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# Introduction

This Potato BioIPM Workbook is written for Wisconsin potato growers and the potato industry. It is organized seasonally to provide a comprehensive, year round self-assessment tool and reference on pest management and cultural practices of the potato production system. The workbook is organized into five chapters – preplant, planting, in-season, harvest, and post-harvest. Each chapter is further divided into pertinent topic sections with self-assessment statements followed by information on standard recommended practices as well as advancements to a biointensive production system.

This workbook is intended as a practical tool for growers' use throughout the entire production cycle. The workbook will help growers learn how to move toward a more biologically-based production system that is ecologically sound and economically profitable.

At the beginning of each topic, there is a set of statements about the farm's current production practices. This self-evaluation section is formatted on a scale, with Category A being the minimal practices that could be used, increasing to Category D that describes advanced, sometimes experimental approaches. For most topics, the biointensive approach utilizes all categories —A through D. By checking all the statements that apply, growers can use the section to assess where their systems fall on various topics – such as managing potato early dying or selecting cultivars before planting. Potato growers can use the statements when making plans for the year ahead or to document practices or inputs used.

After each statement set, there is specific information expanding on the practices described in the categories A-D. Look to these paragraphs to learn how or why to implement specific activities and practices during various times of the year. The authors encourage growers to read about and consider the biologically based practices that may not currently be part of their potato system.

As research and on-farm validation finds new biointensive strategies, this workbook will be updated with new inserts and topic areas. Presently, the workbook's information is not meant to be variety specific, but it is Wisconsin specific.

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# Resistance Management in Rotational Years

Preplant



Resistance management is essential to maintain the efficacy of available pesticide chemistries in the potato system. The goal is to avoid consecutive use of products with similar modes of action, against the same target pest.



Read the following statements in order and check all that apply. Refer to the corresponding sections on the following pages for more information.

- ☐ **A.** *Resistance is considered when managing pests in rotational crops.*
- ☐ **B.** *During rotational years, herbicides are chosen with a different chemical site of action from the potato herbicides.*
- ☐ **C.** *Insecticide and fungicide chemistries are alternated on an area-wide basis.*
- ☐ **D.** *BiolPM strategies are implemented including cultural control methods to manage potato pests in rotational crops.*

## A. Resistance Management for the Entire Potato System

Pesticide resistance is a significant decrease in the sensitivity of a pest population to a pesticide. It results in control failures in the field and often serious economic consequences. Growers need to consider resistance management strategies in the rotational cropping years, both in other crops and between the previous year's potatoes and the current year's potato fields. Do not expose insect, disease, and weed pests to the same chemistries in consecutive applications, whether the exposure takes place within or between years.

General resistance management strategies which should be used in rotational cropping years include:

- Only applying chemicals when pest levels are at or above threshold levels, or when disease forecasting models determine applications are appropriate
- Alternating chemical classes between applications
- Controlling known potato pests in rotational years by using pesticide chemistries not registered in potatoes, but labeled for the rotational crop
- Utilizing bioIPM strategies which decrease reliance on pesticide use



### Potato pests to watch for resistance development

Insects: Colorado potato beetles, aphids

Diseases: early blight, late blight, fusarium, dry rot, silver scurf

Weeds: giant foxtail, green foxtail, velvetleaf, pigweed, large crabgrass

## B. Herbicide Rotation

There are few herbicides registered for potato weed control and maintaining their efficacy is important.

Rotational resistance management strategies can be very effective during the non-potato years. Problem weeds, such as nightshade or **pigweed**, may be difficult to control in potatoes. However, they can be controlled in the rotational crops because more herbicide options with different modes of action are labeled for these crops. Limiting the weeds which are contributing to the seed bank will also reduce populations in the following potato crop.



Look in Appendix C for the EPA resistance management groups for herbicides applied to potatoes and rotational crops (beans and corn). When possible, select herbicides from chemical groups which are not available for the potato crop and alternate chemical groups between years.

Examples of herbicide rotation in the potato cropping system include:

- Plant a round-up ready soybean crop in rotation.
- Rotate herbicide chemistries each year to prevent exposure of the weeds to consecutive applications of the same chemical class.



For example, if metribuzin is applied during the potato crop year, do not apply herbicides that are in the same herbicide group (5) in the rotational crop.

- Use herbicide tank mixes of different chemical classes during the non-potato year. However, remember that the chemical classes should not be ones which are available in the potato year.



## C. Area-wide Resistance Mgmt.

### INSECTICIDES

Insecticides with the same EPA resistance management designation code (see Appendix C for listing) should not be used to control insects consecutively. The Colorado potato beetle has been shown to develop resistance quickly, and it is important to maintain the insecticides available to manage them.

Adult **Colorado potato beetles** exit fields in the fall, overwinter in areas on field edges, and then emerge in the spring to infest nearby potato fields. Therefore, any adult beetle that was exposed to a certain insecticide class the previous fall should not be exposed to that same class in the current season. For example, if chloronicotines (EPA Group 4A) were used in adjacent fields the prior season, a different insecticide class should be considered for the current cropping season.

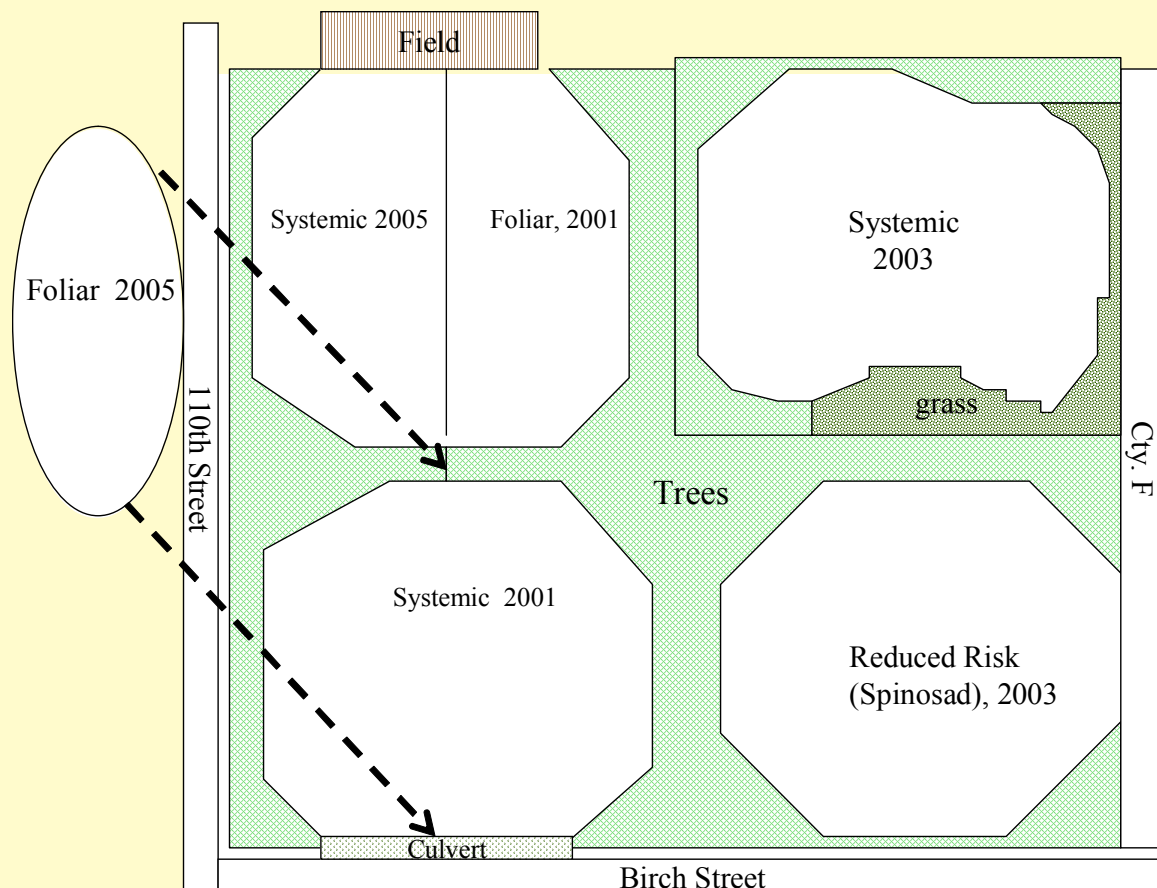


### General Rule for Colorado potato beetle Area-wide resistance management:

When a group 4A systemic (Admire, Gaucho, Genesis, or Platinum) is used in the soil, group 4A systemics **SHOULD NOT** be used on the next year's potato crop unless it is located  $\frac{1}{4}$  mile or more from the previous use site.

