

Crop Profile for Potatoes in Michigan

Prepared Nov, 2000



General Production Information

- In volume and sales, potatoes are Michigan's leading produce commodity (1).
- In 1998, Michigan produced 14,725,000,000 pounds of potatoes with an average yield per acre of 31,000 pounds on 47,500 acres (2).
- Michigan ranked 9th among states in potato production in 1997 producing 3.4% of the nation's fall potatoes. Michigan ranked 10th among states in all potato production with 3.1% of the production (3).
- Michigan is the nation's leading producer of potatoes for chip processing (1).
- Harvest begins in July with approximately 30% of the crop shipped directly out of the field to either processing plants or packing sheds.
- Potato storage begins approximately September 15 with harvest completed by late October
- Most Michigan potatoes are white, which comprise 72% of planted acreage followed by russets and red which comprise 27 and 1 % of planted acreage, respectively (3).
- Over 75% of Michigan potatoes are used for chipping, over 6% for seed, over 18% for fresh market (table) and 1% for other (1).
- The value of potatoes in Michigan in 1999 was approximately \$100 million. The average over the last five years is approximately \$98 million (3).

Production Regions

In 1998, Montcalm County was the largest single potato producing county with 11,900 acres, followed by St Joseph County with 4,600 acres, Bay County with 4,150 acre, Tuscola County with 3,400 acres, Presque Isle County with 2,350 acres. The following map shows the wide distribution of Michigan potato production (2). The most popular chipping potato varieties are Snowden and Atlantic. Many growers also produce proprietary FritoLay varieties. The most popular for fresh potatoes varieties are Onaway, Superior and Russet Norkotah (4).

The most popular type of Michigan potato is the round white, which is used as a fresh market potato and for chips. The table varieties of round whites are well liked for their moistness and soft texture, and russets are preferred for their excellent baking quality. Michigan has also cultivated a market for yellow or "golden" potatoes. These have a unique flavor and may be prepared in many ways (1).

Potatoes are propagated asexually, from cut pieces of potato tubers. Michigan producers purchase their seed potatoes primarily from certified seed growers within the U.S. and Canada. Seed potatoes are delivered as whole tubers, and growers generally cut them up, treat the pieces with fungicides, and cure them for several days before planting. Planting starts as early as late April and continues through early June. Potatoes are grown primarily on

light mineral soils (sandy soils), however some production continues on muck soils (high organic matter soils). Row spacing is typically 34 or 36 inches, and seed pieces are placed 6-12 inches apart in the row. Typically 1000-3000 lbs of seed potatoes are planted per acre, depending on seed piece size, row spacing and spacing between plants.

Soil acidity is extremely important to plant growth and nutrient availability. Potatoes grow best at pH 5.2 to 6.5. Below pH 5.0, aluminum and manganese toxicity occurs reducing both growth and tuber yield. Potatoes are generally limed to pH 6.0. Growers take several precautions to prevent potato scab, which is often promoted by the addition of limestone. Growers use scab-tolerant varieties when they are available and don't apply more than one ton of lime within six months of potato planting. Lime is applied in the fall after potato harvest. Nitrogen (N) is a critical nutrient for potatoes by affecting yield and tuber quality. Inadequate N can drastically reduce yields. Excess N can reduce tuber quality by lowering specific gravity. Potatoes are rather inefficient at making use of soil phosphorus. Potassium (K) can greatly affect potato tuber quality. High rates of K fertilizers will lower specific gravity (percent solids). Complicating the issue is the fact that potatoes have a high requirement for K. Because most potatoes in Michigan are grown on sandy soils and sandy soils do not hold large amounts of K, growers must pay a great deal of attention to K fertilization (5).

Potatoes require a large amount of water, therefore an average of 85% of the Michigan growers irrigate their potato acres, ranging from 49% in the Southeast up to 100% in the Northwest. Hilling takes place to prevent sunscald among other factors. Hilling increases soil volume around tubers, it improves water retention, removes weeds and helps to prevent fungal spore regeneration (4).

Potato harvest begins as early as late July in the southern counties for fresh market crops. Harvest of storage potatoes starts in September. Chemical vine killing is used to aid harvest by desiccating vines and weeds and aids tuber conditioning to reduce bruising and skinning during harvest and bin loading. Vine desiccation suspends tuber bulking thus helping to minimize the incidence of hollow heart, and help prevent diseases such as late blight and leafroll. Under good conditions, the time between vine killing and harvest is 10-14 days. 70% of the Michigan potato crop is placed in storage for shipment through the winter and spring. These potatoes may be treated with sprout inhibitors in the field or in storage to lengthen the natural period of dormancy. For the first two to three weeks in storage, tubers are held at high relative humidity and 50-60EF to cure. Temperatures are then slowly lowered to 40EF for tablestock, 36-38°F for seed, and 45-50EF for chipping potatoes. Most storage units use a forced-air system for ventilation and temperature control. Processing varieties are usually high in specific gravity while table stock varieties are lower (6).

Insect Pests

Colorado Potato Beetle
Leptinotarsa decimlineata



The Colorado potato beetle is an annual problem in Michigan. The use of imidacloprid over several years from 1995 has reduced populations considerably. Colorado potato beetle adults and larvae feed on leaves and stems. Damage can be extensive enough to cause plant death, and less severe infestations can weaken plants and cause decreases in yields.

Biology

Colorado potato beetles overwinter as adults in the soil in fields and field borders. Mortality over the winter may range from less than 10% to greater than 90%. Adults emerge in the spring and begin feeding on potato foliage. Peak emergence is generally during late May or early June. Adult emergence will continue for 3 to 4 weeks or more. Tomatoes, eggplant, nightshade and horse nettle are also hosts. Mating begins within a week of emergence and beetles continue to mate throughout their life. Females require 1 to 2 weeks of feeding before they are capable of laying eggs. After approximately mid-August, egg laying stops, in response to shorter day length. Larvae then feed on foliage and may take from 9 to 10 days to over a month to complete development, depending on temperature. The 4th instar feeds the most and grows the most rapidly. Larvae drop to the ground and dig 4 to 6" into the soil and pupate. The pupa spend 10 to 18 days in the soil before emerging as an adult. When the adult is formed, it burrows out of the soil and begins feeding almost immediately. This stage may be the most damaging to the potato crop. Large amounts of food are required by the beetle at this time, while the potato plant is often in the tuber bulking stage and is no longer producing large amounts of new foliage. In Michigan, there are generally one or two generations per year. In southern Michigan and in exceptionally warm years, there may be three generations (9 & 7).

General Control Information:

Colorado potato beetles have become extremely resistant to insecticides in many parts of Michigan. In 1998, yield loss from Colorado potato beetle was minimal to zero in Michigan and cost of control decreased overall from 1997 to 1998. However, a few districts saw an increase in cost (East Central (14.7% increase), Southwest (45.4%), and South Central (33%)) (4).

Growers reported Colorado potato beetle pressure in 1998 similar to that of 1997, except there was a slight decrease in the proportion of acres experiencing severe potato beetle pressure (more than 5 potato beetles per plant). There was an increase in insect pressure for the Upper Peninsula, Northwest and Northeast districts (4).

Cultural Controls:

Crop rotation is key to Colorado potato beetle management. Rotated fields have fewer beetle problems and may have lower levels of insecticide resistance. Crop rotation forces migration of short distances by beetles from one field to the next with the heaviest infestations in border rows. To reduce migration into new fields, winter wheat or a rye cover crop may be planted to interfere with beetle walking and flight. Like crop rotation, cover crops and a few potatoes can reduce flight out of the previous year's field. Adults may be delayed by 2 to 3 weeks in arriving at the new potato field. Movement results in insecticide-resistant beetles mixing and mating with susceptible beetles, reducing resistance populations (9).

Trap crops consisting of early-planted potatoes on the field border are effective in concentrating adults moving into fields in the spring. In the fall, when vines are killed, adults may be concentrated on late planted trap crops or unkilld strips of foliage, where physical controls such as flaming or vacuum suction are effective (12).

Mechanical Controls:

Growers have built propane “flamers” that kill beetles early in the season without injuring young potato plants. This technique is most effective on plants less than 4 inches high and where trap crops or field edges can be treated. Propane flamers may also be useful at harvest, especially if beetles can be concentrated on cull potatoes or on rows left without vine killing. Crop vacuums can also be effective at controlling adults and larvae early in the season and are more effective on larger plants than propane flamers. However, crop vacuums are more costly to build and maintain than the propane flamers. Trenches lined with black plastic can help prevent beetles from migrating into new fields from adjacent overwintering sites or last year’s field. Trenches need to be only a few inches wide and 6 inches to 1 foot deep (9).

Biological Controls:

A number of natural enemies attack the eggs, larvae, pupae and adults of the Colorado potato beetle. However, none act effectively to control potato beetles in commercial situations. Probably the most severe natural mortality in commercial potato fields occurs from heavy rains. Natural enemies that attack the eggs include: lady beetles and lady beetle larvae, lacewing larvae, stink bugs, and a ground beetle, *Lebia grandis*. Larvae are attacked by stink bugs, *Lebia* ground beetles, and a parasitic fly. Pupae are attacked in the soil by larvae of *Lebia*. Adults are occasionally attacked by stink bugs and species of ground beetles. Efforts have been made to import natural enemies from Mexico. A microscopic mite that attacks potato beetles has been studied and reduces flight activity. A tiny wasp that attacks eggs has been effective in controlling Colorado potato beetle in eggplant, using mass releases of reared wasps. The wasp, however, does not overwinter in the northern US. Other foreign biocontrol agents are being investigated and may prove to be effective. *Bacillus thuringiensis* is used to control Colorado potato beetle larvae. It usually stops larva feeding within 4 to 8 hours, but death may take 3 or 4 days. Small larvae are the most susceptible. Middle-size to mature larvae and adults show little response. Therefore, precise timing of Bt application is critical for effective control. Treatments may need to be repeated in 3 to 5 days if weather is warm and newly hatched larvae are growing rapidly (9).

Chemical Controls:

Abemectin, endosulfan, imidacloprid, esfenvalerate, *Bacillus thuringiensis*, cyfluthrin, carbaryl, cryolite, azinphos-methyl, carbofuran, phosmet, methyl-parathion, permethrin, spinosad, and oxamyl.

Alternative Controls:

NewLeaf is a modified Russet Burbank or Atlantic type of potato highly resistant to Colorado potato beetle and is engineered to express the Bt toxin gene. Widespread use could result in Bt-resistant CPB. Spintor (spinosad) is an effective material, especially used in an IPM/resistance management program. Thiamethoxam, a new insecticide from Novartis, is effective against CPB, although there may be cross-resistance problems with imidacloprid (4 & 8).

Green Peach and Potato Aphids

Myzus persicae, *Macrosiphum euphorbiae*



Potato aphid.

Green peach and potato aphids cause damage annually in Michigan. The aphids injure plants by feeding on plant juices or through transmission of plant viruses. Damage is not often observed until the crop experiences premature death or early senescence. At that point, yield loss is irreversible (6). Aphids affected 6.5% of the acres surveyed in 1998 and 28% in 1997 (4).

Biology:

Green peach aphids overwinter as eggs on peach trees and other stone fruit or sometimes in greenhouses. Potato aphids overwinter as eggs on wild roses and their relatives. The eggs hatch in the spring. After one or more generations on the overwintering host, winged aphids are produced that migrate to a variety of other hosts, including vegetable crops. Winged forms appear throughout the season, especially when the host plant is dying or aphids become crowded. A female does not lay eggs but gives live birth to immature aphids. All offspring will be female. Each aphid can give birth to 50 to 100 young and there may be 5 to 10 generations or more per year. In the fall, a generation with winged males and females is produced. These migrate back to overwintering hosts, mate and lay eggs (7).

