Crop Profile for Corn in Michigan

Prepared Feb, 2002

General Production Information

- Michigan ranked 11th nationally in 2000 for corn grain production (44).
- Michigan contributed 2.4% to the total US production of corn in 2000 (44).
- The total acreage planted in Michigan was 2,200,000 acres in 2000, down 100,000 acres from 1998 (44).
- Total grain corn production for Michigan in 2000 was 244,280,000 bushels, down 4% from 1999 (44).
- Grain corn harvested in 2000 for Michigan was 1,97,000 acres (44).
- Silage corn harvested in 2000 for Michigan was 225,000 acres with an average yield of 14 tons per acre (44).
- Corn grain production was valued at $612 million in 1997, $432.3 million in 1998, $451 million in 1999 and 464 million in 2000 (44).
- The average bushels/acre was 117 in 1997, 111 in 1998, 130 bushels in 1999, and 124 bushels in 2000 (43, 44).
- Corn continued to be Michigan's number one crop in value of production (44).

PRODUCTION REGIONS:
Corn is Michigan's number one crop in both acreage planted and value of production. The top five counties in corn production in 2000 were Huron, St Joseph, Lenawee, Sanilac and Saginaw. In 1998 they were Huron, Sanilac, Clinton, Ionia and Allegan counties and in 1999 Huron, Saginaw, Sanilac, Tuscola and Lenawee counties (43, 44).

The Crop Profile/PMSP database, including this document, is supported by USDA NIFA.

Cultural Practices

Corn can be grown on most soils in Michigan but does best on well drained soils. Soils classified as poorly drained are also suitable for corn production if they are tile drained. The soil pH should be maintained in the 6.2 to 6.5 range. Most corn requires supplemental nitrogen, either through biological amendments such as manure, or from synthetic fertilizers. The nitrogen application is based on yield goal. A projected yield of 120 bushels of corn grain per acre could require 140 pounds of nitrogen per acre. Nitrogen application should be timed to match the need of the growing corn. Typically, some nitrogen is applied at planting time (~20%), with the remainder (~80%) side-dressed when the corn is about a foot in height. Seed selection is critical. A variety should be selected that has the proper maturity for the area and is well adapted to the soils and environmental conditions on a farm. Corn is generally planted in late April or early May when soil temperature reaches 50 degrees. Planting depth is set to approximately 1 ¾" for good moisture conditions and adjusted downward to a maximum of 3" under dry conditions. Mechanical cultivation, herbicides, or a combination of both is usually used for weed control. Silage harvest begins when the corn reaches approximately 30% dry matter. This usually occurs when the milk line in the developing kernels advances 2/3 of the way down the kernel. In Michigan, silage is usually harvested from August 25 through October 20. Corn grain harvest occurs after the plant is physiologically mature and after a dry –down period in the field to allow the corn to reach a kernel moisture of around 25% or less. In Michigan, corn grain is usually harvested from October 1 to December 1. Average corn grain yields in Michigan are approximately 115 bushels per acre over the last five years (1996-2000) (44).

Insect Pests

Armyworm, *Pseudaletia unipuncta*

Armyworm may be a difficult pest to control if undetected in corn especially when field corn is planted late or late maturing hybrids are planted. However, armyworm is rarely a problem in Michigan. Armyworm causes leaf feeding damage as well as direct injury to the ear. All stages of armyworm can damage corn, but the larvae do most of the damage when the corn has not yet silked (10).

Biology: Armyworms migrate to Michigan in the spring and produce 2-3 generations per year. The larvae (caterpillars) vary in color from black to brown to a greenish color. They have a narrow light stripe across their back and broad stripes running down the sides of the their body (1).

Armyworms overwinter in the south as partially grown larvae in grasses or small grain fields. They arrive in Michigan from April to June, where they immediately begin to feed on the crops. When feeding is completed, larvae pupate just below the surface of the soil. Adults of the first generation emerge in April and May and feed on nectar for 7 to 10 days before beginning to lay eggs (2).

General Control Information: Control can only be effective when larvae are small, therefore early detection and proper timing of insecticide application are critical (10).

Cultural Controls: Growers should try to plant as early as possible to minimize the impact of crop injury when armyworms arrive from the South (9). Other cultural controls include good weed management and reduction of grassy borders.

Biological Controls: There are many natural parasitic enemies that regularly keep armyworm population numbers down. Biocontrol is a very common way of controlling armyworm populations in normal years, however in an outbreak, biocontrol may not give economic control needed (9).

Chemical Controls: Esfenvalerate, carbaryl, methomyl, chlorpyrifos, methyl-parathion, permethrin, lamdba-cyhalothrin and Bacillus thuringiensis (1).

Alternative Controls: No information available.

Black Cutworm, *Agrotis ipsilon*

Biology: The larvae (caterpillar) can be up to 2 inches in length. Their coloring is variable from black to tan and greenish-yellow, with a row of light yellow spots down their back. The adults migrate into Michigan in early spring and lay eggs on weeds or crop debris (1). Egg laying may coincide with the planting of the crop and is often associated with the availability of weeds in the field. Larvae of the cutworm have 7 instars of which the 5th through the 7th are most easily detected. The small larvae create shot holes in the leaves. Older larvae feed on the cut seedlings. Larvae feed at night and can tunnel into the lower stalk (1). The mature larvae pupate in the soil and a second and sometimes third generation occurs by fall (3).

General Control Information: "Rescue treatments" with an insecticide or poisoned bait application appears to be the most reliable method of control. This treatment should be implemented as soon as 50% or more of the crop shows damage. Insecticide treatments applied to dry soil can not be expected to provide effective control because of the subterranean habits of the larvae under dry conditions (11).

Cultural Controls: There are several methods of cultural control including good weed control and cultivation.

Biological Controls: Parasitoids attack older larvae, and ground beetle larvae and adults prey on larvae (1).

Chemical Controls: Permethrin, esfenvalerate, carbaryl, chlorpyrifos, methyl-parathion and lambda-cyhalothrin (1).

Alternative Controls: No information available.

<u>Corn Rootworms</u>

Corn rootworms are a key pest of corn in Michigan. Three species of corn rootworm occur in Michigan, including western, northern and southern. The western is the most common species but northern corn rootworms are locally abundant. Southern corn rootworm is not a pest of corn, but can occur in gardens and on vegetable crops (4).

Biology: Western and northern corn rootworms have similar life cycles. They complete one generation per year and have four stages: egg, larva, pupa and adult. Rootworm eggs are laid in soil near corn plants in August and September and hatch during early to mid-June of the following year. Soil temperature is a predominant factor affecting the time of egg hatch and larval development. The larvae feed on corn roots for several weeks before pupating in the soil in mid-July. If feeding is severe enough it can cause goose-necking of the corn plant. The adults emerge from the soil during mid July or early August. Adults prefer to eat fresh corn silks, but will also feed on leaf tissue, tassels and pollen. After feeding and mating, and a period of egg development, females lay eggs in the soil in corn fields. Females may crawl down earthworm burrows or soil cracks and can lay eggs as deep as 12 inches or more (4).

General Control Information: Michigan corn growers use several methods to manage corn rootworm problems. Most growers rotate corn with other crops to break the life cycle of corn rootworm. Others grow corn following corn and use soil insecticides to manage rootworms regardless of pest densities. Many growers are now adopting scouting as a way to determine if rootworm pressure is great enough to justify use of soil insecticides (4).

Cultural Controls: Crop rotation is the most ecologically sound approach to manage rootworms since it eliminates the need for insecticides. Since rootworms lay most of their eggs in corn fields and larvae can move only a few feet on corn roots, rotation of corn with any other crop provides effective control. There have been some cases where northern corn rootworm eggs overwinter in the soil for two winters before hatching. In the states where northern corn rootworm is very abundant, this has resulted in damage on corn in a two-year rotation. Since the northern species is present in low numbers in most parts of Michigan, extended diapause of this species has not been an important factor (4).

There are not any commercially available corn hybrids that are resistant to corn rootworms. There are however hybrids that possess large root systems and good root regeneration capability, which are more tolerant to corn rootworm damage. A deep-rooted hybrid under good growing conditions may rapidly outgrow rootworm damage. The degree of root recovery varies according to the corn hybrid planted and environmental conditions. The effect is usually expressed by the development of a massive fibrous root system. Hybrids with long root systems are less prone to lodge as a result of root damage (4).

A good weed control program aids early plant growth largely by reducing competition for light, nutrients, and moisture. Good weed control may somewhat reduce attractiveness of corn fields to rootworm adults by providing less shade and protection and eliminating other sources of pollen. Any cultural practices that encourage rapid corn growth help reduce the effects of rootworm damage. Early planting allows silks to develop before peak rootworm beetle feeding. Scouting and monitoring are the most effective ways of managing corn rootworm (4).

Biological Controls: There are a few predaceous ground beetles and mites in the soil that feed on rootworm eggs, larvae and pupae. However, natural enemies of rootworms do not generally have a major impact on their numbers. A biological control method using nematodes that infect rootworm larvae is being investigated (4).