An exception to spatial resistance concerns are **potato leafhoppers**. Potato leafhoppers migrate from the southern Gulf States each spring and reach Wisconsin when winds carry them north. Since new potato leafhoppers migrate into Wisconsin each year, there is less chance of resistance developing, and concerns over rotational resistance management are minimal.

### Example of Possible Rotational Schemes for Insecticide Rotations in a Rotational Resistance Mgmt Program



## FUNGICIDES

Fungicide chemistries with single site modes of action have a high probability of developing resistance. Limiting pathogen exposure to these chemistries in the rotational years will delay the onset of resistance and maintain the compound's efficacy. Pathogens that are showing signs of reduced control and increased disease pressure should be monitored for baseline levels of resistance. If populations are shown to be sensitive to resistance, continued exposure to the same chemistries will worsen the problems.

The most serious resistance concerns to fungicides are found with the newer, reduced-risk, single site chemistries such as the strobilurin fungicides (EPA Group 11 in Appendix C). If sensitivity to Group 11 fungicides was observed in the previous year's potato crops, steps should be taken to reduce disease pressure in the current crop while also alternating fungicide classes to reduce exposures to these materials.

For example, **Early blight** spores overwinter in plant refuse. Wind, rain, or insects can move the spores into fields during the current cropping season. Selecting fields that are farther away from the previous year's fields would limit early blight infections. If the



previous year's potatoes showed signs of early blight sensitivity (building resistance) to strobilurins, the Group 11 fungicides should be managed for resistance in the current crop. If fungicides are applied during the rotational year, consider alternating multi-site and single-site fungicides and limit the strobilurin fungicides to not more than 3 applications.

## **D. BioIPM Techniques**

The alternative bioIPM techniques for specific pests are discussed in the next topic section – *Pest Management in Rotational Crops*. General strategies include:

### DISEASE

Use proper bioIPM strategies such as managing weed hosts and utilizing disease forecasting modules to schedule fungicide applications.

Consider long-term cropping systems with grains to reduce the number of *Verticillium* propagules in the soil.

### INSECT

Incorporate bioIPM strategies such as spot treatments, trap cropping, and biological controls whenever possible.

### WEED

Use proper cultural, mechanical and other bioIPM practices to limit weed populations.

### **Common Potato Fungicides with a high relative risk of developing resistance**

<b>EPA Group 1:</b>	<b>Benzimidazoles</b>
<b>Tops</b>	thiophanate methyl
<b>Mertect</b>	thiabendazole
<b>EPA Group 4:</b>	<b>Acylamines</b>
<b>Ridomil</b>	metalaxyl
<b>Ridomil Gold</b>	metalaxyl/mefenoxam
<b>EPA Group 11:</b>	<b>Strobilurins</b>
<b>Gem</b>	trifloxystrobin
<b>Headline</b>	pyraclostrobin
<b>Quadris/Amistar</b>	azoxystrobin



# Pest Management in Rotational Crops

## Preplant



Pest populations in the potato cropping season can be greatly limited if proper management strategies are utilized in the non-potato years. Applying a variety of BioIPM strategies during the non-potato crop will reduce in-season pest pressures. Proper planning and implementation of these strategies will greatly enhance pest management programs during the potato season, and could decrease pest populations and limit pesticide usage.



To effectively incorporate these various strategies, it is recommended that field maps showing pest numbers be maintained from year to year. Use field maps to target those areas which have high pest pressures and to manage pests when they are vulnerable in the non-potato cropping years.

Read the following statements in order and check all that apply. Refer to the corresponding sections on the following pages for more information.

- ☐ **A.** *Cull piles, potato remnants, or other possible sources of late blight inoculum are eliminated.*
- ☐ **B.** *BioIPM techniques are used to manage crucial pest problems (such as *Verticillium*, early blight, Colorado potato beetle, European corn borer, nightshades and other hard to control weeds) in rotational crops.*
- ☐ **C.** *Field maps of pest population levels are maintained for long-term comparisons and evaluation of management strategies.*
- ☐ **D.** *GPS/GIS mapping of pest pressures are used.*

## A. Eliminating late blight inoculum sources

Reducing **late blight** inoculum sources will limit disease outbreaks during the potato season. Cull piles, volunteer potatoes, alternate weed hosts (such as **hairy nightshade**) serve as potential sources of late blight spores. Late blight can be severely limited by eliminating these infection sources prior to potato growth.



By law, cull piles must be destroyed by **May 20th** each year. The safest disposal method is to thinly spread cull potatoes on fields during the winter months. Only spread cull potatoes on fields **not intended for potato production** the following spring. Freezing destroys late



blight infected tubers and late blight spores. Frequently check the cull potatoes for vegetative growth. If they sprout, the plants should be immediately killed with a herbicide or by mechanical control.

Cull piles may also be hauled to commercial landfills or buried on-site at least 3 feet below the soil surface. Feeding culls to livestock is acceptable as long as the tubers are completely consumed, and the manure is not returned to fields used for potato production.

## B. BiolPM Techniques

### DISEASE

To help control **Potato early dying**, utilize cover crops or rotational crops which are not hosts to *Verticillium* or root lesion nematode. These crops include grains, brassica species, and white mustards. More management specifics can be found in the Preplant/Early Dying Management section.



For **early blight**, control volunteer potato and host plants to limit spore formation and the disease's spread. Early blight overwinters as spores and mycelium on crop residue and is distributed by wind during the cropping season. Therefore, field selection and long distance rotations are appropriate cultural control strategies for early blight management.



### Cull Pile Removal

If cull piles are found beyond May 20<sup>th</sup>, contact:

#### **David D. Hyer**

Environmental Enforcement Specialist  
Wisconsin Department of Agriculture,  
Trade and Consumer Protection  
2958 Church Street  
Stevens Point, WI 54481  
phone: 715-342-2640

## INSECTS

**Colorado potato beetles** overwinter as adults, burrowing 6-8" deep in the soil adjacent to field edges. Habitat disruption focuses on lowering soil temperatures to increase winter mortality and reduce emerging spring populations. It is most successful during the coldest period of the year, typically during the month of January. Consider these factors when using this control strategy:



- Snow and mulch at the field margins keep the soil temperatures around 32°F, which is suitable for beetle survival.
- Remove the snow and mulch in Colorado potato beetle overwintering sites when temperatures are below 23°F.



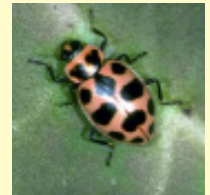
**European Corn Borer (ECB)** commonly overwinters in field and sweet corn plantings although there are many non-crop hosts as well. The European corn borer overwinters as mature 5th instar larvae in corn stalks and the stems of weedy hosts. Pupation occurs in spring with the first moths emerging shortly thereafter, usually in late May and June. Plow down corn stubble in fall to destroy overwintering habitats, especially in areas that are known or expected to have high ECB populations.



As adults, European corn borer moths rest in weedy, grassy areas at field edges during the day and then fly into nearby crops to lay eggs at night. Cleaning up weedy, grassy areas around fields can reduce borer pressure as well.