General Control Information:

Control measures are generally taken from June through vine-kill. Yield losses can be as great as 100% if seed potatoes are rejected because of aphid-transmitted viruses.

Table 1. Regional differences in green peach aphid and potato aphid infestation.

District	Affected		
	# acres	% of acres	% untreated
Upper Peninsula	169	25%	0%
Northwest	295	38%	4%
Northeast	232	40%	18%
West Central and Central	100	1%	1%
East Central	25	0.5%	0%
Southwest	506	35%	0%
South Central	117	2%	2%
Southeast	275	23%	0%
Total	1719	7%	1%

Cultural Controls:

Avoid planting fields immediately downwind of any barrier. Hedgerows, wood lots, or hilly terrain reduce wind velocity and increase the number of dispersing aphids falling into fields. The use of reflective mulches or oil

sprays may limit virus transmission by migrant aphids, but this is not practical for commercial scale plantings. Harvest the crop as early as possible to minimize vulnerability to late-season aphid colonization and virus infection. Elimination of weeds in and around fields may prove to be beneficial. Rogue volunteer plants and diseased plants. Some varieties are virus-resistant (6). Crops should be planted in well-prepared, fertile seedbeds to promote vigorous growth. When possible, avoid planting near fields with a history of infestation or from which an aphid-infested crop has been removed (28).

Biological Controls:

Aphids have an extremely high reproductive rate, but are usually held in check by natural enemies when populations are low (lady beetles, hover fly larvae, lacewing larvae, fungal diseases, syrphid larvae, stilt bugs and tiny wasps) (7). The wasp larvae develop inside the aphid and eventually kill it (7). However if populations are high, natural enemies do not provide adequate control (29). Epidemics of the disease caused by the fungus *Entomophthora aphidis* may kill a portion of the green peach aphid population under some conditions. Parasites include *Lysiphlebus testaceipes*, *Aphidius matricariae*, and *Aphelinus semiflavus* (29).

Chemical controls:

Methamidophos, pymetrozine, imidacloprid, dimethoate, disulfoton, methomyl, endosulfan, and methyl parathion, and phorate.

Alternatives Controls:

Pymetrozine (trade name Fulfil), a new insecticide from Novartis, is a potential alternative, and results from preliminary trials have been encouraging. EPA has fast tracked registration of pymetrozine.

White Grubs and Wireworms

Phyllophaga spp. and *Conoderus spp.*



White grubs and wireworms occur sporadically in Michigan. Surface injury or tunneling in potato tubers is most common in potatoes grown following grassy weeds, hay or pasture (7).

Biology:

Most June beetles have a three year life cycle causing most damage in the second year. In June, the adults lay eggs in the soil. Within two weeks, white grubs emerge. They feed during the warm summer months and 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 (30).

General Control Information:

The best time to control white grubs and wireworms is between June and September (6). There are no reported

regional differences.

Cultural Controls:

Potatoes should not be planted in fields that have been in sod crops for the previous two years. In some cases, wireworm and grub infestations may be initiated in wheat and small grain crops. In these cases, substitution of a row crop such as corn in the rotation is advisable. Avoid planting in poorly drained soils or wet areas. Keeping land free of grassy weeds during the egg-laying period (May through late June) will greatly reduce the potential for infestation (6).

Biological Controls:

There are several natural enemies (skunks, moles, crows and blackbirds) as well as a few parasitic nematodes that control these insect pests (30).

Chemical Controls:

White Grub: effective chemical control is not presently available

Wireworm soil treatment at planting: diazinon and ethoprop.

Alternatives Controls:

Fipronil (trade name Agenda may be a useful alternative in wireworms control in the future, but trials have yet to be conducted) (6).

Potato Leafhopper

Empoasca fabae



Potato leafhoppers occur annually in Michigan affecting 100% of the acres. The potato leafhopper (PLH) is a sucking insect, removing plant sap directly from the vascular system in the leaflet, petioles, and sometimes the stem. Both adults and nymphs feed on the plant sap and cause “hopper burn”. Foliage turns yellow, then brown, and plants may be stunted and yield reduced. In the feeding process, PLH injects a salivary toxin that causes injury to the plant. PLH can stunt potato plants, and may even cause plant death in seedlings (6 & 7). Yield loss occurs even before the development of obvious symptoms. Many varieties will show little evidence of hopperburn, and yet yield losses can be substantial (12).

Biology:

Potato leafhoppers migrate into Michigan from overwintering sites in the south, usually arriving in May. The potato leafhopper feeds on a wide range of plants, including alfalfa and beans, and may migrate into potatoes from these hosts. There may be 4-6 generations per year (7). Eggs are laid singly within the petioles and veins on the under surface of foliage. Eggs hatch in ten days, and the nymph passes through five stages within a period of 12-35 days (6).

General Control Information:

Control measures need to be taken from May, when the potato leafhoppers arrive in Michigan, through August. Yield losses can be as great as 75% in severely infested fields (6). Damage and yield loss is not dependent on region.

Cultural Controls:

Two varieties have some resistance to potato leafhopper, but these varieties are not acceptable to most markets (6).

Biological Controls:

Although a variety of natural enemies of potato leafhopper have been reported, their impact on infestations is not well known (6).

Chemical Controls:

Endosulfan, imidacloprid, esfenvalerate, cyfluthrin, carbaryl, azinphos-methyl, carbofuran, phosmet, methyl-parathion, permethrin, Dimethoate 4EC, malathion, and methamidophos, disulfoton, phorate, methomyl.

Flea Beetles
Epitrix cucumeris



Flea beetles occur annually in Michigan. They chew numerous small holes in foliage and can be especially damaging to young plants. Flea beetle larvae feed on plant roots and sometimes injure potato tubers. Summer adults emerge in late July or August and again feed on foliage (7).

Biology:

Flea beetles overwinter in the soil and emerge early in the spring to feed and lay eggs. Larvae feed on plant roots and adults emerge in late July or August and feed on the foliage (7).

General Control Information:

Control measures are recommended for May, late July and August. Yield losses are minimal. There is no difference between regions.

Cultural Controls:

Controlling weeds in and around the field is important. By eliminating trash where beetles can overwinter, adult beetle population can be reduced. Planting seeds and thinning after early flea beetle season has passed will also reduce beetle populations (31). Late planting also favors growth of host plants over establishment of flea beetles (32).

Biological Controls:

Naturally occurring predators, parasitoids, and pathogens may help suppress infestations (6).

Chemical Controls:

Endosulfan, esfenvalerate, cyfluthrin, carbaryl, azinphos-methyl, carbofuran, methyl-parathion, permethrin, diazinon, methomyl, methyl parathion, methamidophos, disulfoton, phorate.

Alternative Controls:

Planting an early-season trap crop is an option, where a very small planting of one of the cole crops, or another preferred crop such as radish is planted, usually along a field edge. Adult flea beetles will be attracted to the tallest earliest crops available. Once beetles are actively feeding in these crops, a labeled insecticide can be applied. Potatoes should then be planted 7-14 days after the trap crop, to encourage the flea beetles to stay in the trap crop area (33).

Variegated Cutworms and Spotted Cutworms

Peridroma saucia and *Xestia c-nigrum*



Both species of cutworm occur sporadically in Michigan. They cause both foliar and tuber injury to potatoes. Small larvae tend to feed on foliage; larger larvae burrow into the soil and feed on tubers (7).

Biology:

Cutworms overwinter either as large larvae or as eggs in the soil. They tend to be most abundant in weedy areas in a field or adjacent to cover crop strips after the cover crops are killed or tilled under. They pupate in the soil and adult moths emerge in June or July. They may have 1-3 generations per year (6).

General Control Information:

Control is needed all season long. There are no regional differences.

Cultural Controls:

Biological Controls:

There are several insects that are known to parasitize and prey upon the variegated cutworm in the field. *Euplectrus plathypenae* has been reported as a parasite of variegated cutworm. *Archytas cirphis*, *chaetogoedia monticola*, *chelonus texanus*, *eucelatoria armigera*, *Hyposoter exiguae*, *Meterus laphygmae*, *Pesudamblyteles koebelei*, and *Pterocormus rufiverntis* are suspected to parasitize this pest. *Calosoma blaptoides tehuacanum* is a predator (34). Beneficial nematodes eat cutworms and other insects which are found in the soil. Some parasitic wasps deposit eggs in the body of the cutworm which pupate on its back and kill the cutworm (35).

Chemical Controls:

Esfenvalerate, permethrin, cyfluthrin, carbaryl, endosulfan, methomyl, methamidophos, methyl-parathion, and

spinosad.

Alternative Control:

Pheromone traps have been used with limited success to trap out certain pests. However, they are not a control measure, they are simply used to monitor pests). Trapping out is most likely to succeed when the pest density is low initially and immigration into the pheromone treated area is minimal (36).

European Corn Borer

Ostrinia nubilalis



European corn borers occur in the field occasionally, although 100% of fields are at risk. However, only about 25% are affected per year (7). Reduced yields occur when disease organisms cause stems to collapse and tubers rot. Potatoes that are produced on infested plants are often of poor quality due to development of diseases such as black leg (37).

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 in crop residue, and adult moths begin to emerge in late May to early June and reach a peak in mid-June. When the European corn borer attacks potato, egg masses are laid on the undersides of leaves and on stems. The larvae develop through 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 (12).

General Control Information:

Insecticides must be applied weekly from the time of the first application date, which is usually around the first week in May, through significant moth flight. However the only time that growers may consider spraying for ECB is when corn is unsuitable for egg laying, e.g. when it is small, senescing, drought conditions etc., then ECB may lay eggs on other hosts.

Cultural Controls:

Avoid planting potatoes in fields following corn. Mow grassy areas around fields to eliminate breeding areas and disk corn stubble (6).

Biological Controls:

Naturally occurring predators (ladybird beetles, predaceous mites and downy woodpeckers), parasitoids (flies and wasps which have been introduced from Europe), and pathogens may help suppress infestations, but information is lacking (6).

Chemical Controls:

Esfenvalerate, permethrin, cyfluthrin, carbaryl, endosulfan, carbofuran, azinphos-methyl, methamidophos, methyl-parathion, spinosad.

Alternatives:

There is a biological insecticide, *Bacillus thuringiensis* (37).

PESTICIDE PROFILES

(RUP: *Restricted Use Pesticide*)

Abamectin (Antibiotic)

Formulations- Agrimek.

Pests Controlled- Colorado potato beetle.

Acres of Crop Treated- 11,000 (2).

Application Rate- 0.008lb ai/A (2).

Types of Application- Ground applied only (25).

Timing- Application should occur after 50% of the egg masses have hatched and larvae are present (26).

Pre-Harvest Interval- 14 days (25).

REI- 12 hrs (26).

IPM Concerns- No information available.

Use in Resistance Management Programs- One of only a few registered materials that works on resistant CPB.

Efficacy Issues- Only 2 applications per season are recommended to avoid occurrence of resistance(26). There is a short residual, however it works against resistant Colorado potato beetle.

Azinphos-methly (organophosphate)

Formulations- Guthion Solupak 50WP

Pests Controlled- Flea beetle, Colorado potato beetle, leafhoppers, and European corn borer.