Chemical Controls for Corn Rootworms Adults: Esfenvalerate, carbaryl, bifenthrin, dimethoate, malathion, methomyl, chlorpyrifos, methyl-parathion and lambda-cyhalothrin (1).

Chemical Controls for Corn Rootworms Larvae: terbufos, tefluthrin, tebupirimiphos + cyfluthrin, chlorethoxyfos, chlorpyrifos, carbofuran, fipronil, phorate and ethoprop (1).

Alternative Controls: No information available.

European Corn Borer, *Ostrinia nubilalis*

European corn borer (ECB) is a major insect pest in Michigan and depending upon the year most fields could be infested with ECB.

Biology: The ECB is a major pest of corn and an occasional pest of potatoes, snap beans, and peppers. ECB overwinters as a mature larva, and adult moths begin to emerge in late May to early June, reaching a peak in mid-June. When the European corn borer attacks corn, egg masses are laid on the undersides of leaves and on stems. The larvae have five instars, feeding initially on leaves and then boring into stems after the second instar. Stem boring larvae from the first generation are the most damaging stage (5). There are one-generation and two-generation European corn borers in Michigan (13). The second generation may bore into the base of the ear and cause breakage and harvest loss.

General Control Information: The removal of corn stubble from the field to eliminate overwintering larvae is an old cultural recommendation for reduction of corn borer. However, given modern day practices of conservation tillage and the limited occurrence of significant corn borer infestations in the state, widespread removal of corn stubble is no longer considered a valid option. Furthermore, recent research has demonstrated that the corn borer may migrate a quarter to a half mile, thus a grower's effort to reduce corn borer by stubble removal may or may not be effective (14).

Sex pheromone baited traps are available for corn borer, but the existence of various corn borer strains complicates the use of such traps in a practical program. If a given strain of corn borer is known to occur in an area, the pheromone trap may be a useful tool to employ at the field level.

Cultural Controls: Clean plowing in the fall can kill a large percentage of over-wintering corn borers. However, it is now believed that the reduction in corn borers, achieved by plowing, is less important than the soil conservation that could be achieved by reduced tillage (15).

Good weed control minimizes the number of corn borers in a field. Moths normally rest and mate in grassy areas outside the cornfield, but if a field is very weedy they may spend more time in the field resulting in proportionately more egg laying (15).

Early harvesting can help reduce harvest yield loss due to corn borer. The longer a crop stands in the fall and the more wind it is exposed to, the greater the potential for lodging, especially where corn borer populations are high (15).

Resistant hybrids and early crop maturity help suppress ECB. Transgenic Bt hybrids effectively kill ECB; non-Bt corn 'refuge' areas are planted nearby to reduce the chance of resistance to Bt (1).

Biological Controls: Most ECB's are killed by natural factors, such as rain and drought. Predators, especially minute pirate bugs and lady beetle adults or larvae, eat corn borer eggs. Several parasites and pathogens attack corn borers in the fall and increase over-wintering mortality. Unfortunately, beneficial insects do not usually achieve economic control of corn borers (16).

It may also be possible to manage corn borers by releasing tiny wasps called *Trichogramma* into the field several times during the season. The *Trichogramma* are parasitoids of the corn borer eggs and prevent them from hatching. The wasps are harmless to humans. Of the several species of *Trichogramma* that are commercially available, *Trichogramma brassicae* and *T. evanescens* are most effective against corn borers (16)

Chemical Controls: Permethrin, lambda-cyhalothrin, bifenthrin, carbofuran, chlorpyrifos, Bt, terbufos, methyl parathion, esfenvalerate, and carbaryl (1).

Alternative Controls: No information available.

Seed Corn Maggots, *Delia platura*

The seedcorn maggot occurs throughout the United States and Canada. It is an insect pest of corn, beans, peas, cucumbers, melons, potatoes, and other vegetables. In corn specifically, damage is generally not serious, although in some areas where infestation is high, damage could be severe. Damage results in poor stands by direct feeding or by association with a disease. The most severe damage usually occurs to spring crops in high organic, cool, wet soils in which seed is planted too deep (17).

Biology: The winter is passed in the soil as a maggot inside a dark-brown capsule. Small grayish-brown flies emerge in March and April. Adult flies are most active during midday. They are inactive at night, during strong wind and rain and when temperatures are below 50 degrees F or above 80 degrees F. Adults are most abundant in freshly cultivated areas where eggs are laid near or on sources of larval food. Favorite places for laying eggs are near or on sprouting or decaying beans, and peas. They also lay their eggs in the soil, especially in newly plowed areas. Yellowish-white maggots emerge and burrow into the soil and develop on germinating seed. Full-grown larvae are about 1/4 inch long, sharply pointed at the head end, legless, with a tough outer covering. They change to the pupal stage inside a brown puparium in the soil. The entire life cycle may be completed in 3 weeks with many generations per year (17).

General Control Information: Because the weather and seed corn maggot populations are variable, precautions should be taken every year to minimize damage from this insect. If precautions are not taken damage may not be detected until seeds and seedlings are lost. By that time, effective control measures will need to be drastic, such as complete replanting of the crop (18).

Cultural Controls: To prevent seed corn damage the following steps should be taken:

1) plant after the ground is warm enough for rapid germination and growth, 2) plant in a well-prepared seedbed only deep enough for adequate soil moisture, 3) plow heavily manured or over-cropped land early the previous fall, so it will be less attractive to the egg laying flies the following spring, 4) delay planting until the first generation is pupating, and 5) reduce use of organic fertilizer in the seeded row whenever possible (18).

Biological Controls: No information available.

Chemical Controls: Seed & planter box treatments: lindane, diazinon + lindane, and tefluthrin. At plant treatments: chlorpyrifos, terbufos, tebupirimiphos + cyfluthrin, chlorethoxyfos, tefluthrin, fipronil, carbofuran and phorate(1).

Alternative Controls: No information available.

Slugs, *Agriolimax reticulatus*

Slugs occur occasionally on corn in Michigan. Economic damage is uncommon however (1).

Biology: Most field slugs pass through a single generation per year and generally overwinter in the egg stage. However, if the winter is mild, adults may survive the winter. Since field slugs may live 12 to 15 months and eggs are laid both in the early spring and fall, overlapping generations of adult and juvenile stages may be observed. In the winter, adult slugs may enter a state of hibernation, and in the dry and hot summer conditions they enter a similar inactive state of aestivation. Peak slug activity generally occurs in late spring and early summer when the spring hatch attains adult growth and again in the early fall when cooler temperatures resume (20).

Slugs are hermaphrodites (both male and female). As a result, when they copulate, there is a reciprocal exchange of spermatozoa. Self-fertilization is possible in some species such as the marsh slug but in general, pairs of slugs are needed to reproduce (20).

General Control Information: Planting into wheat stubble or other heavy crop residue or into a field with recent history of slug damage may favor damage. Cool, wet conditions also favor damage. At this time there are no developed thresholds although, treat if slug damage threatens to reduce stand density below an acceptable level (1).

Cultural Controls: Occasional use of reduced tillage decreases the development of slug problems in the fields that were maintained under long term no-tillage practices. Slug problems in minimum tillage systems such as ridge tillage are rare. Mechanical devices on planters that remove residue over the seed furrow may reduce slug damage to seeds and emerging seedlings. Reduction of slug populations, once they have become established, is difficult to achieve since the bait treatment only reduces the slug activity buying time to enable the crop to outgrow the problem (20).

Biological Controls: No information available.

Chemical Controls: Metaldehyde.

Alternative Controls: No information available.

White Grubs, *Phyllophaga spp.*

White grubs are the larvae of May (June) and Japanese beetles and European chafer. They are distributed throughout the United States and Canada. However the distribution of individual species is generally more localized (21). White grubs feed on corn roots, often stripping off the root hairs. Corn plants usually reach a height of 2-6 inches before true white grub injury becomes apparent. Severely injured plants turn light tan or yellow, wilt and die. Infestations of white grubs are generally patchy and often located in close proximity to trees, which is the major food source for adults (45).

Biology: Most June beetles have a three year life cycle causing most damage in the second year. In June, the adult beetles lay eggs in the soil. Within two weeks, white grubs emerge and begin feeding during the warm summer months. They then overwinter deep in the soil. Early the following summer, the grubs move close to the soil surface and begin feeding again. They can cause extensive damage in small numbers due to their voracious appetite. After a short feeding period during the third summer, the white grub pupates and turns into an adult. The adult (June beetle) overwinters in soil and lays eggs the following summer, thus completing its life cycle (7). Japanese beetle and chafer adults emerge in mid-summer and lay eggs in fields. Grubs feed until the ground freezes, reaching the largest stage in late fall. Grubs resume feeding in early spring and can do considerable damage to small plants. Chafer pupates in late May and Japanese beetle feed a little longer (1)

General Control Information: Although white grubs can be a problem every year, the most serious damage occurs in regular three-year cycles. The greatest damage to crops occurs the year after the appearance of the adults. During the years of heavy June Beetle infestation, deep-rooted legumes, such as alfalfa or clovers, should be planted (21).

Cultural Controls: Fields kept free of weed growth, particularly grass growth will reduce the number of eggs laid. The year following heavy flights of beetles, planting corn or potatoes should be avoided in fields that were previously under sod or grass (21).