## Beneficial Insects

Managing beneficial insect habitats and augmentative releases of beneficial insects could help maintain beneficial populations that reduce pests during the following potato year. General beneficial predators, such as **lady beetles**, **stink bugs**, and **lacewings** remain in the area as long as there is prey available for them to eat. Developing diverse habitat areas, either in field corners, along windbreaks, or in field edges allows general predators to thrive. Establishing plantings of multiple species and types enhances beneficial habitat. If areas are established, augmentative releases of beneficial insects (for example, dumping a cup of lacewings) may be useful to increase beneficial populations in and around the field. Do not attempt augmentative releases if there are no prey for the predators because the beneficials will not stay in the area.



Growers and researchers need more knowledge of the predator and parasitoid species and their potential for controlling pests. For example, lacewing and lady beetle populations are most effective as biological control agents in their larval stages. Timely releases are necessary to maximize their populations in larval stages during the times when this is most helpful in pest management. The strategies of managing beneficial habitat and species in potato systems are the subject of ongoing research.



In any field recently rotated from sod or pasture, soil sample for **wireworms** before planting potatoes. Wireworms have an extended life cycle that lasts from 1-6 years. Larvae live in the upper six inches of the soil. The adult females migrate only short distances and look for grassy areas to lay their eggs.



If wireworm pressures are expected to be high, dig into the soil to check for worms. Sampling should be done in the fall before first frost or in the spring after the soil has warmed to 45°F. If wireworms are present in high numbers, potatoes should not be planted in that field. If potatoes need to be planted on that field, a soil insecticide should be applied.

## **WEEDS**

Control volunteer potatoes in rotational crops to limit the onset and spread of many diseases including late blight. Volunteer potatoes can be managed through tillage or chemical control methods.

Use mechanical, physical, biological, or cultural practices in the non-potato years to limit the number of weed seeds entering the seed bank. Tillage, burning, or other operations around field edges should occur before weeds reach the seed formation stage to ensure that weeds do not contribute more seeds to the weed seed bank.



Spot spraying of weed patches in and around fields,

and mowing or tilling operations on field edges during the non potato years are effective strategies if implemented prior to seed formation.

Some herbicides applied to small grain and field crops can be biologically active at extremely low rates and residues are found in the soil for a long time (particularly sulfonylurea and imidazolinone products). There are various plant-back restrictions for these materials, so read the labels closely to ensure the herbicides fit in the potato system.



Crop rotation is an important part of any weed management program. Certain weeds naturally become associated with particular crops because of similar life cycles or similar growth requirements. If any one crop is grown continuously, weeds associated with that crop (such as nightshades in potatoes) tend to dominate and proliferate year after year. A diverse crop rotation discourages domination by any one group of weed species and provides the opportunity to control troublesome species.



## **Notes:**

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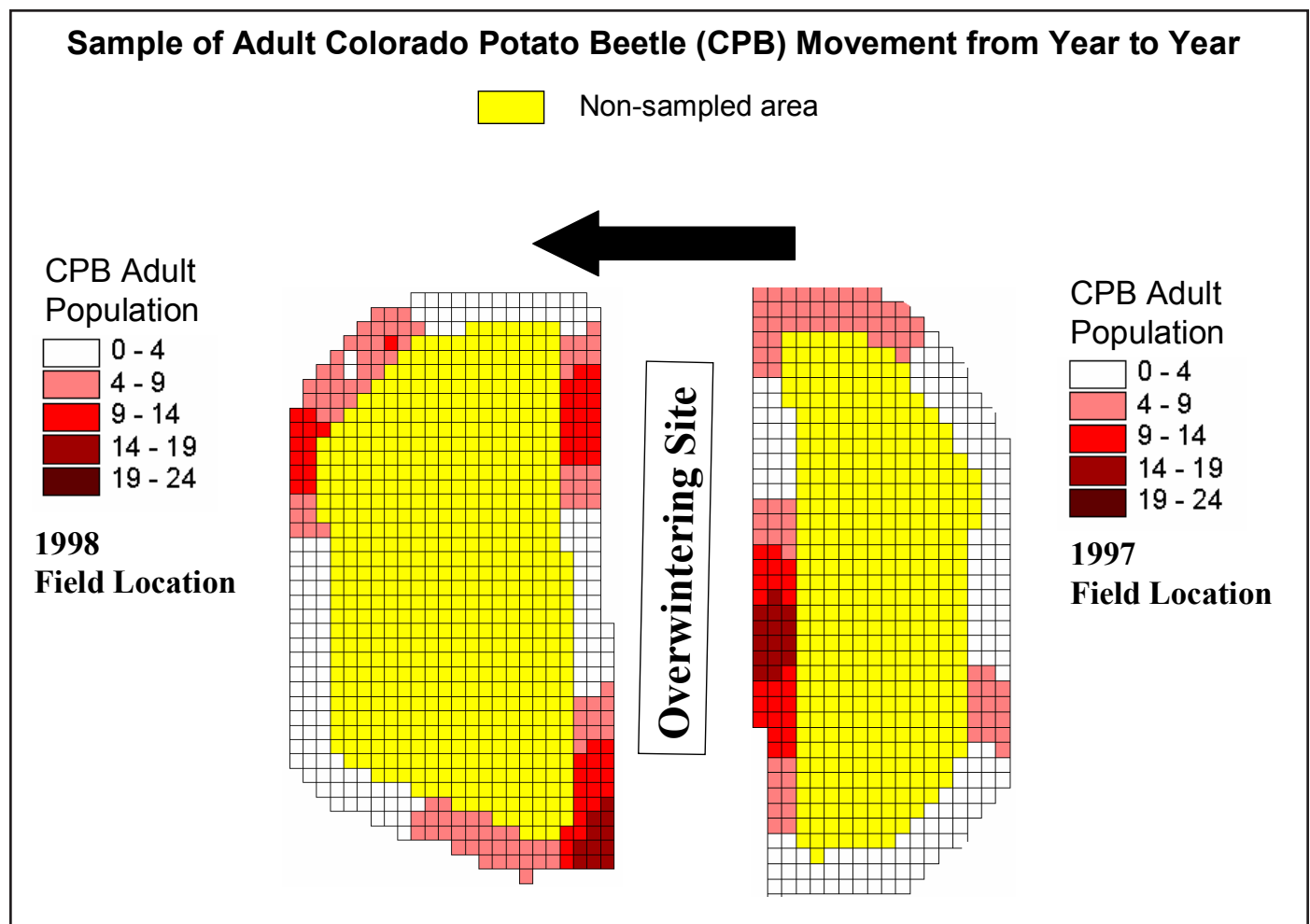
## C. Field Maps of Pest Pressure

Field maps designating areas where insect, disease and weed populations are found should be kept for long-term comparisons of pest populations. Mapping can assist growers in becoming better managers by focusing on key concerns within fields, and by avoiding pests in the potato cropping system when possible.

Draw field maps by hand or create them on a computer. Indicate areas infested by insects, weeds, or disease. Mark Colorado potato beetle overwintering sites, cull pile burial locations, and potential volunteer potato areas. Maps can also be used to track pesticide use, soil fertility, or yield of previous crops.

Field maps should be used as a resource during field selection and when planning crop rotations. To create field maps follow these steps.

- 1) Draw an overview of the entire farm. Include all the farm's fields.
- 2) Record what was planted in each field, including varieties.
- 3) Mark insect infestations from the previous year with X's or another symbol. Be sure to differentiate between different pests.
- 4) Mark disease infestations from the previous year with stripes or another symbol. Be sure to differentiate between different diseases.
- 5) Record what chemicals were used in each field and the rate of application.
- 6) Record weed patches, perennial weeds or weed escapes on the map.
- 7) Record fertilizer programs.
- 8) Record production (quality & yield).