Acres of Crop Treated- 20,172(2)

Application Rate- 0.4(25)

Types of Application- Aerial, ground irrigation and chemigation(26)

Timing- Post Planting

Pre-Harvest Interval- 7 days(26)

REI4 days(26)

IPM Concerns- Broad spectrum insecticide

Use in Resistance Management Programs- Colorado beetle resistance has occurred(26)

Efficacy Issues- Most Colorado potato beetles in Michigan are resistant to it.

Bacillus thuringiensis spp. *tenebrionis*

Formulations- Foil, Novodor, and M-Trak

Pests Controlled- Colorado potato beetle

Acres of Crop Treated- 4830(2)

Types of Application- Ground and aerial

Timing- works best on small larvae(25)

Pre-Harvest Interval- 0 days

REI- 4 hrs(26)

IPM Concerns- no info. available

Use in Resistance Management Programs- Alternative mode of action therefore it works well on resistant Colorado potato beetle. Must not mix Foil with Bravo(25). works well only against small larvae. Timing of application is critical and it does not impact natural enemies.

Efficacy Issues-

Carbaryl (carbamate)

Formulations- Sevin 80S, SevinXLR+

Pests Controlled- Flea beetle, Colorado potato beetle, leafhoppers, cutworms and European corn borer.

Acres of Crop Treated- 10,128(2)

Application Rate (lb ai/A)- 0.95(2)

Types of Application- Ground, aerial, sprinkler irrigation(26)

Timing- Post planting(25)

Pre-Harvest Interval- 7 days(25)

REI- 12 hrs

IPM Concerns- Broad spectrum insecticide

Use in Resistance Management Programs- no info. available

Efficacy Issues- Not used much in Michigan since most CPB populations are resistant.

Carbofuran (Carbamate)

Formulations**Pests Controlled-** Flea Beetle, Colorado potato beetle, leafhoppers, and European corn Borer.

Acres of Crop Treated- 5332.5 (2).

Application Rate (lb ai/A)- 0.54 (2).

Types of Application- Foliar and soil application (25).

Timing- Post planting (25).

Pre-Harvest Interval- 14 days (25).

REI- 48 hrs (26).

IPM Concerns- No information available.

Use in Resistance Management Programs- Must not use more than once a season or serious resistance problems may arise with Colorado potato beetle (26).

Efficacy Issues- Broad-spectrum insecticide. Not used in Michigan very often since most CPB populations are highly resistant.

Cryolite (Inorganic Fluorine)

Formulations- Cryolite (Kryocide, Pro-kil Cryolite) 96W.

Pests Controlled- Colorado potato beetle.

Acres of Crop Treated- 5600 (2).

Application Rate (lb ai/A- 9.05 (1991)-11.19(1995) (2).

Types of Application- Aerial, ground (26).

Timing:- Post planting, most effective on small to medium size larvae (25).

Pre-Harvest Interval- 0 days (25).

REI- 12 hrs (26).

IPM Concerns- No information available.

Use in Resistance Management Programs- No information available.

Efficacy Issues- Must not irrigate within 48 to 72 hours of application (26). Moderate efficacy on resistant CPB. It is very hard on spray equipment.

Cyfluthrin (Synthetic pyrethroid)

Formulations- Baythroid 2.

Pests Controlled- Flea Beetle, Colorado potato beetle, leafhoppers, cutworms and European corn borer.

Acres of Crop Treated- 13,920 (38).

Application Rate (lb ai/A)- 0.04 (2).

Types of Application- Chemigation, sprinkler irrigation, aerial, ground (26).

TimingNo information available.

Efficacy Issues No- Post planting (26).

Pre-Harvest Interval - 0 days (26).

REI - 12 hrs (26).

IPM Concerns - Resistance of Colorado potato beetle with repeated use will occur (26). Will not work on CPB populations that are resistant to pyrethroids.

Use in Resistance Management Programs - information available.

Dimethoate (Organophosphate)

Formulations- Dimethoate 4EC.

Pests Controlled- Leafhoppers.

Acres of Crop Treated- 2722.5 (2).

Application Rate (lb ai/A)- 0.43 (2).

Types of Application- Ground or Aerial (26).

Timing- Post planting (25).

Pre-Harvest Interval- 7 days (25).

REI- 48 hrs (26).

IPM Concerns- No information available.

Use in Resistance Management Programs- No information available.

Efficacy Issues- Insecticide of choice when leafhoppers alone are a concern.

Disulfoton (Organophosphate)

Formulations- Di-syston 8EC.

Pests Controlled- Aphids, flea beetles, leafhoppers.

Acres of Crop Treated- No information available.

Application Rate (lb ai/A)- 2.52 (2).

Types of Application- chemigation, soil-applied (26).

Timing- Pre-plant broadcast, at planting and post planting (25).

Pre - Harvest Interval- 30 days (25).

REI- 48 hrs (26).

IPM Concerns- Resistance in Colorado potato beetle has been recorded (26).

Use in Resistance Management Programs- No information available.

Efficacy Issues- Not generally used since it is used at planting and aphids and leafhoppers are generally not a problem until later in the year.

Esfenvalerate (Pyrethroid)

Formulations- Asana XL.

Pests Controlled- Flea beetle, Colorado potato beetle, leafhoppers, cutworms, aphids and European corn borer (25).

Acres of Crop Treated- 14,430 (2).

Application Rate (lb ai/A)- no more than 0.35/season (25).

Types of Application- Chemigation, aerial and ground.

Timing- Post planting as insects appear (25).

Pre - Harvest Interval- 7 days (25).

REI- 12 hrs (26).

IPM Concerns- No information available.

Use in Resistance Management Programs- Works well on some CPB populations that are resistant to other insecticides.

Efficacy Issues- Must avoid overuse.

Endosulfan (Chlorinated hydrocarbon)

Formulations- Phaser 3EC, or Thiodan 3EC

Pests Controlled- Flea beetle, Colorado potato beetle, leafhoppers, cutworms, aphids and European corn borer (25).

Acres of Crop Treated- 14,430 (2).

Application Rate (lb ai/A)- no more than 3 (26).

Types of Application- Chemigation, aerial and ground.

Timing- Post planting as insects appear (26).

Pre-Harvest Interval- 1 day (25).

REI- 24 hrs (26).

IPM Concerns- No information available.

Use in Resistance Management Programs- Some CPB populations are resistant to endosulfan therefore must avoid repeated applications to prevent resistance development.

Efficacy Issues- No information available.

Ethoprop (Organophosphate)

Formulations- Mocap 10G, Mocap 15G, Mocap 20G.

Pests Controlled- Wireworms (25).

Acres of Crop Treated- No information available.

Application Rate (lb ai/A)- 30 (25).

Types of Application- Soil applied, row treatment, incorporated (26).

Timing- At planting.

Pre-Harvest Interval- 14 days (26).

REI- 48 hrs (26).

IPM Concerns- No information available.

Use in Resistance Management Programs- No information available.

Efficacy Issues- Delayed emergence may result under stressful environmental conditions (26).

Imidacloprid (Chloronicotinyl)

Formulations- Provado 1.6F, Admire 2F.

Pests Controlled- Colorado potato beetle, leafhopper, and aphids.

Acres of Crop Treated- 42,900 (2).

Application Rate(lb ai/A)- 0.14(2).

Types of Application- Ground and aerial (25).

Timing- Post, furrow treatment (25).

Pre-Harvest Interval- 7 days (25).

REI- 12 hrs (26).

IPM Concerns- No information available.

Use in Resistance Management Programs- Concern for potential resistance development.

Efficacy Issues- Provado foliar application following a soil-applied application of Admire on the same crop is not recommended (25). Very effective against CPB and aphids.

Malathion (Organophosphate)

Formulations- Malathion 57EC.

Pests Controlled- Leafhoppers and aphids.

Acres of Crop Treated-

Application Rate (lb ai/A)- 0.86 (2).

Types of Application- Chemigation, ground and aerial (25).

Timing- Post planting as the pest appears (25).

Pre-Harvest Interval- 0 days (26).

REI- 12 hrs (26).

IPM Concerns- No information available.

Use in Resistance Management Programs- No information available.

Efficacy Issues- No information available.

Methamidophos (Organophosphate)

Formulations- Monitor 4EC.

Pests Controlled- Flea Beetle, leafhoppers, aphids, cutworms, and Colorado potato beetle and European corn borer.

Acres of Crop Treated- 18,146 (2).

Application Rate (lb ai/A)- 0.75-1.0(25).

Types of Application- Ground, aerial, chemigation, and soil applied (26).

Timing- Post planting as pests appear (25).

Pre-Harvest Interval- 14 days (25).

REI- 48 hrs (26).

IPM Concerns- No information available.

Use in Resistance Management Programs- Widely used for late-season aphid control (after Admire).
Efficacy Issues- Carryover in soil from year to year and potential for resistance development(25). Very effective against aphids.

Methomyl (Carbamate)

Formulations- Lannate SP.

Pests Controlled- Flea Beetle, leafhoppers, aphids, and cutworms.

Acres of Crop Treated- No information available.

Application Rate (lb ai/A)- No information available.

Types of Application- ground and aerial (25).

Timing- Post planting (25)

Pre-Harvest Interval- 6 days (25).

REI- 48 hrs (26).

IPM Concerns- Should be used in combination with an IPM program (26).

Use in Resistance Management Programs- No information available.

Efficacy Issues- No information available.

Methyl parathion (Organophosphate)

Formulations- Methyl parathion 7.5EC, Penncap-M 2F.

Pests Controlled- Flea beetle, leafhoppers, and aphids.

Acres of Crop Treated- 11,830 (2).

Application Rate (lb ai/A)- 0.74 (2).

Types of Application- Chemigation, sprinkler (overhead) irrigation (26).

Timing- Post planting (25).

Pre-Harvest Interval- 5 days (25).

REI- 5 days (26).

IPM Concerns- No information available.

Use in Resistance Management Programs- No information available.

Efficacy Issues- No information available.

Oxamyl (Carbamate)

Formulations- Vydate 2L.

Pests Controlled- Colorado potato beetle, aphids, flea beetles, and leafhopper.

Acres of Crop Treated- No information available.

Application Rate (lb ai/A)- 0.63 although 0.22 in 1992 (2).

Types of Application- Sprinkler chemigation, drip chemigation (26).

Timing- Pre-plant in-furrow treatment and foliar (26).

Pre-Harvest Interval- 7 days (25).

REI- 48 hrs (26).

IPM Concerns- No information available.

Use in Resistance Management Programs- No information available.

Efficacy Issues- Use light rates at low infestation and high rates at severe infestation (25).

Permethrin (synthetic pyrethroid)

Formulations- Ambush 2EC, 6.4oz or 25WP, 6.4oz (25). Pounce 3.2EC, 4 to 8oz or 25 WP, 6.4 to 12.8oz (25).

Pests Controlled- Flea beetle, Colorado potato beetle, and leafhoppers.

Acres of Crop Treated- 4,000 (2).

Types of Application- Chemigation, commercial impregnation on dry bulk fertilizer (26).

Timing- Post planting.

Pre-Harvest Interval- 14 days (26).

REI- 12 hrs (26).

IPM Concerns- No information available.

Use in Resistance Management Programs- Most CPB populations are resistant to this product. Use of this product on other insects would exacerbate resistance problem.

Efficacy Issues- No information available.

Phorate (Organophosphate)

Formulations- Thimet 20G

Pests Controlled- Aphids, flea beetles, Colorado potato beetle, wireworms, and leafhoppers.

Acres of Crop Treated- 8,700 (2).