Late spring or early autumn plowing destroys many larvae, pupae, and adults in the soil exposing insects to predators, such as birds and skunks. For this cultural practice to be effective, plowing must occur before the grubs migrate below the plow depth. No-tillage or reduced tillage crop management enhances grub populations (21).

Biological Controls: Natural enemies that control white grubs include parasitic wasps and flies in the genera *Tiphia* and *Myzinum* (Hymenoptera: Tiphiidae), and *Pelecinus polyturator* Drury (Hymenoptera: Pelecinidae), and the fly, *Pyrgota undata* (Diptera: Pyrgotidae). Also, *Cordyceps* fungus infects grubs (21).

Chemical Controls: Terbufos, tefluthrin, chlorethoxyfos, tebupirimiphos + cyfluthrin, chlorpyrifos and phorate (1).

Alternative Controls: No information available.

Wireworms

Biology: Wireworms are slender, shiny brown caterpillars with a wiry segmented body. They are generally up to

1.5 inches long. The immature form is a click beetle, which are found everywhere (1). The larval stage of wireworms requires from two to six years or more to complete. In contrast to the long period of larval development, the pupae and adult stage require only a few months before eggs are laid near grassy weeds and the cycle repeats itself (8).

General Control Information: Scout for wireworms with a bait trap at least one week before planting. The threshold for wireworms is one or more per bait trap (1).

Cultural Controls: Since grasses are the primary host plant of various wireworm species, the greatest potential for wireworm problems occurs where there are significant grass weed problems or in crops following pasture or sod. Spring and fall plowing is recommended to established sod before the crop is planted (8).

Biological Controls: No information available.

Chemical Controls: Terbufos, tebupirimiphos + cyfluthrin, carbofuran, phorate, tefluthrin, chlorethoxyfos, chlorpyrifos, ethoprop and fipronil (1).

Alternative Controls: No information available.

INSECTICIDE PROFILES

Bacillus thuringiensis

Formulations; Application Rates:

- Javelin WG; 0.5 to 1.5lb per acre (1).
- Dipel ES; 2-4 pt per acre (1).
- Dipel 10G; 10 lb per acre (1).
- Dipel 2X; 0.5 to 2 lb per acre (1).
- Biobit FC; 2.0 to 7.0 pt per acre (1).
- Lepinox WDG; 1 to 2 lb per acre (1).
- Condor; 0.67 to 1.67 qt per acre (1).

Pests Controlled: European corn borer, armyworm.
Timing: Works best on small larvae.
PHI: 0 days (1).
REI: 4 hours (22).

Bifenthrin (pyrethroid)

Formulations: Capture 2EC.
Pests Controlled: Corn rootworm adults, European corn borer, mites.
Application Rate: 0.033 to 0.1 lb ai/A (1).

Timing: When pests are present.
PHI: 30 days.
REI: 2-18 days.
Efficacy Issues: Do not apply if heavy rain is imminent (1).
Restricted Use Pesticide

Carbaryl (carbamate)

Formulations: Sevin 4F, XLR Plus, 50W, 80S and 80WSP.
Pests Controlled: Corn rootworm adults, European corn borer, armyworm, cutworms, grub adults, flea beetles, grasshoppers.
Application Rate: 1 to 2 lb ai/A (1).
Timing: Post planting.
PHI: 14 days (grazing/silage) and 48 days (grain/fodder) (1).
REI: 12 hours (22).
Efficacy Issues: Full coverage is not required.

Carbofuran (carbamate)

Formulations: Furadan 4F.
Pests Controlled: European corn borer, wireworm, corn rootworm larvae, seedcorn maggots, grasshoppers.
Application Rate: 0.125-1.3 lb ai/A (1).
Types of Application: Foliar and soil applications (22).
Timing: Post planting (22).
PHI: 30 days (1).
REI: 2-14 days (22).
Efficacy Issues: Timing is critical for corn borer control. Large larvae are usually so deep in the whorls or leaf sheaths that insecticides cannot reach them. Do not try to control them if they are hard to reach and already deeply hidden (1).
RUP

Chlorpyrifos (organophosphate)

Formulations: Lorsban 4E and 15G.
Pests Controlled: Corn rootworm adults, European corn borer, armyworm, mites, cutworms, wireworms, corn rootworm larvae, seedcorn maggots, white grubs, aphids, billbugs, flea beetle, grasshoppers, stalk borers.
Application Rate: 0.25-3 lb ai/A (1).
PHI: 14 days (grazing/silage) and 35 days (grain/fodder) (1).
REI: 12-24 days.

Cyfluthrin (synthetic pyrethroid)

Formulations: Aztec 2.1G.
Pests Controlled: Wireworms, corn rootworm larvae, seedcorn maggots, white grubs.
Application Rate: 0.15 lb ai/A (1).

Types of Application: Chemigation, aerial and ground (22).
Timing: Post planting (22).
PHI: 0 days (22).
Restricted Use Pesticide

Dimethoate (organophosphate)

Formulations: Dimethoate 4EC, 400, E26705 lb (1).
Pests Controlled: Corn rootworm adults, mites.
Application Rate: 0.33-.08 lb ai/A
Types of Application: Ground and aerial (22).
Timing: Post planting (22).
PHI: 14 days (1).
REI: 48 hours (22).
IPM Concerns: Do not apply during pollen shedding if bees are actively foraging in treatment area (1).

Endosulfan (chlorinated hydrocarbon)

Formulations: Asana XL 0.66EC.
Pests Controlled: Corn rootworm adults, European corn borer, armyworm, cutworms, aphids, flea beetle, grasshoppers, stalk borers.
Application Rate: 0.03 to 0.05 lb ai/A (1).
Types of Application: Chemigation, aerial, and ground (22).
Timing: Post planting as insects appear (22).
PHI: 21 days (1).
REI: 12 hours (22).
Efficacy Issues: Direct spray for maximum coverage of exposed insects (1).
Restricted Use Pesticide

Ethoprop (organophosphate)

Formulations:

- Mocap 10G; 1.12 to 1.35 lb ai/A (1).
- Mocap 6EC; 0.5 to 1.75 lb ai/A (1).

Pests Controlled: Wireworms, corn rootworm larvae.
Types of Application: Soil applied, row treatment, incorporated (22).
Timing: At planting (22).
PHI: 14 days (22).
REI: 48 hours (22).
Restricted Use Pesticide

Chlorethoxyfos (organophosphate)

Formulations: Fortress 5G and 2.5G.
Pests Controlled: Wireworms, corn rootworm larvae, seedcorn maggot, white grub.

Application Rate: 0.15 lb ai/A.
REI: 48 hrs.
Efficacy Issues: Do not apply as surface band, behind press wheel.
Restricted Use Pesticide

Lambda-Cyhalothrin (pyrethroid)

Formulations: Warrior.
Pests Controlled: Corn rootworm adults, European corn borer, armyworm, cutworms, white grubs, cereal leaf beetle, flea beetle, grasshoppers, stalk borers.
Application Rate: 0.015-0.025 lb ai/A (1).
PHI: 21 days (1).
REI: 24 hrs.
Restricted Use Pesticide

Malathion (organophosphate)

Formulations: ULV Malathion, 5EC, 8EC
Pests Controlled: Corn rootworm adults, aphids, armyworm, grasshoppers, thrips, cereal leaf beetle.
Application Rate: 0.24-1.25 lb ai/A (1).
PHI: 5 days (1).
REI: 12 hrs
Efficacy Issues: Full coverage is not required (1).

Malathion (organophosphate)

Formulations: Malathion 5EC.
Pests Controlled: Corn rootworm adults, armyworm, mites.
Application Rate: 0.63 to 0.94 lb ai/A (1).
Types of Application: Chemigation, ground and aerial (22).
PHI: 5 days (1).
REI: 12 hours (22).
Efficacy Issues: Crop injury may occur in whorl or silk stages (1).

Methomyl (carbamate)

Formulations: Lannate 2.5LV and 90SP, and 1.8L.
Pests Controlled: Corn rootworm adults, European corn borer, armyworm, cutworms.
Application Rate: 0.23 to 0.45 lb ai/A (1).
Types of Application: Ground and aerial.
Timing: Post planting.
PHI: 21 days (grain) and 3 days (forage) (1).
REI: 48 hours (22).

Methyl Parathion (organophosphate)

Formulations: Penncap-M.
Pests Controlled: Corn rootworm adults, European corn borer, armyworm, aphids, flea beetle.
Application Rate0.5-1.0 lb ai/A (1).
Types of Application: Chemigation, sprinkler irrigation (22).
Timing: Post planting (22).
PHI: 12 days (1).
REI: 4 days (22).
IPM Concerns: Do not apply at pollen shed if bees are visiting treatment area (1).

Restricted Use Pesticide

Permethrin (synthetic pyrethroid)

Formulations:

- Ambush 2EC, 25W, 25WSP.
- Pounce 3.2EC, 25WP and WSB.