## D. GPS/GIS Mapping

The past decade has seen advances in agricultural uses of GPS (Global Positioning System) and GIS (Geographic Information Systems) technologies. GIS is the process whereby geo-referenced data is analyzed to

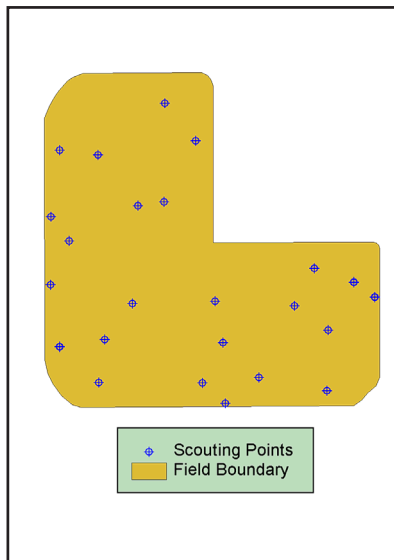
interpret spatial data. GIS includes an organized collection of computer hardware, software, geographic data and personnel designed to efficiently capture, store, update, analyze and display all forms of geographically referenced information.

GPS use satellite signals to geo-reference data (yield, fertility, or pest density) to specific points within the field. GIS is used with GPS to link spatial information with graphic and numerical data.

These technologies allow for quantification of sub-field similarities and differences like crop yield or quality, yield limiting factors including pests, soil fertility or pH, and inputs such as pesticides or fertilizer applications.

Successful implementation of precision agricultural methods has been limited in potato and other production systems. In part, the lack of successful precision agriculture applications is due to the current lack of understanding of how multiple factors influence yield and/or quality.

Therefore, the inability to predict outcomes makes it impossible to optimize inputs and maximize net revenue. Re-



search and on-farm testing continues, and the technology may eventually prove useful and profitable to growers.

### How to get started with a GPS unit & data logger and GIS based software:

GPS field boundaries are taken at any time in the fall or early spring to provide a general overview of the entire farm. Scouting points are marked anytime from planting time to plant emergence. Scouting points provide specific information within each field and are used the entire growing season.

Procedure:

1. Mark individual field boundaries using a GPS unit.
2. Mark all scouting points that will be used for management information throughout the year.
3. Enter field boundaries and scouting sites into the GIS based software.
4. Organize farmview and fieldview in the database by crop year.
5. Create maps according to present and future farming needs.
6. Analyze data to obtain pest control information and evaluate cost effectiveness of control practices and possible effects of production practices on pest distributions and dynamics.
7. Incorporate all crop year information into the GIS database.



# Soil Sampling

## Preplant



Soil sampling is essential to ensure appropriate fertilizer applications. Accurate soil sampling results in more efficient fertilizer use, reduces costs, and reduces the potential for environmental contamination from excess fertilizer applications. Additional soil sampling ensures that disease and nematode population levels are known.



Read the following statements in order and check all that apply. Refer to the corresponding sections on the following pages for more information.

- ☐ **A.** *One composite soil sample for each 5 acres of the field is taken to determine fertility recommendations, pH, and organic matter levels.*
- ☐ **B.** *Each field is sampled for *Verticillium* and nematode levels before deciding to fumigate for early dying.*
- ☐ **C.** *Soil organic matter is monitored and practices that increase organic matter are implemented.*
- ☐ **D.** *Soil sampling determines other soil health characteristics and soil borne disease levels.*

## A. How to Sample Soils

Taking accurate soil samples is the first step in determining fertility, pH and organic matter levels. The following is detailed information on soil sampling.

### NUMBER OF SAMPLES:

One composite sample should be taken for every five acres within the field. This will measure variability across the field. Spatial variability across a field could have a great impact on liming practices, fertility programs, and potato production potential.



### FIELD AREA PER SAMPLE

Within each five acre area, composite samples of 15 - 20 cores taken along a W-shaped pattern should be taken. Each sample area should have a similar crop and fertilizer history for at least the last two years as well as similar soil characteristics. Sample smaller areas within the field that differ topographically if they are large enough to warrant special treatment. A **W**-shaped pattern across the field or sub-field area should be followed.

### WHEN TO SAMPLE

Soil samples may be taken in the fall or the spring before the potato crop is planted. Fall sampling ensures that the test results are ready prior to planting. However, the closer the samples are taken to planting time, the less chance there is for changes in fertility levels. Regardless of timing, it is best to be consistent from one year to the next.



### SAMPLING TOOLS

A stainless steel soil-sampling probe is recommended for obtaining soil samples. Tools must be clean and free from rust. Collect the sub-samples in a plastic or stainless steel container. **DO NOT USE** galvanized or brass equipment of any kind as they may contaminate the samples with micronutrients.



### SAMPLING DEPTH

Sampling depth is based on tillage depth and is generally considered the top 6-8 inches of soil. Maintain the same sampling depth from year to year so soil test values can be more accurately compared. Sampling deeper than the tillage layer potentially results in underestimation of organic matter, phosphorus, and zinc.

### HANDLING AND MAILING

To obtain a composite soil sample, mix sub-samples thoroughly. From the mixed sample, put 2 cups into a clean plastic bag (zip-lock bags work well). Take the sample to a local UWEX office or fertilizer dealer for analysis.

## Notes:

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## B. Sampling to Inform Fumigation Decisions

Potato early dying can cause a tremendous yield loss to susceptible varieties. Since fumigation is expensive and destructive, it should only occur when *Verticillium* and the root lesion nematodes are found at or above the following recommended threshold levels:

- 10 microsclerotia per cubic centimeter without nematodes present
- 7 microsclerotia per cubic centimeter when nematodes are present
- 1 nematode per cubic centimeter of soil

The instructions for *Verticillium* and nematode soil sampling are in this handbook's next section (Preplant/Potato Early Dying Management).



## C. Organic Matter

Organic matter quality and quantity are directly related to many key soil quality indicators. Small increases in organic matter content can have beneficial effects on soil health. These benefits include providing carbon and energy sources for soil microbes, increasing water holding capacity, stabilizing soil particles, increasing soil nutrient availability, resisting compaction, and filtering environmental pollutants. Consider using practices that increase soil organic matter (cover crops, green manures, residue management, tillage systems, organic amendments) when possible. Changes in organic matter content should be tracked from year to year for long-term comparisons.

The soil quality production strategies relating to the changes in organic matter content are currently being researched. Specific recommendations will be included once field data has proven that the strategies are effective and economically feasible.

### Soil Test Results

Growers can use soil test results to plan their fertility programs appropriately, ensuring proper crop growth, production, and quality while limiting adverse environmental effects. Routine analysis of soil samples includes phosphorus (P) and potassium (K) levels, organic matter content (%), and soil pH. The UW soil test report combines these analyses with grower's information on the field, the planned crop, and yield goals to make crop-specific fertilizer and lime recommendations. The soil pH for potatoes

should range from 5.2 to 6.0. Use the test result analysis and the corresponding fertilizer recommendations to plan adequate nutrition for the potato crop.

If requested, the soil analysis can also provide micronutrient quantities (reported in parts per million) of calcium, magnesium, boron, manganese, zinc, and sulfur. To grow adequately, potatoes require low levels of available boron, copper, and molybdenum, but mid-levels of available manganese and zinc.

## D. Advanced screens of soil characteristics and soil borne diseases

Soil quality is defined as the capacity to function within ecosystem boundaries to sustain biological productivity, maintain environmental quality and promote plant and animal health. Healthy, biologically active soils in fields can enhance crop productivity, water and nutrient availability, decrease disease pressures, and filter environmental pollutants.

Laboratories can run a screen for various soil properties to track long-term changes in soil health. These properties include:

- **Aggregate stability:** ability of soil aggregates to resist disruption when outside forces (usually associated with water or wind) are applied. Soils with high aggregate stability are less susceptible to soil loss from water and wind erosion. Soils with high aggregate stability also provide better water and air entry for root growth.
- **Plant available water:** the amount of soil water (volume) that plant roots can access most easily. It is the quantitative means of describing soil water holding capacity.
- **Bulk density:** measure of the weight of the soil per unit volume. It provides an indication of the degree of soil compaction
- **Total soil carbon:** considered the “lifeblood” of the soil and is integrally linked to soil chemical, physical and biological properties. Total soil carbon (C) includes fractions that are very easily degraded (turnover times between 1-5 years) to fractions that are extremely resistant to breakdown or recalcitrant (turnover times from 50-1000's of years). Different C fractions perform different functions in the soil. For example, the active soil carbon fraction is the principal source of nutrients and energy for soil microbes; it is also responsible for disease suppression, nutrient cycling and formation of large (macro) aggregates. Stable or recalcitrant soil carbon contributes to the soil cation

exchange capacity (CEC), soil water retention and formation of smaller (micro) aggregates.