Application Rate (lb ai/A)- no more than 11.5 on light or sandy soils and no more than 17.7 on heavy or clay soils (26).

Types of Application- Furrow treatment.

Timing- Post emergence and at planting (6).

Pre-Harvest Interval- 90 days (26).

REI- 48 hrs (26).

IPM Concerns- No information available.

Use in Resistance Management Programs- No information available.

Efficacy Issues- Not very effective against Colorado potato beetle.

Phosmet (Organophosphate)

Formulations- Imidan 70WP.

Pests Controlled- Colorado potato beetle and leafhoppers.

Acres of Crop Treated- 20,509 (2).

Application Rate (lb ai/A)- 0.8 (2).

Types of Application- No information available.

Timing- Post planting when pests arrive.

Pre-Harvest Interval- 7 days (25).

REI- No information available.

IPM Concerns- No information available.

Use in Resistance Management Programs- Most Colorado potato beetle populations are resistant. Use of this product for other pests would exacerbate resistance problems.

Efficacy Issues- No information available.

Pymetrozone (Antifeedants)

Formulations- Fulfill 50WDG.

Pests Controlled- Aphids.

Acres of Crop Treated- No information available.

Application Rate- No more than 2.75 oz/A (2).

Types of Application- Ground, aerial (25).

Timing- Post planting when Aphids arrive (26).

Pre-Harvest Interval - 14 days (25).

REI - 12 hrs (26).

IPM Concerns - No information available.

Use in Resistance Management Programs - Fulfill is a new class of insecticide that is not known to be cross-resistant with other products. Low toxicity to beneficial insects therefore good insecticide to make use of in an IPM program (26).

Efficacy Issues - Does not kill aphids immediately, causes cessation of feeding and then aphids starve.

Spinosad (Actinomycete)

Formulations- Spintor 2SC.

Pests Controlled- Colorado potato beetle, cutworms, and European corn borer.

Acres of Crop Treated- No information available.

Application Rate- 3-6 oz/A (2).

Types of Application- Chemigation, aerial (26).

Timing- When pests appear, post planting (25).

Pre-Harvest Interval- 7 days (25).

REI- 4 hrs (26).

IPM Concerns- Spintor is recommend to be used in combination with an IPM program including economic threshold (26).

Use in Resistance Management Programs- New mode of action, therefore there has been no resistance built up to this product yet.

Efficacy Issues- Can not apply Spintor to consecutive generations of Colorado potato beetle and not more than two per single generation (26).

Nematodes

Root-Lesion Nematode

Pratylenchus penetrans)



Root lesion Nematode

Root-lesion nematodes are very common parasites of potato. They are found in virtually all fields in which potatoes are produced in Michigan. High populations of lesion nematodes cause areas of poor growth. These nematodes penetrate root tissue and feed within the root cortex destroying cells. The primary symptoms of root-lesion nematode infections are microscopic lesions on roots and stolon tissue. Infected roots usually turn dark brown or reddish in color. Lateral roots are often destroyed. Secondary symptoms include mild yellowing and stunting of the foliage and yield losses. Above ground symptoms due to root-lesion nematode feeding are often quite subtle and are difficult to distinguish from symptoms of other infectious or noninfectious diseases. Root-lesion nematodes are known to interact with the soil fungus, *Verticillium dahliae*. Root-lesion nematodes may also predispose potatoes to infection by other fungi such as *Colletotrichum*, *Fusarium* or *Rhizoctonia* or the bacterium, *Erwinia carotovora* subs. *atroseptica*, the cause of potato blackleg (21).

Biology:

All species of root-lesion nematodes are migratory endoparasites. They usually are found within root tissue but will also invade stolons and tubers. Juveniles and adults infect roots, often migrating in and out of tissue creating many wounds. Once they enter root tissues, they migrate throughout the roots feeding on cortical cells. Eggs are laid within root tissue. Depending on temperature, generation time is about 4 to 8 weeks. Root-lesion nematodes overwinter as adults and juveniles in soil and root tissue. Roots are the preferred overwintering sites (21).

General Control Information:

Control measures should be taken before planting to ensure maximum control of root-lesion nematode and reduce yield loss. Although lesion nematodes can potentially cause yield losses of potato, the greatest losses occur when the nematodes interact with other soil pathogens such as *V. dahliae*. Yield losses of over 100 cwt/A have been documented in situations where lesion nematode and *dahliae* interact.

Cultural Controls:

Excluding or avoiding nematodes and other pathogens should be the principal tactic of any management program. Once fields are infested, these organisms are virtually impossible to eradicate. Purchasing and sowing disease-free tubers is imperative in keeping fields free from disease. Most potato fields in Michigan are infested with at least one species of nematode and *Verticillium dahliae*, therefore utilization of disease-free tubers may not be advantageous except possibly following soil fumigation. Movement of pathogen-contaminated soil from field to field promotes the spread of these problems. All low risk fields should be worked as a unit before entering high risk sites or equipment should be cleaned and preferably sterilized between fields. Control of soil erosion is very critical (21).

Physical controls usually involve the use of steam, water or fire to control plant pathogens. Potato vines can support very high numbers of *Verticillium* propagules. These vines are generally left in the field after harvest and plowed into the soil. Removing and destroying these vines can substantially reduce *Verticillium* populations (21).

Avoid planting rotation crops that are good hosts for root lesion nematodes in the year prior to planting potatoes. Unfortunately, most agronomic crops are good to excellent hosts for lesion nematodes. Plants such as marigolds may reduce the populations of nematodes but these crops are usually of no economic value to the grower. Sorghum or sorghum-sudan grasses are poor hosts for lesion nematodes (22).

Biological Controls:

Organisms have been identified that parasitize lesion nematodes. However, no large-scale biocontrol programs have been implemented.

Chemical Controls:

Fumigants and nonfumigant nematicides are labeled for use in Michigan potatoes. Fumigants are effective but are quite expensive. They provide excellent control of lesion nematodes and good control of *V. dahliae*. They should only be applied to sites where results from diagnostic analyses indicate high risks to subsequent potato crops.

Nonfumigant nematicides can provide excellent control of lesion nematodes. They are beneficial on sites with high nematode pressure where *V. dahliae* levels are low. Use of nonfumigant nematicides can result in improved plant health and yield increases.

Alternative Controls:

Currently there are no known varieties that are resistant to root-lesion nematode, although research is currently being conducted to identify and increase resistance in various varieties (24).

Root-knot Nematodes

Meloidogyne hapla

Root-knot nematodes are often recovered from soil samples collected from Michigan potato fields. There are three species of root-knot nematodes known to infect potatoes but only the Northern root-knot nematode occurs with any great frequency in our state. The Northern root-knot nematode invades the roots and tubers of potato. Feeding within roots produces small, but often distinct swellings on roots known as galls. Infection sites within tubers are identified by small brown spots. Root-knot nematodes affect less than half of the potato fields in Michigan (21).

Biology:

The second-stage juveniles are the infective stages. The juvenile nematodes are attracted to host roots and penetrate them behind the root caps and begin feeding on cells that eventually form vascular tissue. This feeding results in the formation of galls. As infected roots continue to grow, the vascular tissue forms but is disrupted by the presence of the nematodes. Mature females are balloon-shaped. Eggs are produced in a gelatinous matrix by the females. Northern root-knot nematodes overwinter as eggs in the soil.

General Control Information:

Northern root-knot nematodes can cause yield losses of potato, but are typically spotty in fields.

Cultural Controls:

(See Root-lesion) Crop rotation is an effective way to control root-knot nematodes, since root-knot nematodes do not invade annual ryegrass, timothy or cereal crops (23).

Biological Controls:

No large-scale biological control programs have been effective.

Chemical Controls:

Fumigant and nonfumigant nematicides are labeled for use on potato and will provide control of northern root-knot nematodes (23).

Alternative Controls: None.

Nematicide Profiles:**1,3-Dichloropropene(unclassified nematicides)**

Formulations: Telone II, Telone C-17.

Pests Controlled: Nematodes.

Acres of Crop Treated: No information available.

Application Rate: 15 to 40 gal/A (depending on soil type).

Types of Application: Broadcast inject to a depth of 8 inches.

Timing: Fall, when soil temperatures at 6 inches are 50 10.0 F or higher.

REI: 5 days (26).

IPM Concerns: Broad-spectrum biocide will kill many soil organisms.

Use in Resistance Management Programs: No information available.

Efficacy Issues: May not provide effective control when applied to organic soils.

Ethoprop (Organophosphate)

Formulations: Mocap 10G, Mocap 6EC.

Pests Controlled:Nematodes.

Acres of Crop Treated: No information available.

Application Rate: 30 lb ai/A (26).

Types of Application: Broadcast and incorporated or banded at planting.

Timing: Preplant soil treatment and soil treatment at planting (25).

Pre-Harvest Interval:14 days (26).

REI: 48 hrs (26).

IPM Concerns: Will kill beneficialorganisms.

Use in Resistance Management ProgramsNo information available.

Efficacy Issues: Delayed emergence may result under stressful environmental conditions. Does not provide good control unless incorporated into the soil (26).

Metam-sodium (unclassified nematicides)

Formulations: Metam, Busan 1020, and Vapam.

Pests Controlled: Nematodes.

Acres of Crop Treated: No information available.

Application Rate:50 to 100 gal/A.

Types of Application:Chemigation (26).

Timing: Fall application, and in some years spring application is possible (26).

Pre-Harvest Interval: No information available.

REI:No information available.

IPM Concerns: Will kill beneficial organisms.

Use in Resistance Management Programs: No information available.

Efficacy Issues: May be ineffective if applied to warm soils >70°F).

Oxamyl (Carbamate)

Formulations: Vydate 2L.

Pests Controlled:Nematodes.

Acres of Crop Treated: No information available.

Application Rate: 1 to 4 gal/A.

Types of Application: Nonfumigant.

Timing: Preplant soil treatment and soil treatment at planting.

Pre-Harvest Interval: 7 days (25).

REI: 48 hrs (26).

IPM Concerns: No information available.

Use in Resistance Management Programs: No information available.

Efficacy Issues: Use light rates at low infestation and high rate at severe infestation.

Diseases

Seed Piece Decay and Seedborne Pathogens:

Many species of seed piece decay and seedborne pathogens occur sporadically in Michigan, affecting Typically 5-10% of the acres of potatoes grown are affected, although 100% of the acres are at risk. Potato seed pieces can become infected with fungal or bacterial pathogens causing decay. Yield loss is due to loss of plant stand (6).

Biology:

Seed pieces can become infected by *Fusarium*, and *Streptomyces* spp. as well as by a range of bacterial soft rot pathogens. These pathogens may be soil-borne or may come in on the seed potatoes(6).

General Control Information:

Fields can experience up to 50% yield loss in severely affected fields due to stand loss (6).

Cultural Controls:

Proper handling of seed potatoes prior to planting is an essential step in disease management. Growers should inspect seed on receipt and should reject any lot with visible frost injury or with extensive scab or *Rhizoctonia* sclerotia on the surface. Tubers also should be checked for fusarium dry rot. Growers often must store seed potatoes for 6-8 weeks prior to planting. Seed in burlap sacks should not be sorted more than two pallets high, and space must be allowed for adequate aeration. All storage areas should be disinfected prior to receipt of seed potatoes to minimize contamination from pathogens associated with previous crop residues. Seed should be held

below 45 F but above freezing. Seed should be allowed to warm above 55 E F only just before the cutting operation. Cutting of seed pieces from whole “A-size” tubers is a prime point in the production cycle for spread of tuber-borne pathogens, particularly ring rot and soft rot bacteria. Seed-cutting equipment should be thoroughly disinfected before use and again between each seed lot. After fungicide treatment, cut seed should be held at 55EF, with good air movement through the seed piece pile to hasten the healing process. Some growers cut seed pieces and plant immediately. This works well if soil temperatures are in the 55-65 E F range so that healing can proceed rapidly in the soil. In cold, wet soil, unhealed seed pieces are more likely to rot prior to germination. The use of uncut, “B-size” seed tubers avoids the risks of seed cutting and eliminates the need for healing procedures. However, higher cost and horticultural considerations often preclude the use of whole seed (10).