Pests Controlled: Corn rootworm adults, European corn borer, armyworm, cutworm, flea beetle, stalk borer.
Application Rate: 0.1 to 0.2 lb ai/A (1).
Types of Application: Chemigation (22).
Timing: Post planting (22).
PHI: 30 days (grain/fodder) and 0 days (forage) (1).
REI: 12 hours (22).
Efficacy Issues: Full coverage is not required (1).
Restricted Use Pesticide

Phorate (organophosphate)

Formulations: Phorate and Thimet 20G.
Pests Controlled: Wireworm, corn rootworm larvae, seedcorn maggots, white grubs.
Application Rate: 1.3 lb ai/A (1).
Types of Application: Furrow treatment.
Timing: Post emergence and at planting (22).
PHI: 30 days (1).
REI: 48 hours (22).
Efficacy Issues: Phorate 20G for reduction only. Do not use in-furrow application (1).
Restricted Use Pesticide

Fipronil (pyrazole)

Formulations: Regent 80WG and 4SC.
Pests Controlled: Wireworms, corn rootworm larvae, seedcorn maggot.
Application Rate: 0.13 lb ai/A (1).
PHI: 90 days (1).
REI: 24 hrs.

Efficacy Issues: Do not apply on row spacings less than 30 inches. Do not apply on sweet corn or popcorn. Do not plant small grains or other rotation crops within 12 months following application. Regent will aid in control of first -generation corn borer (1).

Tefluthrin (pyrethroid)

Formulations: Force 3G.
Pests Controlled: Wireworms, corn rootworm larvae, seedcorn maggot, and white grubs.
Application Rate: 0.13-0.16 lb ai/A.
Types of Application: Banded, t-banded and in furrow.
Timing: At planting or at cultivation (within 30 days of seedling emergence).
REI: 0-48 hours.
Restricted Use Pesticide.

Terbufos (organophosphate)

Formulations: Counter CR and 15G.
Pests Controlled: Wireworms, corn rootworm larvae, seedcorn maggot, white grubs, European corn borer, billbugs.
Application Rate: 1.3 lb ai/A (1).
PHI: 30 days (forage).
REI: 48 hrs.
Efficacy Issues: Apply cultivation treatments in a band over the row or directed to both sides of the plant ahead of cultivar shovels and cover with soil around the brace roots (1).
Restricted Use Pesticide

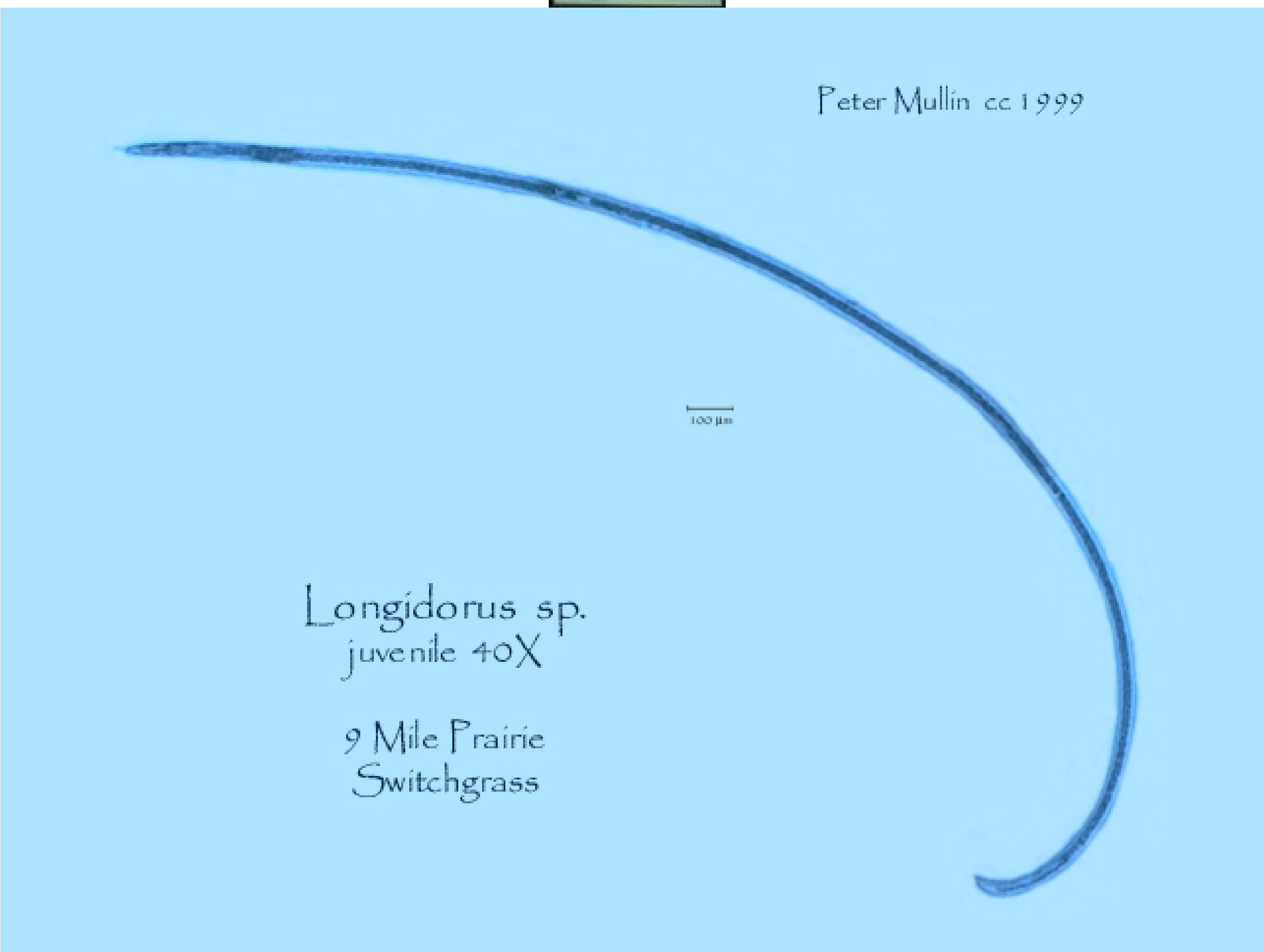
Nematodes

Nematodes that attack corn are microscopic roundworms, the longest of which measures about 1/4 of an inch in length. 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. 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 (6).

Symptoms: 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 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 can be stunted, discolored, swollen, or lack fine roots and may contain dark brown or black lesions. However, other factors that can also cause these types of above-ground and below-ground symptoms, may also be present on roots, so nematode damage may be misdiagnosed (6).

Management: Chemical options for nematodes in corn are limited. Many effective nematicides have been removed from the market and very few new nematicides are being developed. A few compounds are still labeled for control of plant-parasitic nematodes on field corn particularly many of the corn insecticides. Cultural control tactics include crop rotation, delayed planting, and soil health management (6). These tactics can be effective if targeted against specific nematodes. Samples of soil and root should be collected and submitted to a nematode diagnostic lab before implementing any management tactics against nematode parasites of corn. There are no corn hybrids with resistance to plant-parasitic nematodes. However, some hybrids are more tolerant of nematodes than others.

Corn Needle Nematode



Symptoms: Symptoms of damage by needle nematode include patches of yellowed and stunted corn seedling early in the growing season. Feeding by the nematode causes root growth to be thickened and stubby with short, stiff root hairs that resemble herbicide injury. The damage is generally most severe in areas of the field with highest moisture and sandy soil. Above the soil, the yellowed plants show appearance of nutrient deficiencies (42). Corn needle nematodes can reduce corn yields up to 50 bu/A (41).

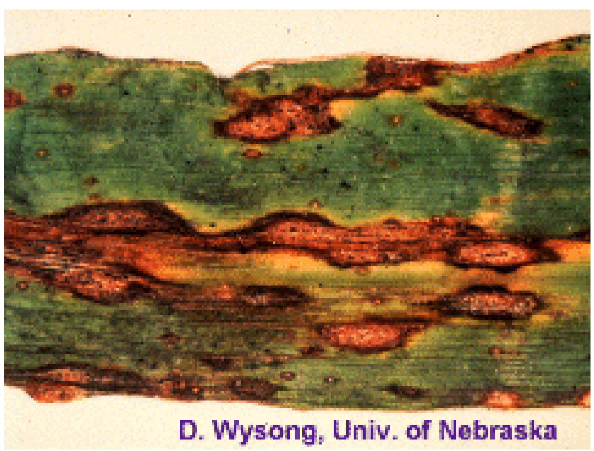
Conditions Favoring Disease: Corn needle nematode is found where soil texture is greater than 80% sand. As with other pathogens, it is generally more common and symptoms more severe in fields where corn is grown continuously (41).

Management: The best control for needle nematodes is crop rotation. A leguminous crop, such as soybeans or alfalfa, should be grown for at least one season to reduce the population of needle nematode sufficiently to allow normal growth of corn the following year. It is important that the rotation crop be grass free, or else the nematode will have a host on which to maintain itself and the rotation will not be effective. Wheat, oats, Sudan grass, and other monocots are potential hosts of this species and should not be considered for rotation. Currently, nematicides registered for corn are not cost effective controls for needle nematode (42).