Increasing soil carbon by adding organic materials like crop residues, green manures, and organic amendments (manure, compost, paper mill residuals, cannery wastes, etc.) can improve many soil properties. These properties include increased soil porosity, lower bulk density, higher water-holding capacity, greater aggregation, increased aggregate stability, lower erodibility, enhanced nutrient availability and increased CEC.

- **Soil compaction:** impedes root growth limiting the amount of soil explored by roots for air, nutrients and water. The degree of soil compaction can be determined from bulk density measurements or by measuring penetration resistance (using a penetrometer).

Additional soil samples and screens for soil-borne pathogens may be warranted if concern is high. Long-term field comparisons should be kept to document year to year changes in disease pressures. Screening procedures exist for these potato pathogens:

- *Verticillium dahliae*
- *Pratylenchus penetrans* (root lesion nematode)
- *Streptomyces scabies* (scab)
- *Pythium*
- *Rhizoctonia*
- *Phytophthora* root rot



# Potato Early Dying Management

## Preplant



Growers must consider managing the early dying complex, a potentially damaging problem in the potato cropping system. Practices which enhance soil quality and limit the onset of the potato early dying complex should be implemented to reduce the need for fumigation.



Read the following statements in order and check all that apply. Refer to the corresponding sections on the following pages for more information.

- ☐ **A.** *Fields which have a history of early dying, *Verticillium*, or nematode damage are fumigated.*
- ☐ **B.** *Fields are sampled prior to each potato crop to assess the level of nematodes and *Verticillium* in the soil. Fields above threshold levels are fumigated.*
- ☐ **C.** *Cover crops and non-host crop rotations are added to the potato system.*
- ☐ **D.** *Additional BiolPM practices, such as cultivar selection, potato vine removal and site specific sampling, are used.*

# General Information

Early dying is associated with two components, the **Verticillium fungus** and the **root lesion nematode**. The fungus survives as microsclerotia which germinate in the presence of growing roots of susceptible host plants. The fungus penetrates root hairs and the presence and feeding of root lesion nematodes enhances the fungal infection. As the plant dies, the fungus grows throughout the dying tissue and releases more fungal structures into the soil. Dissemination of the fungus and the plant parasitic nematodes occurs via infected seed pieces, tubers, tillage equipment, and infested soil moved by wind and water erosion or other means.



The small spot on the penny's letter "I" is a *Verticillium* propagule.



A root lesion nematode.

## A. Fumigation

Fumigants are non-specific, gaseous chemicals that are injected into the soil to control soil borne pests. Fumigants are lethal to many soil organisms, including weed seeds, but may also cause unintended side effects such as the loss of beneficial soil fungi and nematodes.

Fumigation is the most effective under the following conditions:

- The optimal soil temperature for fumigation is between 50-70°F. Do not fumigate when soil temperatures are below 45°F since the gas will not



disperse properly in cold soils.

- For best results, fine-textured soils should contain 65-75% of available soil water, and coarse textured soils should contain a slightly higher percentage.
- Fumigation should occur at depths of 2-4 inches for fungi and greater than 4 inches for nematode control. Make sure that the fumigant is evenly distributed throughout the correct depths. Read the pesticide label for specific requirements.



## Verticillium and Nematode Soil Sample Analysis

- 1) 20 core samples per 5 acres is recommended although more intense sampling provides more accurate information.
- 2) Combine all core samples and mix well.
- 3) Remove 1 pint (2 cups) of soil from mix.
- 4) Place sample in a plastic bag.
- 5) Seal plastic bag to maintain soil moisture. **The sample should not dry out!**
- 6) Do not leave samples in the sun or hot areas.
- 7) Send samples to an appropriate testing service.

The University of Wisconsin has the ability to test the soil. For UW analysis, send samples to:

UW-Madison Plant Pathology Dept. c/o Ann MacGuidwin, 1630 Linden Drive, Madison, WI 53706 Phone: (608) 263-6131 FAX: (608) 263-2626



- Because most fumigants are toxic to plants, a waiting period is required between application and planting the crop. Usually two to three weeks between fumigation and planting allows time for the fumigant gases to dissipate.
- Fumigation is usually done after tillage, because good soil preparation and proper application procedures are important to achieve the desired results. Before a soil-injected fumigant is applied, the soil should be in good condition. It is important that clods are broken up and crop residues are finely chopped and thoroughly incorporated. If this is not done, target organisms may survive, because they are not exposed to lethal levels of fumigant.

## B. Soil Sampling for Early Dying Pathogens

Soil sampling to determine root lesion nematode and *Verticillium* levels should be done before deciding if fumigation or other appropriate management is necessary. The best time to sample is late July or early August in the year prior to planting potatoes. Samples may also be taken to coincide with soil testing samples taken in the fall prior to potatoes.



### Thresholds to implement a management control program for the potato early dying complex

The threshold for ***Verticillium*** control is:

**10** microsclerotia per cubic centimeter of soil when nematodes are not present

**7** microsclerotia per cubic centimeter of soil when nematodes are present

The threshold for **nematode** control is 1 nematode per cubic centimeter of soil

## C. Cover Crops and Crop Rotation

### COVER CROPS

Cover crops have many benefits such as increasing soil organic matter, improving soil structure, reducing soil erosion, providing weed management, and attracting beneficial insects. Some cover crops can be grown specifically as green manure crops to aid in control of the potato early dying complex. Certain cover crops like rape-seed release a chemical similar to the chemistry from conventional fumigants, providing a “biological fumigant” response.



Cover crops also benefit the soil by adding organic

### Cover crops which may aid potato early dying management

<u>Cover Crop</u>	<u>Seeding Rate (lbs/A)</u>
Essex rapeseed	20
Humus rapeseed	20
White mustard	20
Forage sorghum	40
Sudan grass	25
Kale	10
Oats	75
Rye	75
Alfalfa	20
Clover	15-20
Vetch	25-50

matter resulting in better overall soil quality. The improvements to the physical properties of the soil benefit the microbial community which exists in the soil. The activities of this microbial community have many benefits and may limit detrimental organisms, including *Verticillium* and root lesion nematodes.

Cover crops can be incorporated in the fall or spring prior to potatoes. Research is currently being conducted to provide specific recommendations on the best choices, seeding rates, incorporation time, and biomass potential.

## CROP ROTATION

Since microsclerotia of *Verticillium dahlia* persist in the soil up to 7 years, one of the best cultural strategies to limit potato early dying is to lengthen potato rotations. Three year rotations are a minimum to reduce inoculum levels and can be effective in limiting the fungus when populations are low (below 10 microsclerotia per cubic centimeter). Long-term rotations are recommended in heavily infested fields, with rotations as long as possible.

When implementing these long-term rotations, choose crops which are not hosts to either *Verticillium* or the root lesion nematode. Non-host crops include snap bean, peas, sweet corn, field corn, small grains, and alfalfa.