Biological Controls:

Post-Harvest Controls:

Thiabendazole (Mertect 340) is used to treat seed going into storage or at the time of shipping. This must be done at least 6 weeks before planting. 0.42 fl oz/ton of potatoes is applied in enough water for complete coverage. It is applied as a spray to potato tubers (seed and table stock) at the time of storage and again at removal (8)

Alternatives:

None available at this time.

Fungicides for Seed Treatments:

Fludiozonil, thiophanate-methyl (8).

Late Blight



Late blight was confirmed in 1998 at one site(4). Although all fields are potentially at 100% risk of infection. In the past several years Late Blight has affected 20-30% of the potato acres in Michigan. During favorable weather - periods of moderate temperatures, high humidities, and frequent rainfall - the disease can spread rapidly by means of air borne and rain splash borne spores known as sporangia, and it has the potential of completely defoliating fields within three weeks of the first visible infections if no control measures are taken. In addition to blighting the foliage, the spores of the fungus can infect tubers before or during harvest and lead to tuber rot(13).

Biology:

Late blight is a water mold that forms relatively large, clear, lemon-shaped spores called sporangia on stalks called

sporangiophores. Sporangia may germinate at temperatures of 44E F when free water is present on leaves by forming 8 to 12 motile zoospores each. These swim freely in water films, encyst on leaf surfaces and infect the plant. Encysted zoospores infect leaves by penetrating leaf surfaces with a germ tube, either through stomata or by means of direct penetration through the epidermis of leaves, petioles or stems. At temperatures of 55 to 70EF, sporangia germinate by means of a single germ tube. Night temperatures of 50 to 60EF accompanied by light rain, fog or heavy dew, followed by days of 60 to 75EF with high relative humidity, are ideal for late blight infection and development. Tubers may become infected if sporangia produced on the foliage are washed down into the soil by rain or irrigation water. It appears that water-borne spores follow stems and stolons in a water film into the soil, reach tubers, and cause infection. Tubers near the soil surface are more likely to be infected. Irregularly shaped, slightly sunken areas of brown to purplish color characterize late blight infection on tubers. A tan to brown, dry granular rot found under the skin extends into the tuber. How far rotting extends into the tuber depends on the susceptibility of the cultivar, the length of time after infection, and temperature. Late blight usually survives from year to year in infected tubers placed in storage, in piles of cull potatoes, or in volunteer potatoes. However, infected seed is the primary source of infections (13).

General Control Information:

Control measures should be taken throughout the season and in storage. There have been up to 100% yield losses both in the field and in storage from late blight.

Cultural Controls:

Clean certified seed should always be planted. All seed lots should be carefully inspected and any tubers suspected of being infected with late blight should be tested. Contaminated loads should be rejected. If irrigation is applied, try to apply water during the hours of midnight to 8 AM to avoid prolonging the length of time leaves are wet. Alternatively, apply irrigation during daylight hours, beginning after leaves have been dry for at least two hours and ending two hours before dark, again so leaves have a dry period before and after irrigation. Kill vines at least two weeks before harvest in blight-infected fields. Make sure vines are completely dead. If blight is present in the field or in the vicinity of the field at harvest, spray foliage after vine killing with a fungicide. Remove cull piles, inspect and treat rock piles containing discarded tubers and seed pieces (13).

Biological Controls:

None, although seed piece transmission can be reduced with *Trichodium atroaviride* applied during seed cuttings.

Post-Harvest Control Practices:

If tubers are stored, they should be dry when placed in storage, and the storage air temperature and humidity should be managed so that the tubers remain dry. Potatoes should be held at the lowest temperature possible consistent with their ultimate use (13).

Foliar Fungicides for Late Blight Control by District:

Control costs fell to an average for Michigan of about \$82/acre (chemical only) and continued a decline from 1996. Preventative programs based on contact fungicides were perceived as the most effective management strategy and there was minimal use of systemic and semi-systemic fungicides. Average water volumes remained at 20 gal/acre for ground applications and 5 gal/acre for aerial applied fungicides. Aerial applications provided effective late blight control. Most growers applied fungicides between 8-12 times and a few growers applied in excess of 13 applications. The number of applications were reduced in comparison to 1997. It was perceived that the dry weather prevented a severe epidemic from developing. However, the cumulative disease severity valued for 1998 was similar to that of 1997 in irrigated fields. Additionally, it was concluded that the early application of fungicides was key to effective late blight control (4).

Chlorothalonil, copper hydroxide, copper sulfate, cymoxanil, dimethomorph, maneb, mancozeb, metiram, propamocarb, natenoxan, and triphenyl hydroxide

Early Blight



Early Blight occurs annually in Michigan affecting up to 25% of the fields. It is one of the most common foliar diseases in Michigan. On leaflets, symptoms begin as small, dark brown to black spots. As the spots enlarge, they develop a characteristic target spot or bulls-eye due to concentric rings appearing in the dead tissue. Spots may enlarge, coalesce, and cause leaflets to die, dry up and drop. Spots may appear on vines, but usually do only minor damage. Early blight lesions appear on the surface of tubers as dark, sunken, roughly circular to irregularly shaped areas. The fungus will invade the tuber, causing shallow to deep, dark, necrotic, hollowed-out areas in the tuber that can be traced to surface lesions (11).

Biology:

The early blight fungus overwinters in the field on dead leaves and vines of several crop species, or on infected tubers. Primary infection occurs at sprout emergence from the soil, spores are picked up on emerging stems. Spores are carried primarily by wind and infect potato leaves under favorable conditions of warm temperatures (68-86°F) and heavy dews or rain. Early blight development is favored by high (about 90%) relative humidity. Early blight is often more severe when the potato crop has been under stress of poor nutrition, injury, insect damage, drought, or other types of stress (11).

General Control Information:

Control measures generally begin in early June and continue through harvest (6). If not controlled properly yield reductions of 50 bushels or more per acre due to early blights are not uncommon (11).

Cultural Controls:

Several varieties have some resistance to the disease. Rotation away from solanaceous crops for a minimum of two years is recommended. Use of disease-free seed is important. Allowing tubers to mature in the ground for at least two weeks after the vines die reduces tuber infection. Wounding tubers during harvesting should also be avoided. Crops should be maintained without nitrogen deficiency (6).

Biological Controls:

None.

Post-harvest Controls:

Plow under all plant debris and volunteer potatoes immediately after harvest(6).

Chemical Controls:

Azoxystrobin, chlorothalonil, iprodione, mancozeb, metiram, metalaxyl, and triphyltin hydroxide.

Alternatives:

None.

Botrytis Blight or Gray Mold

Botrytis Blight or gray mold, occurs sporadically but is becoming more common in Michigan. About 100% of the fields are at risk in Michigan and up to 5% are affected each year (6).

Biology:

Botrytis cinerea is a commonly occurring soil fungus. The fungus typically attacks dead tissue and can be seen as a fuzzy, grey growth on dead blossoms or senescent leaves. Under wet conditions and when vine growth is lush, the fungus may move into the stem tissue. The stem rot is initially wet and slimy. The fungus sporulates on infected tissue and produces a dense, gray to off-white growth (6).

General Control Information:

Control measures are generally taken throughout July and August. There is generally very little yield loss due to this disease(6).

Cultural Control Practices:

Nitrogen rates that result in excess vine growth aggravate this disease. Planting in poorly drained soils should be avoided. No resistant varieties are available (6).

Biological Control Practices:

None.

Post-harvest Control Practices:

None.

Chemical Controls:

Chlorothalonil, maneb, and mancozeb can suppress but not control botrytis blight.

Alternatives:

None.

Potato Scab

Raised, tan to brown, corky lesions of potato scab.

Some scab is seen in potato growing areas annually, but usually at low levels. Once the disease has infected a field, scab will likely affect successive crops (15). Scab causes cosmetic damage to tubers, running from superficial russetting to deep pitting (6).

Biology:

The bacterium can overwinter in infected seed pieces and contaminated soil. It thrives in soil when the pH range is 5.5 to 7.5, although there is an “acid-scab” which can occur in soils with a pH below 5.2. The organism can be spread by contaminated manure if livestock have been fed infected tubers. The bacterium infects only when they are immature shortly after initiation tubers through the lenticels(6).

General Control Information:

Most control measures are taken before planting. Yield losses are due to cosmetic damage and run as high as 75%, although this is very unusual.

Cultural Controls:

Use of resistant varieties is by far the best control for controlling scab. Use of rye winter cover as a green manure prior to planting potatoes has been effective in reducing scab. In addition, rotations that separate potato crops by several years will help suppress the disease. Using an acid-forming fertilizer such as ammonium sulfate will help acidify soil and may decrease the severity of the disease. If lime needs to be added to a field, use the smallest amount necessary. Scab is generally much more severe under dry, warm conditions. Since the scab pathogen attacks only the young, developing tubers, it is critical to maintain adequate soil moisture levels during early tuber development. Irrigation is necessary from the start of tuber initiation until the point when tubers have completed their initial formation and are beginning to put on size. Avoid planting scabby seed. This is especially important

when planting into land that has been free of the disease. Do not use barnyard manure on potato fields (15).

Biological Controls:

None.

Post-Harvest Control Practices:

None.

Chemical Controls:

None.

Verticillium Wilt and Early Vine Death



Verticillium Wilt and Early Vine Death occur sporadically in Michigan. However 100% of the fields are at risk. These fungi cause premature maturation and death of vines and result in reduced yields (16). This is the result of micro sclerotia traveling throughout the vascular tissue and causing a mechanical plugging of these tissues retarding the movement of water (21).

Biology:

Verticillium dahliae, produces tiny black micro sclerotia in root or stem tissue favored by higher soil temperatures. *Verticillium albo-atrum* forms enlarged darkened fungal strands known as resting mycelia and is favored by cooler temperatures. The micro sclerotia and hyphal strands produced by these two related fungi are resistant overwintering structures and can survive for several years in the soil between potato crops (16). *V. dahliae* overwinters in the soil, potato stems, and on tubers as micro sclerotia. Micro sclerotia germinate in the spring and hyphae invade potato roots usually through wounds. The fungus then enters the vascular tissue. It travels throughout the vascular tissue as conidia or hyphae to leaves and leaf petioles. Additional conidia are produced as secondary inocula as conidiophores emerge from leaf tissue. When the potato dies, micro sclerotia are again produced as overwintering structures (21).

General Control Information:

Control measures are generally taken before planting to reduce infestation. If not controlled, yield losses can result in up to 50% loss. In many cases growers do not recognize that they have a problem because the disease-causing organisms build up slowly over time so that yield potential becomes gradually lower. *Verticillium dahliae* is found in all potato-producing areas of Michigan. *V.albo-atrum* is occasionally found in northern Michigan (16).

