - 5 leaf corn.
Pre-harvest interval: 12 days
REI: 48 hours
Component of other products: Laddok 5L, Headline B&G

Bromoxynil:

Trade name and formulation: Buctril 2EC, Buctril 4EC, Moxy 2E
Use rates: 0.25-0.38 lb a.i./A
Application timing: postemergence from 3 leaf until prior to tassel emergence
Pre-harvest interval: 45 days
REI: 12 hours
Component of other products: Buctril+Atrazine

Carfentrazone:

Trade name and formulation: Aim 40WDG
Use rates: 0.008 lb ai/A
Application timing postemergence up to 8 collar
Pre-harvest interval: None
REI: 12 hours
Componet of other products: None

PSII inhibitors (mobile)

Atrazine:

Trade name and formulation: many formulations - commonly found in 4L and 90DF formulations

Use rates: 1-2 lb a.i./A
Application timing:
pre-plant - up to 30 days prior to planting.
preplant incorporated - apply within 2 weeks prior to planting.
preemergence - apply during or shortly after planting and before weeds emerge.
apply before broadleaf weeds exceed 4 inches in height, grasses exceed 1.5 inches and corn exceeds 12 inches in height.
Pre-harvest interval: do not graze treated area or feed treated forage to livestock for 21 days following application.
REI: 12 hours
Component of other products: Contour 3.38SC, Extrazine II, Basis Gold 89.5DF, Bicep II 5.8L, Bicep II Magnum 5.5L, Bicep Lite II 4.9L, Bicep Lite II Magnum 6.0L, Buctril+Atrazine, Bullet 4ME, Extrazine II 4L, FieldMaster, FulTime 4CS, Guardsman 5L, Harness Xtra, Laddok S-12, Lariat 4L, Marksman 3.2L, Shotgun 3.25L, Surpass 100SL

Cyanazine:

Trade name and formulation: Bladex 4L, Bladex 90DF
Use rates: 1 lb a.i./A (maximum rate due to phase-out restrictions, not labeled for use after 2002)
Application timing:
early preplant - up to 15 days prior to planting
preplant incorporated or preemergence
postemergence - 90DF may be applied from crop emergence through the 4-leaf stage of corn but before weeds exceed 1 to 1.5 inches in height.
Pre-harvest interval: none listed
REI: 12 hours
Component of other products: Extrazine II 4L, CyPro AT 4L
Comments: DuPont plans a complete phase-out of cyanazine by 2002.

Metribuzin:

Trade name and formulation: Sencor 75DF
Use rates: 0.05-0.14 lb a.i./A
Application timing: postemergence
Pre-harvest interval: may be grazed or harvested for grain 60 days after application
REI: 12 hours
Component of other products: Axiom 68DF

Root inhibitors

Pendimethalin:

Trade name and formulation: Prowl 3.3EC, Pentagon 60DG, Pendimax 3.3EC
Use rates: 0.74-1.98 lb a.i./A

Application timing: preemergence (do not incorporate), postemergence, Culti-spray (applied after corn is 4 inches in height and incorporated with cultivator.)
Pre-harvest interval: none. Livestock can graze or be fed forage from treated corn after 21 days following application.
REI: 12 hours
Component of other products: Pursuit Plus EC

Shoot inhibitors

Acetochlor:

Trade name and formulation: Harness 7EC, Surpass 6.4EC, others
Use rates: 1-3 lb a.i./A
Application timing: early preplant (up to 30 days prior to planting), preemerge, or early postemerge before corn reaches 11 inches in height.
Pre-harvest interval: no restriction
REI: 12 hours
Component of other products: DoublePlay 7EC, FieldMaster, FulTime 4CS, Harness Xtra, Surpass 100

Alachlor:

Trade name and formulation: Lasso 4EC, Lasso II, Partner WDG, CropStar 20G
Use rates: 2.5-4.0
Application timing:
Pre-harvest interval:
REI:
Component of other products: Freedom, Bronco, Bullet, Lariat

Dimethenamid:

Trade name and formulation: Frontier 6EC
Use rates: 0.75-1.5 lb a.i./A
Application timing: early preplant (30 days prior to planting), premergence, or postemergence (up to 8 inches tall)
Pre-harvest interval: 40 days
REI: 12 hours
Component of other products: Guardsman

EPTC:

Trade name and formulation: Eradicane 6.7EC
Use rates: 4-6 lb a.i./A
Application timing: preplant incorporated

Pre-harvest interval: no restrictions
REI: 12 hours
Component of other products: DoublePlay

Flufenacet:

Trade name and formulation: Define 60DF
Use rates: 0.45-0.79 lb a.i./A
Application timing: early preplant, preplant incorporated, preemerge, early postemerge (prior to corn emergence)
Pre-harvest interval: none
REI: 12 hours
Component of other products: Axiom,

Metolachlor:

Trade name and formulation: Dual II 7.8EC, Dual II Magnum 7.64EC
Percent crop treated: 35.7%
Use rates: 1.5-3.75 lb a.i./A
Application timing: Fall application, early preplant (up to 30 days prior to planting), preemergence, or postemergence (corn not more than 12 inches tall)
Pre-harvest interval: 30 days
REI: 24 hours
Component of other products: Bicep (various formulations)

Growth regulators

2,4-D:

Trade name and formulation: various formulations of 2,4-D amine and 2,4-D ester
Use rates: 0.25-0.5 lb a.i./A (amine), 0.15-0.33 lb a.i./A (ester)
Application timing: postemerge when weeds are small and corn is less than 8 inches. For corn over 8 inches drop nozzles should be used. Preharvest applications may be made of 2,4-D ester following the denting stage.
Pre-harvest interval: 7 days
REI: 48 hours
Component of other products: Shotgun 3.25L, various others

Clopyralid:

Trade name and formulation: Stinger 3EC
Use rates: 0.1-0.25 lb a.i./A
Application timing: postemergence from corn emergence to 24 inches of corn height
Pre-harvest interval: Do not allow livestock to graze or harvest treated corn silage as feed within 40

days after last treatment
REI: 12 hours
Component of other products: Accent Gold, Hornet 85.6WG, Scorpion III 84.3WG

Dicamba:

Trade name and formulation: Banvel 4SC, Clarity 4SC
Use rates: 0.25-0.5 lb a.i./A
Application timing: postemergence from emergence to 36 inch tall corn or 15 days prior to tassel emergence, whichever occurs first
Pre-harvest interval: do not harvest or graze prior to milk stage
REI: 24 hours (Banvel), 12 hours (Clarity)
Component of other products: Celebrity, Celebrity Plus, Distinct, Marksman 3.2L, Resolve 75SG

Diflufenzopyr:

Trade name and formulation: Distinct 70 WDG
Use rates: 0.18-0.26 lb ai/A
Application timing: postemergence from 4 to 24 inch tall corn, dependent on rate.
Pre-harvest interval: Do not apply within 32 days of corn forage harvest. Do not apply within 72 days of corn grain, and stover harvest.
REI: 12 hours
Componet of other products: Celebrity Plus, Distinct
Unclassified

Glufosinate:

Trade name and formulation: Liberty 1.67S
Use rates: 0.209-0.119 lb a.i./A
Application timing: apply postemergence by broadcast or directed drop-nozzles from corn emergence until 24 inches or V7, whichever occurs first. Use only drop nozzles to apply when corn is 24 to 36 inches.
Pre-harvest interval: Do not apply within 60 days of harvesting corn forage or 70 days of harvesting grain and/or corn fodder.
REI: 12 hours
Component of other products:

Glyphosate:

Trade name and formulation: Glyphomax 4SL, Glyphomax Plus 4SL, Roundup, Roundup Ultra 4SL, Roundup UltraMax, Touchdown 5S
Use rates: 0.75-1.0 lb a.i./A
Application timing: emergence to 30 inches or V8 growth stage. For applications after 24 inches use drop nozzles.

Pre-harvest interval: 50 days
REI: 4 hours
Component of other products: FieldMaster

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