## D. BiolPM Techniques

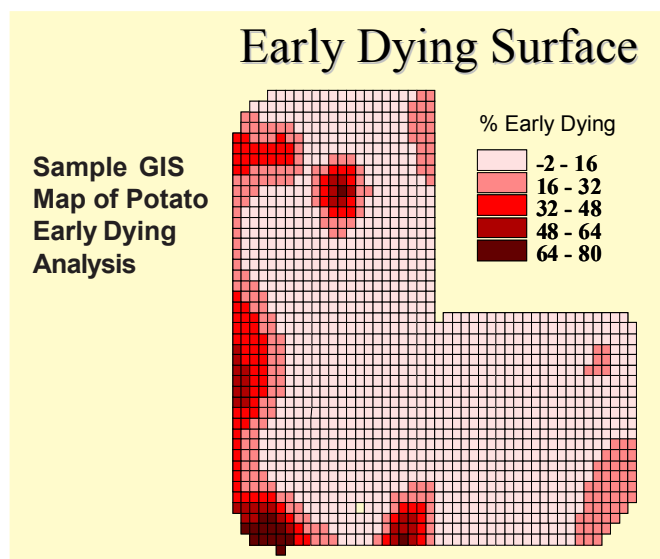
### RESISTANT AND/OR TOLERANT CULTIVARS

There are some tolerant varieties which may be planted to limit the onset of potato early dying. These cultivars include Ranger Russet, Russet Nugget, Bannock Russet, Frontier Russet, and NorKing Russet. Growing resistant cultivars in the long term rotational system may reduce *Verticillium* populations in the soil over time.

Russet Norkotah is an extremely susceptible cultivar to potato early dying. When the pathogens are present, disease symptoms can commonly be found on this cultivar early in the growing season.

## VINE REMOVAL

Vine removal can help mitigate the effects of potato early dying. This takes *Verticillium* spores present throughout the living plant tissue off the field, reducing microsclerotia movement into the soil as vines die. Vines removed with a forage chopper can be composted along field edges or in large, open areas. Be sure that vines are composted in areas which will not spread microsclerotia through wind or water erosion. Vines can be actively composted by adding external carbon sources and turning the pile frequently throughout the winter months. Temperatures in the compost pile should reach high levels to kill microsclerotia (113° F for one hour). Properly composted vines can be reapplied to fields to increase soil quality.



### SITE SPECIFIC FUMIGATION

Grid soil sampling on a 1 to 5 acre grid can be useful in locating potential early dying “hot spots.” Intense soil sampling for root lesion nematodes and *Verticillium* levels within a field can locate specific sites for fumigation. This method decreases the amount of fumigant applied to the entire field which limits fumigation’s negative effects. Site-specific fumigation is promising in Wisconsin potato production systems.

Maintaining good field records of potato early dying locations and effects from year to year will help decide if grid sampling and site-specific fumigation

is likely to be profitable. Site-specific fumigation can be cost effective when a small percentage of the field needs to be fumigated. In this case, the savings from limited fumigation overcomes the increased cost of soil sampling. However, if the field is heavily infested and the majority of the field needs to be treated, the cost of the increased number of soil samples (which can exceed \$1200 for a 100 acre field) is quite expensive. When this cost is combined with the cost of fumigation (>\$150 per acre), this approach is not economical.

## SOIL SOLARIZATION

Soil solarization successfully limits *Verticillium* and nematode populations and may be useful in reducing potato early dying. Solarization is a tactic which may be used either as a stand alone strategy or in combination with other practices such as fumigation, cover cropping, or vine removal. The idea behind soil solarization is to lay transparent polyethylene covers on top of the soil to trap heat under the plastic. This raises soil temperatures to kill *Verticillium* and plant pathogenic nematodes. Studies have shown that heating the soil to levels of 140° F for a few minutes is adequate to kill *Verticillium* propagules. Similar results can also be seen from cumulative exposures of *Verticillium* and the nematodes to soil temperatures as low as 100° F for several hours.



Using soil solarization as a fumigation alternative is currently being researched in Wisconsin potato production systems. The application of these techniques to the state's conditions is not yet known. Specific recommendations will be made once field data has proven that solarization is effective and economically feasible.

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# Field Selection

Preplant



Potato management begins with selecting the appropriate planting site. Field placement and selection should be based on pest and crop management considerations that assure a healthy crop.



Read the following statements in order and check all that apply. Refer to the corresponding sections on the following pages for more information.

- ☐ **A.** *Potatoes are rotated across fields on a three-year (or more) schedule.*
- ☐ **B.** *Potatoes are rotated spatially, keeping a 1/4 mile distance from last year's potato fields.*
- ☐ **C.** *Field maps or records of past pest pressure are consulted.*
- ☐ **D.** *Soil qualities and field characteristics are considered in the selection process.*



## A. Temporal Rotation

Potatoes should not be grown on fields where they were planted the previous year. Temporal (or time in years) rotations should be increased for as long as possible. A rotation of at least 3 years is recommended. Longer rotations have benefits for disease suppression, insect control, weed management, soil quality characteristics, and soil biodiversity. Long-term rotations are among the most effective cultural control strategies for pest populations.

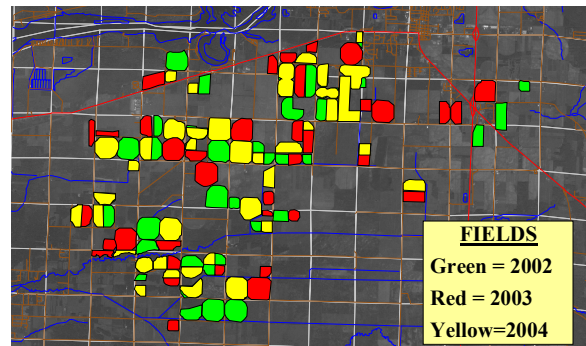


**Temporal rotation** – refers to the number of years since potatoes were planted. A rotation of potatoes-snap beans-sweet corn-potatoes is a 3 year rotation.

**Spatial rotation** – refers to the distance from the current potato field to last year's potato fields.

overwintering sites. By increasing the distance between overwintering sites and newly planted potato fields, the colonization by Colorado potato beetles is delayed. **A distance of at least ¼ mile** between the previous year's potatoes and the current year's field significantly reduces beetle infestations in the spring.

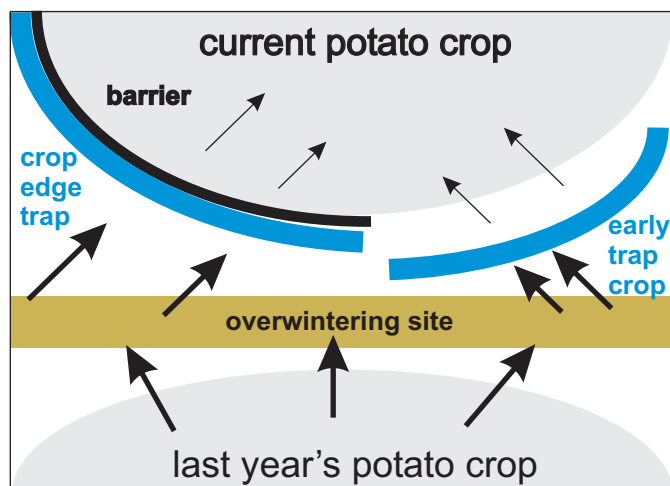
### Example of Spatial Field Locations



**Early blight** spores can move via air and water and **longer distances** between the previous year's and current year's potato crops can help in limiting infections.

## B. Spatial Rotation

The distance between the current season's potatoes and the previous year's crop can have an effect on the current pest pressures. Considering the spatial dynamics of **Colorado potato beetle** migration is essential for managing beetle populations. Adult beetles usually walk into fields from

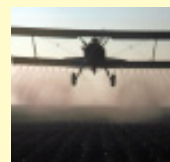


Spring Distribution of CPB

### Spray Equipment

Growers should consider how they will apply crop protectants when deciding field locations. These factors should be taken into account:

**Aerial spraying:** windbreaks, building and power lines can interfere with aerial applications of potato pesticides. Apply backup spray with ground equipment to field borders and other areas that are not well covered.



**Ground spraying:** odd shaped fields are difficult to treat with large sprayers.





## C. Past Pest Pressure

Pest management and production practices are influenced by previous crops and rotational histories. Growers can be better managers by keeping field records of cropping history, pest populations, and management practices. Field mapping systems should be used to designate possible problems.