Cultural Controls:

Certified seed should always be planted to avoid early infection. In problem fields, rotate every three years into crops other than potatoes and related susceptible crops, such as eggplant or tomato. Avoid cultivars very

susceptible to *Verticillium* such as Superior and Russett Norkotah. Avoid over irrigation(16).

Biological Controls:

None.

Post-Harvest Controls:

None.

Chemical Controls: None.

Alternative Controls: None.

Bacterial Ring Rot(*Corynebacterium sepedonicum*)



Bacterial ring rot occurs rarely in Michigan and rarely affects potato fields. Infected stems are usually shorter than healthy stems, and leaves tend to be closer together and twisted. The vascular tissue becomes discolored during later stages of the disease, and thick exudate may be expressed out of the cut end of stems. Early tuber symptoms consist of a slight yellow to brown discoloration of the vascular ring. Later a yellow to pale brown, odorless rot develops, which has a crumbly to cheesy consistency. As the vascular tissue decays, the inner part of the tuber often separates from the tuber skin, resulting in a brown colored cavity. This often results in external skin cracking on the tubers and may cause total breakdown of the tuber (17).

Biology:

The ring rot bacterium does not overwinter in the soil in a free living form, but can overwinter in infected tubers left in the field. Volunteer plants arising from infected tubers can serve as a source of infection the following year. One of the primary sources of infection is bacteria which overwinter in infected tubers in storage (17).

General Control Information:

Control measures are generally taken before planting to reduce infestation. If not controlled, yield losses can be up to 100% in severely affected fields.

Cultural Controls:

Use certified seed. Certification agencies have a zero tolerance level for ring rot. Equipment, storage surfaces, etc., should all be disinfected between lots and before moving into a clean field. Remove all infected potatoes and potatoes suspected of being contaminated. Practice adequate rotation of crops and destroy all volunteers in potato fields known to have had ring rot. Keep seed lots separate. Use new bags for seed storage or store seed in disinfected storage bins (17). Inform Michigan Potato Seed Association.

Biological Controls:

None.

Post-harvest Controls:

None.

Chemical Controls:

None.

Silver Scurf (*Helminthosporium solani*)

Silver scurf occurs annually in Michigan affecting a few table-stock storages. The brown blemishes that develop on the tuber surface lower the market value of the crop. Buyers are increasingly unwilling to purchase tablestock potatoes showing silver scurf lesions. Silver scurf infects only the skin on the potato. Symptoms appear at the stolon end as small, pale, brown spots. Severe browning of the surface layers of tubers may occur, followed by sloughing-off of the outer layers of the periderm (6).

Biology:

Silver scurf is seedborne and infected seed tubers are probably the main source of inoculum. The pathogen produces reproductive structures on the surface of the seed tuber. These are washed off the seed tuber and through the soil by rain or irrigation. The structures germinate in response to free moisture and infect tubers directly through the periderm or lenticels. Infection can occur as soon as tubers are formed and may continue throughout the growing season (18).

General Control Information:

Control measures should be taken before planting to reduce infestation. If not controlled, marketable losses can be as great as 100% from severely infected fields.

Cultural Controls:

Cultural practices for silver scurf include; harvest tubers early, use uninfected seed, control volunteer potatoes, and rotate crops. Fluctuation of temperatures, and cold spots that allow moisture condensation or dripping on tubers, will stimulate disease spread in storage (18).

Biological Controls:

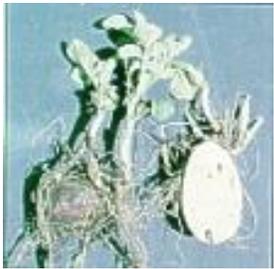
None.

Post-Harvest Controls:

None.

Chemical Controls:

Fludiozonil, and thiophanate-methyl.

Rhizoctonia Stem Canker & Black Scurf (*Rhizoctonia solani*)

Rhizoctonia stem canker is found in most potato-growing areas of Michigan. It typically affects 50% of the potato fields per year. The fungus limits growth by forming cankers on sprouts, underground stems and stolons and makes tuber unsightly by forming black scurf (sclerotia) on tuber surfaces (19).

Biology:

The sexual stage of the fungus may appear on lower stems of potato especially in humid weather. This stage appears as a white to gray mycelial mat just above ground level. The mat is easily rubbed off and the stem tissue below the mat appears healthy. The fungus then forms small black sclerotia which are oppressed to tuber surfaces. These sclerotia overwinter in the soil and tubers and begin the disease cycle in spring. Yield losses can be as high as 34% and can cause a significant change in size distribution of tubers (19).

General Control Information:

Control measures should be taken before planting to reduce infestation (19).

Cultural Controls:

Rotate one year of potatoes with two years of wheat, barley, corn, or onions, which normally are not attacked by Rhizoctonia; avoid planting potatoes following red clover, alfalfa, oats or sugar beets. Plant good quality potato seed that is clean and free from sclerotia. Plant seed pieces at a depth of two inches when soil temperatures are at least 55 EF to encourage rapid germination and emergence. Harvest tubers as soon as vines are killed and skins are set; leaving tubers in the ground longer, especially when soils are moist and warm, encourages development of black scurf on tubers (19).

Biological Controls:

None.

Post-Harvest Controls:

None.

Chemical Controls: Fludiozonil, and thiophanate-methyl.

Fusarium Dry Rot/Soft Rot (*Fusarium sambucinum* and *F. solani*)



Infected areas of tubers with
Fusarium dry rot often have
internal cavities containing
white or pink mold.

Fusarium dry rot occurs annually in Michigan affecting up to 50% of the potato fields each year. This disease causes a dry rot of potatoes in storage. Symptoms include sunken and shriveled areas on the surface of tubers. The rot may extend to the center of the tuber and contain a fungal growth. Affected tissue often becomes colonized by soft rot bacteria (6).

Biology:

The causal fungi (*Fusarium sambucinum* and *F. solani*) cause dry rot in stored tubers as well as in seed pieces (see “Seedpiece decay and Seedborne Pathogens Section”). *Fusarium* spp. can survive for several years in field soil, but the primary inoculum is generally borne on seed tuber surfaces. Infected seed tubers and pieces decay and infest the soil that adheres to the surfaces of harvested tubers. Tubers become more susceptible to infection during storage, especially during the spring (6).

General Control Information:

Control measures can be taken at planting, at harvest or postharvest. Yield losses can be as great as 75% in severely affected storages (6).

Cultural Controls:

Purchase seed with as little dry rot as possible. Seed becomes more susceptible as the storage season progresses. Warm seed to at least 50 EF before handling and cutting; and minimize bruising (6).

Biological Controls:

None.

Post-Harvest Controls:

Harvest tubers after skins are set and when pulp temperature is greater than 50EF. Avoid injuries through which the fungus can infect tubers. Cure tubers carefully after harvest, and follow with storage under as low a temperature as possible. Do not move potatoes in storage (6).

Other Issues:

Because of the problems of resistance to both thiophanate-methyl and thiabendazole, research has been conducted on new seed piece fungicides, including Maxim (6).

Chemical Controls:

Maneb, fludiozonil, and thiophanate-methyl.

Alternatives:

None at this time.

White Mold (*Sclerotinia sclerotiorum*)

White mold occurs sporadically on potatoes in Michigan affecting about 100% of the fields in conducive seasons. The fungus attacks stems, generally at the soil line, weakening the plant (6).

Biology:

The causal fungus, *Sclerotinia sclerotiorum*, is a common soilborne pathogen in the soil. It generally infects stems at the soil line, but infection can occur on any part of the plant. Symptoms include dense, cottony white growth and the production of hard, black, irregularly shaped sclerotia on infected tissue. The disease is common on potatoes in Michigan(6).

General Control Information:

Control measures are generally taken between July and August. Yield losses are usually minimal (6).

Cultural Controls:

Excessive irrigation and high nitrogen rates should be avoided. Rotation with grains (but not beans) reduces soil populations. No resistant varieties are available (6).

Biological Controls:

None.

Post-Harvest Controls:

None.

Chemical Controls:

Copper hydroxide, copper sulfate, iprodione.

Alternatives:

None available at this time.

Pink Rot (*Phytophthora erythroseptica*)



Pink rot occurs occasionally in Michigan on potatoes, affecting 5% of the fields each year. The pseudo-fungus infects tubers. External symptoms appear around the stem end or eyes and lenticels. The infected area turns purple to dark brown with a black band. Tubers become rubbery or spongy and exude a liquid when squeezed. When cut, the infected tissue turns pink in a matter of minutes, then darkens to brown and finally to black. The pathogen will spread in storage if potatoes are not kept dry (6).

Biology:

The fungus, *Phytophthora erythroseptica*, is soilborne and endemic in many soils. Zoospores, sporangia, or oospores may serve as inoculum, but oospores are probably the significant propagule in pathogen disseminations and survival in soil. Plants of all ages are susceptible but the disease is most frequently observed in mature plants approaching harvest (6).

General Control Information:

Control measures are needed all season especially in storage areas. Yield losses can be from 5-100% in severely affected fields or storage lots.

Cultural Controls:

Avoid planting in poorly drained areas (6).

Biological Controls:

None.

Post-Harvest Controls:

None.

Chemical Controls:

Metalaxyl.

Alternatives:

None.

Fusarium Wilt (*Fusarium spp.*)



Fusarium wilt occurs occasionally in Michigan on potatoes, affecting 0 to 5% of the fields each year. Fusarium species can cause wilt, seedpiece decay, and tuber rots. Fusarium wilt occurs when the fungus attacks the vascular system of the plant. Severely infected plants can wilt, turn yellow and collapse. Tuber lesions can also occur (6).

Biology:

Fusarium wilt of potato is caused by *F. oxysporum* and *F. solani*. Both fungi are common soil inhabitants that increase in numbers with continued potato culture. Both survive in soil as dormant spores or in crop refuse. Infection is favored by hot weather and high soil moisture. Small feeder roots come in contact with dormant spores, which germinate and invade the roots. The fungus moves up the plant through the vascular system (6).

General Control Information:

Control measures should be taken before planting to reduce infestation of Fusarium wilt. However, yield losses can be up to 50% in severely infected fields.

Cultural Controls:

No resistant varieties are available. Crop rotation is not useful because the fungi survive in the soil for long periods without host plants (6).

Biological Controls:

None.

Post-Harvest Controls:

None.

Chemical Controls:

None.

Leak (*Pythium spp.*)



Several species of Leak occur annually in Michigan, affecting approximately 5-10% of the fields each year. However 100% of the fields are at risk. Infected tubers show lesions, typically around wounds or near the stem. A freshly cut tuber turns reddish tan, then brown and finally black. Infected tubers decay during storage (6).

Biology:

A number of fungi in the *Pythium* genus infect potato tubers. They are common inhabitants of soils, and have a very wide host range (6).

General Control Measures:

Control measures are generally taken at planting and at flowering. Yield losses can be up to 75% in severely affected fields (6).

Cultural Controls:

No resistant varieties are available. Avoid harvesting immature tubers during hot or wet weather. Storage temperatures should be kept low if the disease is detected (6).

Biological Controls:

None.

Post-Harvest Controls:

None.

Chemical Controls:

Metalaxyl.

Powdery Scab (*Spongospora subterranea*)



Powdery scab is not currently known in Michigan. Damage is similar to that caused by scab, but the texture of the lesions are powdery. In storage, powdery scab may lead to dry rot, and infections can spread in storage (6).

Biology:

The fungus survives in soil as resting spores. After germinating, spores infect roots, stolons, and tubers. Invasion by spores stimulates the host cells to become larger and more numerous, and galls are produced. Within these galls, balls of resting spores are produced (6).