Diseases

Anthracnose

Colletotichum graminicola



Anthracnose is made up of two distinct diseases; anthracnose leaf blight and anthracnose stalk rot. *C. graminicola* infects field corn, seed corn and sweet corn.

Symptoms: Leaf blight symptoms progress from lower to upper leaves and vary in size and color with host genotype. Typical symptoms on a susceptible hybrid appear as small, oval to elongated water-soaked lesions. Spots enlarge and become brown and spindle shaped with yellow to reddish-brown borders. Lesions may coalesce and blight entire leaves. Older lesions will turn gray in the center with small black specks (acervuli with sterile black hairs). Leaf blight may be followed by top kill and stalk rot (24,26).

The stalk rot phase of anthracnose typically exhibits both internal and external symptoms. Infection may occur at any point in the growing season, but is most prevalent after tasseling. The initial symptom of stalk rot is a water-soaked discoloration of rind tissue in the lower internodes. Lesions begin as streaks then enlarge to oval shapes and eventually cover the entire internode. In the final stages of development, lesions are dark brown to shiny black and sunken. Internal tissue associated with the lesions is also discolored. Pith either disintegrates or becomes soft and watery and lodging occurs (26).

Methods of Transmission: *C. graminicola* overwinters as a saprophyte on corn residue and on seeds as spores and mycelia and have been known to survive between seasons in kernels. Penetration occurs directly through the epidermis or stomata (23, 26). Primary infection of leaves occurs when conidia are windblown or splashed from debris to leaves. Conidia germinate and infection occurs directly through the epidermis or through stomata (26).

Conditions Favoring Disease: Favored by cool to warm, wet, humid weather, and continuous corn with reduced tillage (24). Free water on leaves is necessary for disease development (23).

Management: Resistant hybrids are available for both leaf blight and stalk rot. Although, hybrids showing resistance to anthracnose stalk rot may not be resistant to stalk rots caused by other fungi (26).

Anthracnose is generally more severe on continuously cropped corn where residue remains on the surface between seasons. Burial of residue has been shown to be effective in reducing inoculum. Residue burial would be most effective when rotating to a nonhost crop such as soybeans. In a conservation tillage system with continuously cropped corn, destruction and burial of residue is not possible, therefore a selection of a resistant hybrid would be beneficial (26). Leaf blight rarely causes large yield losses (23,24).

Common Rust

Puccinia sorghi

Common rust (Puccinia sorghi) on corn.
Courtesy Harold Kaufman, TAEX, 1996.

Damage related to common rust varies widely from year to year. The earlier the infection the more severe the disease is likely to become. Under heavy infestations, such as in 1993, yields can be reduced as much as 50% (28). Common rust affects field corn, seed corn and sweet corn in Michigan.

Symptoms: Early symptoms of common rust are chlorotic flecks on the leaf surface. These develop into powdery, brick red pustules (uredinia) as the urediniospores break through the leaf epidermis. The uredinia can be on either leaf surface, and may appear on husks, leaf sheaths, and stalks. They are oval or elongated, about 1/8-inch long and scattered sparsely or clustered together. The leaf tissue around the pustules may become yellowed, or it may die, leaving small or large dead leaf lesions. The lesions sometimes form a band across the leaf. Entire leaves will die if severely infected. As the uredinia age, the red urediniospores turn into black teliospores, so the pustules (now called telia) appear black and continue to erupt through the epidermis (27).

Methods of Transmission: Common rust fungi are unique among fungal pathogens of corn because they do not overwinter in the north. *P. sorghi* has five different spore types, but only brick-red urediniospores are important in the North. The urediniospores survive the winter on corn in the southern United States, then they are carried long distances by wind and eventually reach the north (24). New infections occur every 14 days (23).

Conditions Favoring Disease: *P. sorghi* infection is favored by cool (60° to 72° F optimum), humid weather and bright days (23, 24).

Management: Cultural practices do not influence the development of rust, since it does not survive in crop residue. Hybrids and inbreds vary in their resistance to common rust, and most hybrids are fairly resistant. However some inbreds are quite susceptible (27).

Fungicides can be used to control leaf diseases in corn but they usually are only economical in seed corn, popcorn or sweet corn production. Registered fungicides include several EBDC's, propiconazole, chlorothalonil, and azoxystrobilurin (27).

Common Smut

Ustilago maydis

Common smut (Ustilago maydis) on corn.
Courtesy Harold Kaufman, TAEX, 1996.

Common smut is found worldwide wherever corn is grown, although it is most prevalent in warm and moderately dry areas. Common smut affects field corn, seed corn and sweet corn.

In Mexico and Central America the galls of corn smut have been used as food for centuries. They are even thought to be a delicacy served in soup and other dishes (29).

Symptoms: Galls begin to form in young, actively growing tissue (axillary, buds, tassel, ear, leaves, and stalk). The ears are the most predominant part of corn for galls to develop, although they may be found on any and all above ground parts of a corn plant. Galls are first covered by greenish white covering, then later turn silver-gray. When galls become mature, they rupture, revealing their black contents. Small galls may not rupture, remaining hard (29).

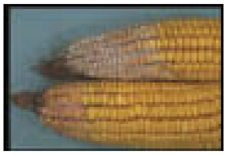
Methods of Transmission: Teliospores germinate to form basidiospores, which are windblown or splashed onto the host plant. A fine hypha penetrates the host by direct penetration. Following infection a compatible haploid hypha must contact and fuse with another compatible haploid hypha forming a dikaryotic mycelium for the infection to occur. Plant cells begin to divide and enlarge as gall formation proceeds. The mycelium produces teliospores, which are released as the galls rupture and may re-infect young plant tissues or drop to the soil and overwinter (29).

Conditions Favoring Disease: When conditions are dry and temperatures are between 78° to 94° F, common smut will often be seen on corn. Common smut also prefers high N and injury (23).

Management: Corn hybrids with some level of resistance are available. It is important to avoid mechanical injury to plants and maintain balanced soil fertility (23). Exploitation of the disease cycle has lead to an economic product in that the young galls are marketed for human consumption (29).

Gibberella Ear Rot

Gibberella zeae



Gibberella ear rot is the sexual reproductive stage of *Fusarium graminearum*, which also causes stalk rot and overwinters in corn residue (30). This is the most consistently important mycotoxigenic fungus in the northern corn belt, producing vomitoxin, zearalenone, and other toxins (6).

Symptoms: Gibberella ear rot can be identified most readily by the red or pink color of the mold, which generally begins at the tip of the ear. The silks and husks may adhere to the ear due to excessive mold. In severe cases, the pink mold is visible on the outside of the husks at the ear tip. In some cases, the color is too pale to be seen readily, so the mold appears white. In this case, it may not be possible to distinguish Gibberella ear rot from Fusarium ear rot without a microscope. Gibberella ear rot can be destructive to the ears, often involving the entire ear (30).

Methods of Transmission: *G. zeae* survives as perithecia on crop debris on and in the soil. The spores are spread by splashing rain and wind, infecting ears through the silks. Silks are most susceptible 2 to 6 days after emergence (30). Ears are infected directly or through wounds from earworms, corn borer or other insects (23).

Conditions Favoring Disease: Cool to warm wet weather after silking favors Gibberella ear rot (23).

Management: Resistant hybrids should be planted when available. Resistance to Gibberella ear rot 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 ear rots. Insect control may reduce ear rot to some extent. Harvest early and store properly (below 18% ear moisture and 15% for shelled grain) (23).

Gray Leaf Spot

Cercospora zeae-maydis

Symptoms: Lesions on maturing corn leaves are pale brown or gray to tan, long, narrow and rectangular, being characteristically restricted by the veins. The lesions may coalesce, killing the leaves. The disease is usually first noticed attacking the lower leaves. Extensive leaf blighting may occur until all the leaves are killed, finally resulting in stalk breakage and lodging. Total loss may occur if gray leaf spot infection occurs early and favorable environmental conditions exist following infection (39).

Method of Transmission: *C. zeae-maydis*, like many other foliar fungal pathogens of corn, is a poor competitor in the soil and survives on infested corn debris. Infested corn debris on the soil surface is the source of primary inoculum for the next corn crop. The fungus colonizes this debris producing conidia (spores) as early as May. These airborne spores are the means by which the fungus infects the new corn crop (40).

Conditions Favoring Disease: Gray leaf spot is a highly weather-dependent disease. The pathogen requires long periods of high relative humidity and free moisture (dew) on the leaves for infection to occur (40).

Management: Tillage, the turning of corn residues, is beneficial in reducing pathogen survival and inoculum of the succeeding corn crop. The burial of infested debris facilitates rotting and deprives the fungus of a good base. The fungus is unable to survive freely within the soil. It can only overwinter within and on dead corn tissue remaining on or above the soil surface. Disking does not sufficiently bury the infested debris. Moldboard plowing does, but it may not be advisable in some fields because of increased erosion potential (40).

Taking a field out of corn production or rotating to a non-host crop for one year can reduce gray leaf spot severity. The fungus is unable to survive more than one season in infested corn debris. Corn is the only crop this fungus is known to attack. However, the potential for herbicide carryover may restrict the selection of crops in the rotation scheme (40).