Field maps provide an overview of a particular farm. These maps should designate areas infested by insects, weeds, or disease in previous years. Field maps can help in decision-making. For example, if the field had soil borne pest problems, rotate to a non-host crop to reduce the pest

populations. Field mapping methods are described in the Preplant/Pest Management in Rotational Crops section.

Problem pests and concerns to record in rotational years include:

- Insects — wireworm and white grub.
- Disease — *Rhizoctonia*, pink rot, scab, nematodes and *Verticillium*.
- Weeds — quack grass, hairy nightshade, and Eastern black nightshade.
- Production information — yields, quality, and marketability.

### Colorado Potato Beetle Area-wide Management

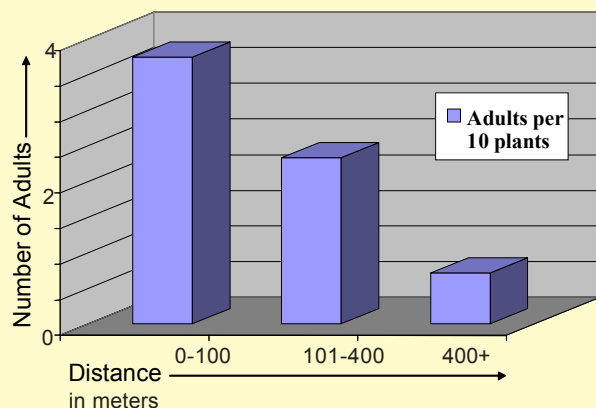
If high populations of Colorado potato beetles are expected, plant potatoes at least 1/4 mile from fields that were planted with potatoes the previous year. If small populations are expected, closer rotations may be considered.

Field isolation can be difficult for one farm, but more likely if a cooperative approach is followed by adjacent landowners. Since a 1/4 mile is needed to optimize management, growers collaborating on an area-wide basis can plan rotations over time and location, and discuss insecticide applications. This will maximize Colorado potato beetle management in the area.

To utilize an area-wide management strategy, consider each of the following questions prior to determining field locations.

1. Where were the previous year's fields?
2. How large was the Colorado potato beetle population exiting the previous year's potato crop?
3. Where are the beetle overwintering sites?
4. What was the control method used in the previous year's field?
5. Are there obstacles (such as roads or streams) in the way of the beetles' migration?
6. Can long distance rotations be used to manage beetle populations?

**Effect of Distance Traveled by Colorado Potato Beetle Adult Populations - Plover, WI 1998**



## D. Soil Quality and Field Characteristics

Enhanced soil quality can result in better production (see the Preplant/Soil Sampling section for more details). The following characteristics may be considered as field selection criteria.

- Compaction can decrease drainage thus causing water to pool, increasing disease and tuber deformities.
- Organic matter is an important factor in soil quality. It helps to retain water and allows for optimal crop growth.
- Controlling wind erosion keeps the soil and nutrients in place and prevents crop damage.
- Damaging pesticide residues may occur when some herbicides that have active ingredients in the sulfonylurea and imadazolinone families are used. These herbicides can remain at levels toxic to potatoes for several years following application.

## Notes:

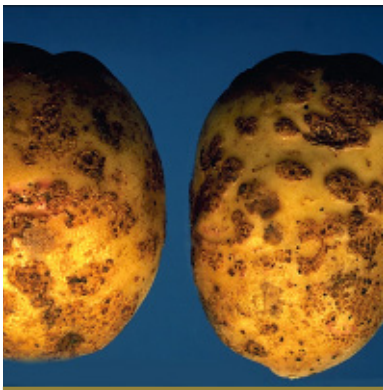
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# Cultivar Selection

Preplant



Consider factors beyond market demand when selecting cultivars. Criteria to consider include disease tolerance, certification system, seed source and availability, field factors, and previous pest pressures.



Read the following statements in order and check all that apply. Refer to the corresponding sections on the following pages for more information.

- ☐ **A.** *Cultivars are selected according to marketability of the potato crop.*
- ☐ **B.** *Certified seed is purchased.*
- ☐ **C.** *Seed production practices are reviewed with the seed producer prior to purchase and delivery.*
- ☐ **D.** *Pest susceptibility is considered in cultivar selection.*

## A. Potato Marketability

Potato marketability is a key component in growers' varietal selection. Market analysis should take place over the winter to determine what the crop will be used for, where it will be marketed, and what varieties suit these marketing criteria. Trends in fresh, processed, specialty, and seed markets should be watched carefully and tracked from year to year.



Remember that field selection criteria (soil type, draining, yield potential, type of sprayer) as well as pest concerns should also be taken into consideration when selecting cultivars. Refer to the previous Field Selection section in this Preplant chapter for more information.

## B. Certified Seed

Planting certified seed potatoes is the foundation of any management program for a productive potato crop. Planting healthy seed is a basic component for disease management and may also help control insects and weeds. Once appropriate cultivars have been selected, a supply of high quality, certified seed potatoes must be obtained.

Seed potato certification programs were started to



reduce the incidence of tuber-borne pathogens and to provide seed stock clones of improved cultivars free from varietal mixing. Certified seed potatoes are produced under stringent standards and must meet baseline field and winter test tolerances.

Wisconsin seed potatoes are classified as "Certified" or "Foundation" depending on disease and varietal mixing levels. Foundation seed meets much stricter tolerances required to protect the integrity of the seed industry.

Seed quality is difficult to define, but it is generally accepted that a healthy seed lot should be:

- Free of cultivar or clonal mixtures.
- Within established certification tolerances for certain diseases and pests.
- Free of bacterial ring rot.
- Physically sound, with minimal mechanical and cold injury.
- Properly sized and classed A-size or B-size.

A-sized tubers, which will be cut into seed pieces, weigh between 4-10 ounces and are between 1 ½ - 3 ¼ inches in diameter.

B-sized tubers (single drop), which will be planted whole, generally weigh less than 4 ounces and are between 1 ½ - 2 ¼ inches in diameter.

- True to grade, with few knobs and second growth.
- Free of excess soil, stones and other debris.
- Of the desired physiological age.
- Properly inspected and certified.

Examine the records for all seed lots and discuss the reasons for rejection of any lot with the seed grower. The seed grower should have certification records for specific seed lots readily available.

## C. Communication with Seed Suppliers

Maintaining positive communication between the seed producer and seed buyer is important. When contracting to buy seed, visit the seed producer in the year prior to purchasing the seed to inspect the crop before buying the seed. Communicate to the seed producer any comments or observations on the performance of the given seed lot, both positive and negative. The seed producer is an important partner in commercial production, and two way communications should be maintained.

## D. Pest Susceptibility of Cultivars

### DISEASE

The **early blight** pathogen overwinters as spores in the soil or on plant debris. In the spring, spores are released and spread to other plants by wind, rain, insects, and other wildlife. The fungus penetrates the leaves through natural openings causing characteristic brown lesions with concentric rings. As leaves age, they become more susceptible to the early blight fungus. Stress caused by nutritional deficiency, air pollution and weed competition can increase susceptibility to early blight.



Cultivars differ greatly in their susceptibility to **early blight**, but all cultivars currently grown in Wisconsin exhibit symptoms at some point during each growing season. Resistance levels are as follows:

**Highly susceptible to early blight** (early and mid season cultivars): Norland, Redsen, BelRus, Norchip, Norgold Russet, Early Gem, Superior, Monona, LaChipper, Atlantic

**Moderately susceptible to early blight** (late season cultivars): Russet Burbank, Kennebec, Katahdin, Rosa

**Lowest susceptibility to early blight** (very late cultivars): Butte, Nooksack, Ontario

### DISEASE

**Common scab** is caused by the bacterium *Streptomyces scabies* and can be a serious tuber pest. The organism causes raised corky lesions, russet scab and pitted scab. All of these lesions cause economic losses in fresh market potatoes and to a lesser degree in processing stock. The scab organism is usually introduced by infected seed pieces and can survive indefinitely in the soil on decaying plant material. Scab bacteria can also survive passage through an animal's digestive tract and be distributed in manure.