General Control Information:

Control measures should be taken before planting to reduce infestation of powdery scab. Yield losses are usually minimal.

Cultural Controls:

Avoid planting in low spots with poor drainage. Plant disease-free seed (6).

Biological Controls:

None.

Post-Harvest Controls:

None.

Chemical Controls:

None.

Bacterial Soft Rot (*Erwinia spp.*)

Some bacterial soft rot is found in most growing areas each year, although usually at low levels. 100% of the potato fields in Michigan are at risk. *Erwinia spp.* can cause a blackening and decay of the stem (known as “black leg”), and soft rot of infected tubers. Yield and quality can be diminished (6).

Biology:

Bacteria overwinter in the soil or in plant debris, but more commonly overwinter in infected seedpieces. The bacteria can spread to healthy seedpieces readily during cutting and planting. Bacteria from an infected plant may infect tubers through the soil water. Tubers are infected through wounds or lenticels, and these bacteria survive the entire storage period. Tubers harvested when soil temperatures are high or those grown under conditions of high nitrogen are highly susceptible to soft rot. Environmental factors that create anaerobic conditions, such as poor aeration, flooding, or a water film on tubers, favor disease development. Soft rot bacteria can also act as secondary pathogens in tubers infected with other diseases (6).

General Control Information:

Control measures should be taken before planting to reduce infection by bacterial soft rot. Yield losses can be high in severely affected fields. Although typical losses run from 0 to 10%.

Cultural Controls:

Avoid poorly drained areas, and injuries to the tuber during harvest. Plant disease-free seed (6).

Biological Controls:

None.

Post-Harvest Controls:

The use of chlorine water treatments can prevent the spread of decaying bacteria by killing the organism on contact. Provide good conditions for wound healing for two to three weeks after harvest. Following this, temperatures should be kept as low as possible (6).

Chemical Controls:

None.

Alternatives:

None.

Viruses (several)



Wrinkling of leaves, a common potato virus symptom. Viruses occur sporadically in Michigan affecting 5 to 10% of the potato fields each year, however 100% are at risk of infection. Virus infections can cause distorted growth, stunting, distortions in leaf coloration, and small misshapen tubers (6).

Biology:

Several viruses and a viroid are spread by potato tubers. These include potato leaf roll virus (PLRV), potato virus Y (PVY), and potato virus A (PVA), potato viruses S and M (PVS and PVM), alfalfa mosaic virus (AMV), potato spindle tuber viroid (PSTV). These viruses are spread by tuber seedpieces. Some are also spread by aphids and by mechanical means (6).

General Control Information:

Control measures should be taken before planting and throughout the season as needed. Yield losses are generally minimal.

Cultural Controls:

The major method for controlling viruses in potatoes is through the production of disease-free seed potatoes. This is controlled through the Certified Seed Program. Potato stocks are tested for viruses (6).

Biological Controls:

None.

Post-Harvest Controls:

None.

Chemical Controls:

No pesticides are registered to control viruses. However, control of aphid vectors using insecticides can be effective, especially in seed potato production (6).

Pesticide Profiles

Azoxystrobin (Strobin)

Formulations: Quadris 2.08SC.

Pests Controlled: Early blight, late blight, rhizoctonia (sexual stage).

Acres of Crop Treated: 25440 (38).

Application Rate: 0.4-0.8 pt/A (25).

Types of Application: Foliar (8).

Timing: 14 day interval alternating with residual protectant fungicides (25).

PHI: 14 days (25).

REI: 12 hr (8).

IPM Concerns: Moderate concerns of resistance development.

Use in Resistance Management Programs: Azoxystrobin can be effectively used in an alternate spray program with protectant fungicides (6).

Efficacy Issues: In Michigan, preferred use in mixture with residual protectant fungicide, excellent early blight control.

Captan (Dicarboximide)

Formulations: Captan.

Pests Controlled: Fusarium tuber rot (8).

Acres of Crop Treated: No information available.

Application Rate: 12 oz product/50 gal water (8).

Types of Application: Seed piece dust (8).

Timing: Before planting (8).

REI: 4 days (26).

PHI: No information available.

IPM Concerns: No information available. (B2 Carcinogen).

Use in Resistance Management Programs: No information available.

Efficacy Issues: Limited disease spectrum.

Chlorothalonil (Aromatic)

Formulations (Application Rate)(25):

*Bravo ZN -1.5 lb/A.

*Bravo WS 6SC - 1 to 1.5 pt/A.

*Bravo Ultrex 82.5DG - 0.9 to 1.4 pt/A.

*Bravo ZN NS 6SC - 1.0 to 1.5 pt/A.

*Equus 6SC - 1 to 1.5 pt/A.

*EchoZN 6.25SC - 1.5 to 2.2 pt/A.

Pests Controlled: Late blight, and early blight (4).

Acres of Crop Treated: 15783 (38).

Types of Application: Ground, air, and irrigation (4).

Timing: As needed through season(4).

PHI: 7 days (25).

REI: 48 hrs (26).

IPM Concerns: No information available.

Use in Resistance Management Programs: No information available.

Efficacy Issues: Broad spectrum.

Copper hydroxide (Inorganic)

Formulations: Champ.

*Kocide DF-2.0 pt

*Kocide 2.4LF - 2.0 lb/A (25).

Pests Controlled: Late blight, white mold (4).

Acres of Crop Treated:10212 (38).

Types of Application: Ground (4).

Timing: As needed through season(4).

PHI:0 days (25).

REI:24 hrs (26).

IPM Concerns: No information available.

Use in Resistance Management Programs: No information available.

Efficacy Issues:Best used in tank mix with chlorothalonil, limited efficacy.

Copper Sulfate (Inorganic)

Formulations: Copper Sulfate - 3.75 lb product (5.0 lb -Southwest) (4).

*Blue Viking Star Glow Powder 100SC - 10 lb (25).

*Blue Viking Star Shine Crystals 100SC - 10 lb (25).

Pests Controlled: Late blight, white mold, and early blight (4).

Acres of Crop Treated:11880 (38).

Types of Application:Ground and chemigation (4).

Timing: As needed through season(4).

REI: 24 hrs (26).

PHI: No information available.

IPM Concerns: No information available.

Use in Resistance Management Programs: Limited.

Efficacy Issues: No information available.

Advantages: Limited although cheap.

Cymoxanil (Aliphatic nitrogen)

Formulations: Curzate 60DF.

Pests Controlled: Late blight (4).

Acres of Crop Treated:11550 (38).

Application Rate (lb ai/A):0.21 (25).

Types of Application:25% Ground; 75% Air (4).

Timing: As needed through season(4).

PHI:14 days (26).

REI:12 hrs (26).

IPM Concerns: No information available.

Use in Resistance Management Programs: Low resistance risk.

Efficacy Issues: Needs to be mixed with a residual protectant fungicide, may be used to prevent spread to uninfected foliage from within infected field and can be used only in a tank mixture with other fungicides, from when foliage meets within rows to early senescence (25).

Dimethomorph (Morpholine)

Formulations: Acrobat MZ.

Pests Controlled: Late blight (4).

Acres of Crop Treated:2750 (38).

Application Rate (lb ai/A):2.25 (25).

Types of Application: Ground or aerial (26).

Timing: As needed through season(4).

PHI:14 days (26).

REI: No information available.

IPM Concerns: No information available.

Use in Resistance Management Programs: No resistance issues.

Efficacy Issues:Very effective but only against late blight, may be used to prevent spread to uninfected foliage from within infected field (25).

Fludioxonil (Pyrrole)

Formulations: Maxim MZ, Maxim.

Pests Controlled: Fusarium tuber rot, silver scurf and rhizoctonia (8).

Acres of Crop Treated:24,000 (38).

Application Rate:0.5/100 lb seed (8).

Types of Application: Seed piece dust (8).

Timing:Before planting (8).

PHI:No information available.

REI:24 hr (26).

IPM Concerns: No information available.

Use in Resistance Management Programs: Because of the concern of resistance development to fludioxonil, its use is limited to commercial (non-seed) production (6).

Efficacy Issues:Fludioxonil is not a systemic fungicide and therefore is most effective in controlling diseases on the seed tuber. Very effective although difficult to apply at full rate (6).

Iprodione (Imidazole)

Formulations: Rovral 4F and Rovral 50W.

Pests Controlled: Early blight and white mold (25).

Acres of Crop Treated: No information available.

Application Rate: 2 pt (25).

Types of Application: Seed piece dust (8).

Timing:Once at fall canopy (25).

PHI:14 days (26).

REI: 24 hr (26).

IPM Concerns: Related to other dicarboximides which diseases have already shown resistance to (26).

Use in Resistance Management Programs: Limited.

Efficacy Issues: Can give good control but efficacy is unreliable.

Mancozeb (EBDC)

Formulations: Dithane - 1.25 lb/A (4).

*Dithane F-45 4F - 1qt product/50 gal water (4).

*Dithane F-45 80W - 1/14 lb product/50 gal water (4).

*Dithane Rainshield - 2 lb/A (25).

*Penncozeb 75DF - 2.25 lb/A (4).

*Penncozeb 80W - 1.25 lb/gal (25).

*Manzate 75DF - 1 to 2 lb/A (25).

Pests Controlled: Late blight, white mold, early blight (4) and fusarium tuber rot (8).

Acres of Crop Treated:30,000 (38).

Types of Application:Ground (4), seed piece dip (8) irrigation and aerial (26).

Timing: As needed through season,before planting (8).

PHI:3 days (25).

REI:24 hr (8).

IPM Concerns: No information available.

Use in Resistance Management Programs: Excellent.

Efficacy Issues: No information available.

Maneb (Dithiocarbamate)

Formulations: Manex 4F - 0.8 qt product/10 gal water (8).

*Maneb 80W - 1 lb product/10 gal water (8).

*Manex 4 FL - 3.2 pt/A (25).

Pests Controlled: Fusarium tuber rot, fusarium dry rot, late blight, and botrytis blight(25).

Acres of Crop Treated:3753 (38).

Types of Application:Seed piece dip, aerial and ground (8).

Timing: Before planting or 7 day intervals (8).

PHI:3 days (25).

REI:24 hr (8).

IPM Concerns: No information available.

Use in Resistance Management Programs: Yes.

Efficacy Issues: No information available.

Metalaxyl (Xylylalanine)

Formulations:Ridomil Gold (26).

Pests Controlled:Late blight, late blight tuber rot, pink rot, and leak (4).

Acres of Crop Treated:13926.

Application Rate: 2.0 lb/A (26).

Types of Application: Ground and air (4).

Timing: As needed through season(4).

PHI:14 days (26).

REI: 48 hrs (26).

IPM Concerns: No information available.

Use in Resistance Management Programs: The recent introduction of metalaxyl-resistant strains of late blight has had a dramatic impact on foliar disease management in potatoes (6).

Efficacy Issues: Can control tuber borne *pythaecous spp.*

Metiram (EBDC)

Formulations: Polyram 80DF.

Pests Controlled: Late blight, white mold, and early blight (4).

Acres of Crop Treated:7920.

Application Rate (lb ai/A):1.5 to 2 lb (25).

Types of Application: Ground (4).

Timing: As needed through season (4).

PHI:3 days (25).

REI:24 hr (26).

IPM Concerns: No information available.

Use in Resistance Management Programs: Yes.

Efficacy Issues: No information available.

Advantages: Cheap.

Thiabendazole (Benzimidazole)

Formulations: Mertect 340.

Pests Controlled: Fusarium tuber rot and fusarium dry rot (8).