Losses from gray leaf spot can be reduced by planting hybrids that are less susceptible or more tolerant to this disease. Unfortunately, no hybrid currently available to the grower is immune to gray leaf spot (40).

Eye Spot

Kabatiella zeae

Eyespot affects field corn, seed corn and sweet corn.

Symptoms: The disease usually spreads from the lower leaves upward. But if spores are blown in from neighboring fields, lesions can be random or concentrated in the upper leaves. Infections first appear as small, water-soaked, circular lesions that are about 1/16-inch in diameter, and become chlorotic, then necrotic, with a tan center and a darker brown or purple margin. The spot is usually surrounded by a larger yellow "halo," which is most visible when light passes through the leaf. Halos are observed by holding a leaf up toward a blue sky background. Spots can vary in size and color depending on the hybrid and can coalesce into larger necrotic areas. It is common to observe bands of lesions across a leaf, indicating that infection took place in the moist environment of the whorl after a period of spore dispersal. Lesions often are concentrated along the leaf edges and leaf tips. Severely infected leaves can be entirely blighted, however the dark margins of the lesions remain visible on dead leaves (31).

Methods of Transmission: *K. zeae* overwinters in corn debris. The primary method of dispersal is by wind to the corn plant. Secondary methods include rain and wind-blown spores. The fungus can also be seed-borne (23).

Conditions Favoring Disease: Cool and humid weather favor infection and disease development.

Management: Resistant hybrids should be the first choice. Most commercial hybrids are less susceptible to eyespot. It is a good idea to select resistant hybrids when the disease has previously been severe in the area (31).

Rotation with crops other than corn allows the fungus in the residue to break down before another corn crop is planted. Usually one year out of corn will reduce the inoculum adequately to grow another corn crop, but it may take longer under reduced tillage conditions. Tillage will hasten the decline of fungal survival, because contact with the soil results in faster residue decomposition and exposes the pathogen to antagonistic microorganisms (31).

Fungicide sprays early in the epidemic can have a significant impact on disease and yield. Fungicides can be economically beneficial in seed corn production, but may not be in hybrid corn. Fungicides should be considered only when corn grown the previous year was affected by eyespot and reduced tillage practices are being used (31).

Northern Corn Leaf Blight

Exserohilum turcicum

The fungus *Exserohilum turcicum*, previously called *Helminthosporium turcicum*, causes northern corn leaf blight (NCLB). 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 (6). NCLB also affects seed corn and sweet corn and can cause severe damage in these crops.

Symptoms: Lesions are long, elliptical in shape, and grayish-green or tan in color. They generally occur on the lower leaves first (23). NCLB lesions differ from bacterial wilt lesions in that they are generally definite in shape, have greater width and do not follow leaf veins for extended lengths (25). Spores produced in the lesions are olive-green to black and may be produced in concentric rings giving the spot a target like appearance. Spores from the primary lesions reinfect the host producing secondary cycles of the disease (32).

Method of Transmission: *E. turcicum* overwinters as mycelium and conidia in corn debris. Conidia are then wind-blown a long distance to corn plant leaves (23). Conidiospores have a slightly protruding hilum, which aids in identification of the fungus. The conidiospores germinate and penetrate leaf tissue directly or through stomata, and infection occurs when free moisture is present on the leaf surface (32).

Conditions Favoring Disease: Northern corn leaf blight is favored by extended wet, cool, humid weather, minimum tillage and continuous corn. It usually occurs during or after pollination (24).

Management: Hybrids are available with both monogenic and polygenic resistance and should be used whenever possible. Severe outbreaks of northern corn leaf blight are sporadic but the potential for a major outbreak is present where corn is being continuously cropped in a conservation tillage system. Since the fungus that causes the disease survives between seasons on crop residue, reduction of the residue should reduce the amount of inoculum present in the spring. However, it is not practical (or legal in some government programs) to abandon conservation tillage. In this case a grower may find it useful to rotate to an unrelated crop such as soybeans (32). Fields with infected residue should be cleanly plowed under (24).

Root Rot

Fusarium, Pythium

Symptoms: Small, yellowish-brown lesions occur on the primary roots and later on the first and second whorls of secondary roots. The affected roots later become black and necrotic. Aboveground symptoms such as wilting, stunting and yellowing of leaves may accompany root rot but these symptoms are not always apparent (39).

Methods of Transmission: Sporangia and oospores are produced within or outside of host tissue. Germ tubes or mycelia contact the seeds, seedling tissues, or root tips of corn either by chance or by chemical attraction (39).

Conditions Favoring Disease: Early season root rots occur in soils where oxygen is deficient due to poor drainage or compaction. Root rot fungi are found in water, muck or heavy soils in association with dead organic matter or in the roots of susceptible plants (39).

Management: Good cultural practices include planting seed in warm, fairly moist soil, proper seedbed preparation, correct placement of fertilizer, and herbicides and other pesticides. Treat seeds with Captan, Thiram, Apron, Maxim and dividend. Plant injury free seed with high germination (39).

Seed Rots and Seedling Blights

Pythium spp., *Fusarium* spp., *Diplodia* spp., *Penicillium* spp., *Aspergillus* spp., *and Rhizoconia* spp.

Seed rots and seedling blights are caused by a number of fungal pathogens including *Pythium* spp., *Fusarium* spp., *Diplodia* spp., *Penicillium* spp., *Aspergillus* spp., *and Rhizoconia* spp. They affect field corn, seed corn and sweet corn.

Symptoms: There is a broad range of symptoms for seed rots and seedling blights, from yellowing, wilting, death of leaves, to soft rot of the stem and water-soaking of seedling tissue. Small yellowish-brown lesions appear on the primary roots and later on the secondary roots. After time the lesions become black and necrotic (23).

Seed Rot: Rotting of seed before germination (39).

Damping off and Seedling Blight: Soft rot of stem tissues (mesocotyl) near the ground level and water-soaking of seedling tissues. The rotted area may be dark with sporangia and oospores in the tissues (*Pythium*), or with whitish-gray (*Diplodia*), white-to-pink (*Fusarium*), or bluish (*Penicillium*) mycelium and masses of spores (39).

Seedling Wilt: A gray coloration starts at the leaf tips and extends rapidly to the whole leaf, causing complete collapse of seedlings in 24 to 48 hours. This symptom is suggestive of kernels infected with *Helminthosporium maydis*, especially when no fungus can be isolated from infected leaves. Wilting may also occur following infection by *Penicillium oxalicum* (39).

Methods of Transmission: The soil borne fungi are commonly found in all soils (23).

Conditions Favoring Disease: Seed rots and seedling blights occur in poorly drained soils during periods of cold, wet weather, when soil temperatures are below 60° F (23).

Management: Plant injury-free seed in warm, moist soil, with correctly placed fertilizer and herbicides and use seed-protectant fungicides (Fludioxonil, Captan or Metalaxyl) (23).

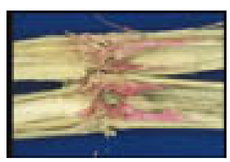
Stalk Rot

(Gibberella, Fusarium and Diplodia Stalk Rot)

Stalk rots are a consistent problem in field 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 be greatly affected, and rotted stalks will easily lodge, making harvest difficult. Gibberella stalk rot is caused by three main stalk rot pathogens, *Fusarium* spp., *Colletotrichum graminicola (anthracnose) and Gibberella zeae*. It has a worldwide distribution and is capable of causing serious crop damage. Gibberella stalk rots can cause crop losses between 10 to 30% (34).

Symptoms:

Gibberella: Leaves on early infected plants suddenly turn a dull grayish green while the lower internodes soften and turn tan to dark brown. The stalks often show an internal pink to reddish discoloration of the diseased tissue. The fungus causes shredding of the pith and may produce small, round, black perithecia superficially on the stalks. Lesions may develop concentric rings. This disease can be differentiated from Diplodia stalk rot by pith discoloration and the superficial perithecia.



Gibberella Stalk Rot

Fusarium spp.: This rot is difficult to distinguish from Gibberella stalk rot. Rotting commonly affects the roots, plant base, and lower internodes. It normally begins soon after pollination and becomes more severe as the plant matures. A whitish-pink to salmon discoloration of the pith, stalk breakage, and premature ripening are the same as for Gibberella stalk rot.

Fusarium Stalk Rot

Diplodia: The disease commonly appears several weeks after silking. Affected plants die suddenly, and leaves wilt, become dry, and appear grayish-green resembling frost injury. The lower internodes are brown to straw colored, spongy and easily crushed. The pith disintegrates and becomes discolored with only the vascular bundles remaining intact. A characteristic sign is the presence of subepidermal, minute, dark brown to black pycnidia clustered near the nodes. White fungal growth may also be present on the surface.

Diplodia Stalk Rot

Methods of Transmission: The fungus overwinters as perithecia, mycelium or chlamidiospores in infected plant debris. Perithecia on infected corn stalks mature and give rise to ascospores that are released in the spring under warm wet conditions. The ascospores are vectored by wind to cornstalks where they will germinate and penetrate the host tissue resulting in a new infection (34). The pathogen survives in soil and on crop residues. Spores are wind-borne (23).