Acres of Crop Treated:10% of storage.

Application Rate:0.42 oz product/ton of potatoes (8).

Types of Application:Spray (8).

Timing: At harvest (8).

PHI: No information available.

REI:12 hrs (26).

IPM Concerns: High resistance risk.

Use in Resistance Management Programs: Problems with resistant strains of Fusarium have caused the use of thiabendazole to decrease significantly. The industry has a need for other effective control measures for Fusarium dry rot (6).

Efficacy Issues:Resistance.

Thiophanate-Methyl (Carbamate)

Formulations: Evolve.

Pests Controlled: Fusarium tuber rot, fusarium dry rot and rhizoctonia (8).

Acres of Crop Treated:1000.

Application Rate:1 lb product/100 lb seed, 0.5 lb/100 lb seed (8).

Types of Application:Seed piece dust (8).

Timing: Before planting (8).

PHI: No information available.

REI: 12 hr (8).

IPM Concerns: No information available.

Use in Resistance Management Programs: A number of strains of Fusarium and silver scurf have become resistant to thiophanate-methyl, and use of this fungicide has decreased accordingly (6).

Efficacy Issues: No information available.

Triphenyltin hydroxide (Fentin hydroxide)

Formulations: SuperTin 80DF.

Pests Controlled: Late blight and early blight (4).

Acres of Crop Treated:24,000 (38).

Application Rate: 1.0 oz to 3.75 oz (Max = 11.75 oz/season) (4).

Types of Application: Ground or aerial (4).

Timing: As needed through season(4).

PHI:7 days (25).

REI:48 hrs (26).

IPM Concerns: No information available.

Use in Resistance Management Programs: Effective.

Efficacy Issues:Highly effective anti-sporulant. Can only be applied by tank mixing with other fungicides (25). It is a broad-spectrum pesticide.

Weeds



Weeds occur annually in all regions of Michigan affecting 100% of the farms across the state each year. They reduce yields by competition for nutrients with the crops. Weeds can interfere with harvesting, and weeds can act as alternate hosts for diseases and nematodes.

Biology:

Annual and perennial weeds such as nightshade, redroot pigweed, common lambsquarter, velvetleaf, yellow nutsedge, quackgrass and barnyard grass are a problem throughout the season (4).

General Control Information:

Weeds can be controlled preplant, preemergence or postemergence. If weeds are not controlled by herbicides or cultivation, yield losses can be as high as 100%. While weed species spectra may vary regionally, weeds are a problem throughout the entire potato growing areas of Michigan.

Cultural Controls:

Cultivation is an important cultural practice used to control weeds.

Biological Controls:

None.

Post-Harvest Controls:

Cultivation. Post-harvest application of herbicides to control perennial weeds.

Chemical Controls:

EPTC, glyphosate, linuron, metolachlor, metribuzin, pendimethalin, rimsulfuron, and sethoxydim.

Alternatives : None.

Herbicide Profiles

EPTC (Thiocarbamate)

Formulations: Eptam 7E (28).

Pests Controlled: Annual grasses and broadleaves (28).

Acres of Crop Treated: No information available.

Application Rate(lb ai/A): 4 to 6 (28).

Types of Application: Spray (28).

Timing: Preemergence (28).

PHI:No information available.

REI:12 hrs (26).

IPM Concerns: Repeated use of EPTC will reduce EPTC efficacy.

Use in Resistance Management Programs: No information available.

Efficacy Issues: Incorporate 3 inches deep immediately following application and follow with delayed preemergence application of linuron or metribuzin (28).

Advantages: Controls many grasses.

Disadvantages: Not effective on muck soil (28).

Glyphosate (Organophosphorus herbicides)

Formulations: Round-Up Ultra, roundup Original, Glyphomax, Glyphomax Plus, Acquire, Mirage, Silhouette, Credit, Touchdown, Gly-flo, Rattler, Glyfos (28).

Pests Controlled: Emerged quackgrass and other perennials (28).

Acres of Crop Treated:1920 (4%) (38).

Application Rate(lb ai/A): 2 (28).

Types of Application: Pre-plant burndown (28).

Timing: Apply to actively growing weeds before crop emerges (28).

PHI:14 days (26).

REI:4 hrs (26).

IPM Concerns: No information available.

Use in Resistance Management Programs: No information available.

Efficacy Issues: Include 1 pt NIS/A (28).

Advantages: Nonselective control on weeds.

Disadvantages: Cannot be sprayed on the crop. Weak on some perennials and biennials.

Linuron (Substituted urea)

Formulations:Linuron (28).

Pests Controlled:Delayed emergence of broadleaves (28).

Acres of Crop Treated:37,920 (38).

Application Rate(lb ai/A): 1 (28).

Types of Application:Spray (28).

Timing:Delayed preemergence (28).

PHI:No information available.

REI:24 hrs (26).

IPM Concerns:No information available.

Use in Resistance Management Programs:No information available.

Efficacy Issues:Apply before potatoes emerge but before weeds emerge (28).

Advantages:Controls many broadleaves.

Disadvantages:Weak on most grasses.

Metolachlor (Chloracetanilide)

Formulations:Dual 8E (28).

Pests Controlled:Annual grasses and broadleaves (28).

Acres of Crop Treated:38,400 (38).

Application Rate(lb ai/A): 1.5 to 3 (28).

Types of Application:Spray (28).

Timing:Preemergence (28).

PHI:40 days (28).

REI:24 hrs.

IPM Concerns:No information available.

Use in Resistance Management Programs:Dual + Lorox has been the most effective nightshade control program to date in Michigan potatoes, but nightshade continues to be a problem in potato production.

Efficacy Issues:Apply soon after planting and follow with a delayed preemergence application of linuron or metribuzin (28).

Advantages:May be applied to emerged potatoes to extend grass control (28).

Disadvantages:Weak on most broadleaves.

Metribuzin (Triazinone)

Formulations:Lexone 75DF and Sencor 75DF (28).

Pests Controlled:Broadleaves and grasses (28).

Acres of Crop Treated:36,960 (38).

Application Rate(lb ai/A): 0.5 (pre) and 0.25 (post) (28).

Types of Application:Chemigation, aerial, ground.

Timing:Preemergence and post emergence (28).

PHI:60 days (28).

REI:12 hrs (26).

IPM Concerns:No information available.

Use in Resistance Management Programs:No information available.

Efficacy Issues:Apply just before potatoes emerge and after weeds have emerged but are less than 1 inch tall (28).

Advantages:Control many broadleaves and the foxtails.

Disadvantages:Do not use on Atlantic or Shepody varieties (28).

Pendimethalin (Dinitroaniline)

Formulations:Prowl 3.3E and Pentagon 60DG (28).

Pests Controlled:Broadleaves and grasses.

Acres of Crop Treated:No information available.

Application Rate(lb ai/A): 0.75 (28).

Types of Application:Chemigation, ground (26).

Timing:Preemergence (28),Preemergence Incorporated and Early postemergence (26).

PHI:

REI:24 hrs (26).

IPM Concerns:No information available.

Use in Resistance Management Programs:No information available.

Efficacy Issues:Apply soon after planting. Should be followed with a preemergence application of linuron or metribuzin (28).

Advantages:Control most annual grasses.

Disadvantages:

Cannot be used on muck soil or on soil with less than 5% organic matter. It also needs rain within 7 days to be active (28). Cannot make more than one application of Prowl per season. Do not apply to sweet potatoes or yams.

Rimsulfuron (sulfonylurea)

Formulations:Matrix 25DF (28).

Pests Controlled:Broadleaves and grasses (28).

Acres of Crop Treated:8160 (38).

Application Rate(lb ai/A): 0.0238 (pre) and 0.0156 (post) (28).

Types of Application:Spray (28).

Timing:Pre and Post emergence (28).

PHI:60 days (28).

REI:4 hrs (26).

IPM Concerns:ALS mode of action; herbicide resistance to this mode of action has been found.

Use in Resistance Management Programs:To control triazine resistant redroot pigweed growers apply Matrix (4).

Efficacy Issues:Apply after hilling or drag off before potatoes and weeds emerge. Needs moisture for activation (28) .

Advantages:Control a few broadleaves and grasses.

Disadvantages:Do not use on Atlantic, Shepody, Chip Belle, Bell chip or Centennial varieties (28).

Sethoxydim (Cyclohexandione)

Formulations:Poast 1.5E (28).

Pests Controlled:Grasses (28).

Acres of Crop Treated:No information available.

Application Rate:(lb ai/A) 0.19 to 0.28 (28).

Types of Application:Aerial, ground (26).

Timing:Postemergence (28).

PHI:30 days (28).

REI:12 hrs (26).

IPM Concerns:ACCase mode of action;Resistance to this mode of action has been found.

Use in Resistance Management Programs:No information available.

Efficacy Issues: Apply to actively growing grasses. Use high rates on perennial grasses and large annual grasses (28).

Advantages: Controls most grasses.

Disadvantages: Does not control broadleaves.

Vine Killers and Volunteer Potato Controls

Frequency of Occurrence: Annually.

Vine-killers Used in Potatoes: (4)

District	Product	% Growers	Ave. Rate	Ave. # Apps	Very Good	Good	Average
1	Diquat	100%	1.33	1.44	33.3%	33.3%	33.3%
2	Diquat	100%	1.19	1.50	33.3%	33.3%	33.3%
3	Diquat	100%	1.00	1.69	0.0%	100.0%	0.0%
4 & 5	Diquat	100%	1.22	1.79	6.7%	86.7%	6.7%
6	Diquat	75%	1.05	1.67	16.7%	33.3%	50.0%
	None	25%					
7	Diquat	100%	0.95	1.50	40.0%	40.0%	20.0%
8	Diquat	80%	0.92	2.00	25.0%	50.0%	25.0%
	None	20%					
9	Diquat	100%	1.00	2.00	33.3%	33.3%	33.3%
Total			1.11	1.70	19.05%	59.52%	21.4%

Volunteer Potato Controls:

Michigan potato growers tried different options for volunteer potato control in 1998. 2,4-D and Buctril provided good control in corn according to the 1998 Michigan Potato Pest Survey. Starane also provided good control. One grower reported very good control of volunteer potato with Tough herbicide in corn. MSU has not evaluated Tough in their research. In university research Starane has provided very good control of volunteer potatoes in corn and small grains (4).

District	Product	Rate/acre	Crop used in	Acres	Effectiveness
1	MCPA	1.0 pt	oats	130	poor
2	Starane	1.0 pt	corn	40	good
4	2,4-D	1.0 pt	sweet corn	0.5	Good
5	Atrazine	1.5 lb	corn	No response	No response
5	Buctril	1.0 pt	seed corn	500	good
5	Buctril	0.75 pt	corn	No response	No response
5	Tough	1.0 pt	corn	1000	very good

8	Lines	2.0 lb	carrots	70	very good
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Contacts

Heather E. Johnson
Center for Integrated Pest Systems
Michigan State University
(517)432-9806

Lynnae Jess
Center for Integrated Pest Systems
Michigan State University
(517)432-1702

Beth Bishop
Department of Entomology
Michigan State University
(517)355-5154

Willie Kirk
Department of Plant Pathology
Michigan State University
(517)353-4481

Fred Warner
Department of Entomology
Michigan State University
(517)432-1333

Chad Lee
Department of Crop and Soil Science
Michigan State University
(517)432-6754

Ben Kudwa
The Michigan Potato Industry Commission
(517)669-8377

Prepared by:

Heather E. Johnson
on September 20, 2000

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