Conditions Favoring Disease: High nitrogen (N) and low potassium (K), high plant populations, and loss of leaf area through disease, hail, or insect damage predispose plants to infection. As well as dry conditions early in the season accompanied by warm, wet weather 2 to 3 weeks after silking. Early-maturing hybrids are generally more susceptible than full-season hybrids (39).

Management: Plant resistant hybrids and varieties. Balance soil fertility and avoid high levels of N and low levels of K. Lower plant populations.

Stewart's Wilt

Erwinia stewartii

Stewart's Wilt affects seed corn and sweet corn. Commercial hybrid corn can become infected, but yield losses are usually not greatly effected. Commercial corn becomes more resistant as the plants mature.

Symptoms: Susceptible hosts may be infected at any stage of development and a wide range of symptoms are associated with this disease. Plants infected as seedlings whither and die. Plants infected early that do not die are stunted, have abnormal ears and bleached or dead tassels. When infection occurs after tasseling, distinct leaf lesions develop. Watersoaked streaks are formed parallel to the vein. The streaks are light green to yellow with a wavy, irregular margin. They turn tan, enlarge and coalesce with age, resulting in blighting or "firing" of leaves. Insect feeding scars can be observed in these lesions when they are held up to the light. Secondary spread of the pathogen also occurs via leaf lesions. Severely infected plants have discolored cavities in the pith near the soil line. The bacteria spread through the vascular system and may enter the kernels. When stalks or leaves of these plants are cut open, droplets of yellow bacterial ooze extrude from the vascular tissue (35).

Methods of Transmission: Several insects transmit Stewart's Wilt, but the corn flea beetle is considered the most important in the life cycle of the pathogen. Flea beetles overwinter as adults and the bacterium survives between crops in the insect. The pathogen is transmitted to the new crop when flea beetles begin feeding. Warm winter temperatures result in a high survival rate of insects and a higher incidence of Stewart's Wilt in the spring. The bacterium can also survive in seed but this type of transmission is considered most important in carrying the disease to new areas rather than as a source of primary inoculum in areas with a history of Stewart's Wilt. Secondary infection occurs when insect vectors transfer the bacterium to healthy plants (35).

Conditions Favoring Disease: High temperatures (88° to 98° F) aggravate disease severity (23), and the disease is prevalent following mild winters (25).

Management: Resistant hybrids should be planted when possible. Application of high levels of calcium (Ca) and potassium (K) tend to decrease plant susceptibility. Another method of management is to control the flea beetle with insecticides to reduce Stewarts Wilt.

FUNGICIDE PROFILES

*There are no fungicides used to treat corn diseases in the field, rather corn seed is treated prior to the farmer receiving the seed.

Weeds

Annual weed species comprise a majority of the weed control problems in Michigan field corn production. Many of the primary weed species are introduced rather than native. The competitiveness of weeds in a crop field is determined by many factors. One important factor is the crop itself. Crop variety, row spacing, and plant population may influence weed competitiveness. 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. In general, the longer the weeds are allowed to compete with crops, the greater the crop yield loss. The amount of loss will depend upon the type and number of weeds present, the availability of nutrients, water and light, and the competitive characteristics of the crop plant (6, 36, 37).

Methods of Weed Control

There are four general methods used in the control of weeds: cultural, mechanical, chemical and biological. Successful control of weeds in corn requires a system that integrates these methods (38).

Cultural Weed Control: Corn is a very competitive crop. If managed properly, corn can provide considerable competition to weeds growing in the field. Research has shown that annual weeds emerging 4 weeks or more after the corn are unlikely to reduce crop yields. It is important to manage the crop to maximize its competitiveness with weeds. Fortunately, the practices that increase competitiveness with weeds are also the practices that maximize yield potential. It is important to establish a uniform stand at the desired density. Soil tilth, fertility, pH, and drainage must be suitable for the crop to be competitive with weeds. To the extent possible, the crop must be managed to minimize stresses on the corn from insect damage, environmental stresses (frost, flooding, etc.), or other stresses (38).

Row spacing is an important cultural practice affecting weed control. Corn in narrow rows will shade the soil surface earlier than corn in wide rows. Once a canopy has closed, very little light reaches the soil surface or weeds below the canopy. The value of early canopy closure for weed control is evident when herbicides with no soil activity, such as Roundup Ultra, are used for weed control. For example, if the crop canopy closes early, a second herbicide application is less likely to be needed (38).

Another example of cultural control of weeds that is currently attracting a great deal of interest is the use of cover crops. Cover crops offer several potential benefits to corn production, including nitrogen trapping, soil erosion protection, and weed control. However, these systems also carry risks including the potential for moisture depletion and excessive competition with the crop. In the future, cover crop systems that are commercially beneficial and easily adopted may be developed for corn production (38).

Mechanical Weed Control: The most common means of mechanical weed control in corn is with tillage. Tillage for weed control can be divided into two categories: seedbed preparation and cultivation (38).

Seedbed preparation kills most of the weeds present at planting time and gives the crop an even start with the weeds. Tillage implements commonly used for seedbed preparation are field cultivators, disks, and implements that combine two or more tillage types. All of these tillage implements are highly effective at controlling weed seedlings when operated properly. Cultivation is used to remove weeds after the crop has been planted. Cultivation can be accomplished with a rotary hoe or a cultivator. Rotary hoes will remove small seedlings before or shortly after emergence. Rotary hoes are most effective on small-seeded broadleaved weeds and grasses, but they are less effective on large-seeded broadleaves such as velvetleaf, cocklebur, or morningglory. They should be used after weed germination and preferably before the crop has emerged. Rotary hoes are operated at a relatively high speed. Rotary hoes are especially useful when soil-applied herbicides fail to control weeds due to lack of rainfall. Cultivation removes weeds in the inter-row areas. Cultivators come in a wide range of designs. Some have C-shanks with wide sweeps while others have S-tine shanks with narrow shovels. Cultivators may also have rotary cultivators. Many cultivators also have guards that can be used to prevent throwing soil onto small crop seedlings. The key to using cultivators is to adjust the equipment to effectively remove as many weeds as possible from the area while minimizing the disturbance of the crop (38).

Biological Weed Control: Biological control refers to the use of natural enemies (insects or pathogens) to control weeds. Biological control is very important in the management of certain perennial weeds in non-cropland situations. However, the use of biological agents in the control of weeds in corn has had very limited success. There currently are no commercial products for biological weed control in corn. However, this area offers great potential for new weed control options in the future. The most promising area is with biopesticides, the application of plant pathogens that selectively attack specific weeds species and do not attack the corn crop or other desirable plants. One example of a commercial bioherbicide is Colego, a fungal herbicide used to control northern jointvetch in rice in the southern U.S. (38).

Chemical Weed Control: Herbicides continue to be an integral part of weed control systems in corn. They are selected by the great majority of corn growers as an effective, economical tool for weed management (38).

HERBICIDE PROFILES

Ammonia Assimilation Inhibitors

Glufosinate (organophosphate)

Formulation: Liberty 1.67S. (Applied only to corn resistant to Liberty herbicide)

Use rates: 0.31 lb ai/A.

Types of application: Ground (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).

Timing: Postemergence (POST).

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: Liberty ATZ.

Amino Acid Synthesis Inhibitors

Glyphosate (organophosphate)

Formulation: Roundup Ultra. (Applied to Roundup Ready Corn only)

Acres crop treated: 330,000 acres (15%) (44).

Actual use rate: 0.74 lb ai/A (44).

Use rates: 0.56 - 0.75 lb ai/A (44).

Types of application: Ground (For applications after corn reaches 24 inches use drop nozzles).

Timing: Emergence to 30 inches or V8 growth stage.

Pre-harvest interval: 50 days.

REI: 4 hours.

Component of other products: FieldMaster.

ALS-inhibitors

Flumetsulam (triazolopyrimidine)

Formulation: Python 80WDG.

Acres crop treated: 440,000 acres (20%) (44).

Actual use rates: 0.05 lb ai/A (44).

Use rates: 0.023 - 0.056 lb ai/A (44).

Types of application: Ground (band and impregnation with fertilizer).

Timing: Can be applied preplant incorporated (PPI), preemergence (PRE) or postemergence (POST). Python can be applied from 30 days prior to planting until corn spike stage.

Pre-harvest interval: 85 days.

REI: 12 hours (Python).

Component of other products: Broadstrike+Dual, Hornet, Bicep Magnum TR, Accent Gold.

Comments: Primary activity is on broadleaf species. Has a groundwater advisory statement.

Use in Resistance Management Programs: Shows good to excellent control of pigweed species (non-resistant), velvetleaf and smartweed.

Halosulfuron (sulfonylurea)

Formulation: Permit 75WDG.

Use rates: 0.03 - 0.06 lb ai/A.

Types of application: Ground (do not apply by air).

Timing: Postemergence (POST) 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.

Imazethapyr (imidazolinone)

Formulation: Pursuit 2AS, Pursuit 70DG, Lightning.

Use rates: 0.042 lb ai/A.

Timing: Postemergence (POST)- apply to weeds less than 3 inches in height or before corn exceeds the 8-leaf stage.

Pre-harvest interval: 45 days.

REI: 4-12 hours.

Component of other products: Lightning 70DF.

Nicosulfuron (sulfonylurea)

Formulation: Accent 75DF.

Acres crop treated: 176,000 acres (8%) (44).

Actual use rates: 0.02 lb ai/A.

Use rates: 0.03 lb ai/A.

Types of application: Ground and aerial (but only on IMI corn).

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 for grain or silage following application.

REI: 4 hours.

Component of other products: Accent Gold, Basis Gold.

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 (sulfonylurea)

Trade name and formulation: Beacon 75DF.

Use rates: 0.035 lb ai/A.

Types of application: Ground.

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: Northstar.

Comments: Provides excellent control of shattercane. Provides good to excellent control of numerous broadleaves including pigweed, Jimsonweed, sunflower, velvetleaf, cocklebur and smartweed.

Rimsulfuron (sulfonylurea)

Formulation: Component of Basis & Basis Gold

Acres crop treated: 110,000 acres (5%) (44).

Actual use rates: 0.01 lb ai/A (44).

Use rates: 0.012 lb ai/A.

Types of application: Ground.

Timing: Early postemergence and postemergence (POST).

Pre-harvest interval: Do not graze or feed forage, grain or stover from treated areas to livestock within 30 days of application.

REI: 4 - 12 hours.

PSII inhibitors (non-mobile)

Bentazon (benzothiodiazole)

Formulation: Basagran 4S.

Use rates: 0.75 - 1.0 lb ai/A.

Types of application: Ground and aerial.

Timing: Postemergence (POST) 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.

Bromoxynil (nitrile)

Formulation: Buctril 2EC, Buctril 4EC, Moxy 2E.

Acres crop treated: 198,000 acres (9%) (44).

Actual use rate: 0.46 lb ai/.A (44).

Use rates: 0.25 - 0.38 lb ai/A.

Types of application: Ground, aerial and sprinkler irrigation.

Timing: Postemergence (POST) from 3 leaf until prior to tassel emergence.

Pre-harvest interval: 45 days.

REI: 12 hours.

Component of other products: Buctril+Atrazine.

PSII inhibitors (mobile)

Atrazine (triazine)

Formulation: many formulations - commonly found in 4L and 90DF formulations.

Acres crop treated: 1,540,000 acres (70%) (44).

Actual use rate: 0.96 lb ai/A (44).

Use rates: 0.5-2 lb ai/A (44).

Types of application: Ground and aerial.

Timing:

1.Pre-plant (PP)- up to 30 days prior to planting.

2.Preplant incorporated (PPI)- apply within 2 weeks prior to planting.

3.Preemergence (PRE)- apply during or shortly after planting and before weeds emerge.

4.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: 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, FieldMaster, FulTime 4CS, Guardsman 5L, Harness Xtra, Laddok S-12, Lariat 4L, Marksman 3.2L, Shotgun 3.25L, Surpass 100SL, Liberty AT2.

Cyanazine (triazine)

Formulation: Bladex 4L, 90DF.

Use rates: 1.0 lb ai/A.

Types of application: Conventional tillage and conservational tillage.

Timing: Preemergence (PRE) preplant incorporated (PPI).

Pre-harvest interval: N/A. Applied 30 days before planting.

REI: 12 hours.

Comments: This product may not be used after Dec. 31, 2002 nor sold after Sept. 30, 2002.

Simazine (triazine)

Formulation: Princep 80WP and 90DG.

Use rates: 1.0 lb ai/A.

Types of application: Ground or aerial.

Timing: Preplant incorporated (PPI) and preemergence (Pre)

REI: 12 hours.

Metribuzin (triazine)

Formulation: Sencor 75DF.

Use rates: 0.09 lb ai/A.

Types of application: Chemigation, ground (band) and aerial.

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.

Comments: Do not apply on coarse soils with less than 1.5% organic matter and do not apply on soils having pH 7.0 or greater.

Root inhibitors

Pendimethalin (dinitroaniline)

Formulation: Prowl 3.3EC, Pentagon 60DG.

Acres crop treated: 396,000 acres (18%) (44).

Actual use rate: 0.90 lb ai/A (44)

Use rates: 0.74-1.98 lb ai/A.

Types of application: Ground (broadcast and band), aerial and chemigation.

Timing: Preemergence (PRE), postemergence, Culti-spray (applied after corn is 4 inches in height and incorporated with cultivator).

Pre-harvest interval: 0 days. 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.

Comments: Do not apply preplant incorporated (PPI) since injury to the corn plants may result.

Shoot inhibitors

Acetochlor (acetanilide)

Formulation: Harness 7EC, Surpass 6.4EC, others.

Acres crop treated: 1,056,000 acres (48%) (44).

Actual Use Rates: 1.64 lb ai/A.

Use rates: 1 **-** 3lb ai/A.

Types of application: Ground (broadcast boom and banded) and dry bulk fertilizer impregnation.

Timing: Preplant incorporated (PPI), and preemergence (PRE).

Pre-harvest interval: 0 days.

REI: 12 hours.

Component of other products: FieldMaster, FulTime 4CS, Harness Xtra, Surpass 100.

RUP

Alachlor (acetanilide)

Formulation: Lasso 4EC, Lasso II.

Use rates: 2.5 - 4.0 lb ai/A.

Types of application: Ground (broadcast and band applied).

Timing: Preemergence surface applied.

REI: 12 hours.

Component of other products: Freedom, Bronco, Bullet, and Lariat.

Dimethenamid (amide)

Formulation: Frontier 6EC

Use rates: 0.75 - 1.5 lb ai/A.

Types of application: Ground (broadcast and dry bulk fertilizer).

Timing: Early preplant (EPP) (30 days prior to planting), preplant incorporated (PPI), preemergence (PRE), or early postemergence (E.POST) (up to 8 inches tall).

Pre-harvest interval: 40 days.

REI: 12 hours.

Component of other products: Guardsman.

EPTC (thiocarbamate)

Formulation: Eradicane 6.7EC.

Use rates: 4 - 6 lb ai/A.

Timing: Preplant incorporated (PPI).

REI: 12 hours.

Flufenacet (anilide)

Formulation: Axiom 68DF (a premix with metribuzin).

Use rates: 0.4 - 0.78 lb ai/A.

Types of application: Ground (broadcast, band and dry bulk fertilizer).

Timing: Preplant (EPP), preemergence (PRE), early postemergence (E.POST) (prior to corn emergence).

REI: 12 hours.

Component of other products: Epic 58DF (Not currently labeled in Michigan).

Comments: Do not incorporate.

Metolachlor (acetanilide)

Formulation: Dual II 7.8EC, Dual II Magnum 7.64EC.

Acres crop treated: 374,000 acres (17%) (44).

Actual use rates: 2.26 lb ai/A (44).

Use rates: 1.5 **-** 3.75 lb ai/A.

Types of application: Ground and aerial.

Timing: Early preplant (EPP)(up to 30 days prior to planting), preplant incorporated (PPI), preemergence (PRE), or postemergence (POST) (corn not more than 12 inches tall).

Pre-harvest interval: 30 days.

REI: 24 hours.

Component of other products: Bicep (various formulations).

Growth regulator

2,4-D (phenoxy)

Formulation: various formulations of 2,4-D amine and 2,4-D ester.

Acres crop treated: 198,000 acres (9%) (44).

Actual use rates: 0.44 lb ai/A (44).

Use rates: 0.25 - 0.5 lb ai/A (amine), 0.15 - 0.33 lb ai/A (ester).

Types of application: Ground and aerial.

Timing: Postemergence (POST) 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 (pyridine)

Formulation: Stinger 3EC.

Acres crop treated: 220,000 acres (10%) (44).

Actual use rates: 0.10 lb ai/A (44).

Use rates: 0.1 to 0.25 lb ai/A.

Types of application: Ground (broadcast).

Timing: Postemergence (POST) 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.

Dicamba (benzoic acid)

Formulation: Banvel 4SC, Clarity 4SC.

Acres crop treated: 374,000 acres (17%) (44).

Actual use rates: 0.18 lb ai/A (44).

Use rates: 0.25 - 0.5 lb ai/A.

Types of application: Ground (band).

Timing: Preplant (PP) and preemergence (PRE) for no-tillage; PRE for conventional or reduced tillage; early POST for all tillage systems from spike through 8" and late POST from 8" to 36."

Pre-harvest interval: Do not harvest or graze prior to milk stage.

REI: 24 hours (Banvel), 12 hours (Clarity).

Component of other products: Celebrity, Marksman 3.2L, Northstar, Distinct.

Contacts

Chris DiFonzo
Department of Entomology
Michigan State University
difonzo@msu.edu
(517)353-5328.

Chad Lee
Department of Crop and Soil Sciences (Weed Science)
Michigan State University
leechad@msu.edu
(517)432-6754.

Pat Hart
Botany and Plant Pathology Department
Michigan State University
hartpat@msu.edu
(517)353-9428.

Kurt Thelen
Department of Crop and Soil Sciences
Michigan State University
thelenk3@msu.edu
(517)353-1939.

Lynnae Jess
North Central Pest Management Center
Michigan State University
jess@msue.msu.edu

(517)432-1702.

Written by Heather Johnson

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