Resistance to scab is related to the tuber's ability to form corky tissue that walls off the pathogen and prevents further infection. Susceptible and moderately resistant cultivars are listed below.

#### **Susceptible cultivars to common scab:**

Centennial Russet, Chippewa, Denali, Elba, Hampton, Irish Cobbler, Jemseg, Kanona, Katahdin, Red Pontiac, Rosa, Shepody, Steuben, White Rose and Yukon Gold.

#### **Moderately Resistant Cultivars to common**

**scab:** Atlantic, BelRus, Conestoga, Crystal, Islander, Kennebec, LaRouge, Monona, Norchip, Norgold Russet, Norland, Onaway, Ontario, Pungo, Rideau, Russet Burbank, Sebago, Superior and Viking.

**See fact box for Common scab on following page.**



**Potato leafhoppers** are one of the most damaging insects of Wisconsin potatoes. Variety selection plays a role in the susceptibility of potatoes to leafhoppers.



Although it is not commonly grown in Wisconsin, the potato variety Delus is highly resistant to potato leafhoppers. Wisconsin varieties and their level of susceptibility include:

**Highly susceptible to potato leafhoppers:**  
Norland, Norchip, Atlantic, Superior

**Moderately susceptible to potato leafhoppers:** Goldrush, Snowden, Norgold Russet, Kennebec, Red Pontiac

**Least susceptible cultivars to potato leafhoppers (but NOT resistant cultivars):**  
Ranger Russet, Russet Norkota, Russet Burbank, Ontario, Red LaSoda

## Common Scab

*S. scabies* survives in soil with pH ranges between 5.5 – 7.5, but is generally less of a problem if the pH is maintained at or below 5.5. Tubers are infected through stomata and lenticels, and infection can occur as soon as tuberization begins. Lesions continue to enlarge as tubers bulk, increasing the size and severity of the infected tissue. Mature tubers are not susceptible to infection, however, as they have a well-developed skin.

### Scab Control

For scab control, no single tactic will completely work. Manage scab using several different cultural controls including:

1. Maintain a three to four year rotation with non-susceptible crops such as alfalfa, rye, and soybean.
2. Avoid rotations with other root crops such as carrot or beet.
3. Maintain soil pH at or below 5.5.
4. Infection by scab is inhibited by moist conditions, so limit infection by maintaining moisture levels at 80-90% of available soil water during tuber initiation and for the next 6-8 weeks.
5. Purchase scab-free seed and select resistant cultivars.

## Notes:

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# Seed Preparation

## Planting



Seed selection and careful handling ensures vigorous seedling growth while limiting seed piece and seedling diseases.



Read the following statements in order and check all that apply. Refer to the corresponding sections on the following pages for more information.

- ☐ **A.** *Certified seed is purchased.*
- ☐ **B.** *Seed tubers are carefully stored, handled, and warmed prior to cutting.*
- ☐ **C.** *Proper sanitation and cutting practices are used.*
- ☐ **D.** *Cut seed is carefully stored and allowed to cure and suberize for at least 7 days.*

## A. Certified Seed

Planting certified seed is a crucial phase in the potato bioIPM system. Non-certified seed may contain high levels of virus or other pathogens which will cause problems during the season.

An important step is meeting with the seed producer before the season begins. Growers should discuss seed production practices, scouting numbers and certification with their certified and/or foundation seed potato producers. Make every effort to ensure that clean, non-infected seed is purchased and seed borne problems are avoided.

## B. Storing and warming seed tubers

When seed arrives, the shipment should be thoroughly inspected to detect disease or other disorders. To minimize bruising, the seed should never drop more than six inches during the handling, storing and cutting operations.

Before cutting the seed, it should be stored in cool (38-40°F), well ventilated bins at 90-95% relative humidity until it is time to cut.

Seed tubers should be allowed to warm to 50-55°F before handling. Begin warming the tubers very slowly, about 0.5-1.0°F per day, seven to ten days prior to cutting. Warming the seed before cutting serves three purposes:

1. Reduces bruising during handling.
2. Promotes rapid healing after cutting.
3. Initiates sprouting before planting.

## C. Proper Seed Cutting

Careful seed handling and cutting are important steps in a healthy potato management program. Improper seed cutting has the potential to spread diseases or lead to planting and emergence problems.



Cut seed tubers in a clean, relatively humid area, preferably indoors. The flow of seed potatoes into the cutters should be adjusted so that they are not more than one tuber deep.

Mechanical cutters should be set to provide seed pieces of 2-3 ounces with 1-2 eyes on each seed piece. Smaller seed pieces may result in weak plants, while seed pieces above three ounces produce plants with excessive numbers of stems, possibly leading to higher tuber numbers and lower yields. A wide variation in size results in problems with planting and a higher number of skips and doubles in the field. Keep the blades sharp and adjusted to deliver seed pieces in the appropriate size range.

Regardless of the type of mechanical cutter used, it is essential that the equipment be thoroughly cleaned and sanitized prior to each season. Cutters with water-impermeable sponge rollers are recommended since open-cell rollers may harbor ring rot bacteria and other decay pathogens.

To reduce disease spread, clean and disinfect the equipment before cutting each new seed lot and whenever possible during the cutting operation. In addition, disinfect the conveyers and



other equipment used to transport the tubers between each seed lot. Provide workers with disinfectants and washing facilities to minimize potential infection spread during the cutting operation. It is also advisable to provide workers with new plastic disposable boots and gloves each day.

## D. Cut Seed Storage before Planting

Seed pieces need to be handled with care. Optimum stands are more likely when disease exposure is minimized, mechanical and physiological damage to seed piece reduced, and favorable conditions for rapid plant development are provided.



After cutting, it is critical that cut seed be stored in an environment that favors rapid wound healing. Some growers use pallet bins or boxes to hold cut seed, while others place seed in piles no more than 4-6 feet deep over air ducts. Air movement must be adequate to provide oxygen and prevent the accumulation of high levels of carbon dioxide.

Storage temperatures should be between 50-55°F. Keep the relative humidity high at 90-95% (but no free water). Because cultivars and local storage conditions may vary, monitor the humidity carefully. Do not humidify the storage during the first 24-48 hours after cutting if there is condensation and surface moisture on the seed pieces.

Warm seed pieces or tubers before planting. Ideally, the difference in temperature between seed and soil should be no more than 5°F at planting time. However, warming seed for periods longer than 2 weeks or to temperatures higher than 55°F can result in excessive sprouting and physiological aging. This can lead to lower yields and reduced quality.

## Wound Healing and Suberization

Immediately after cutting seed, a natural wound healing process begins. The healing process benefits from abundant fresh air, high relative humidity (95-99%), and temperatures at 55-60°F. Maintaining humidity above 90% is critical to prevent death of cells on the cut surfaces and allows proper healing.

Although high humidity is required, the formation of free water (condensation) must be avoided, because water film on cut surfaces acts as an oxygen barrier to cells on the cut surface. Free water on seed pieces interferes with wound healing and may allow soft rot bacteria to become established. When wound healing is completed, the suberized layer and wound periderm prevents both moisture loss and infection of the cut surfaces by bacteria and fungi.

The cut surface of a potato tuber heals in two phases. The first phase is suberization: cells just below the cut surface produce a waxy, fatty compound called suberin. This seals the wound, prevents water loss, and blocks infection by pathogens. Suberization begins 1-3 days after cutting and is complete in 4-7 days.

The second phase of healing is the formation of wound periderm. The periderm is a permanent, protective layer of cells that replaces the tuber's skin when it is destroyed. The new periderm is a corky layer, which serves as the final covering to prevent infection and desiccation. Periderm formation begins shortly after suberization and is complete in about 1-2 weeks.

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# Field Preparation

## Planting



Fields should be prepared properly to maintain soil moisture and allow for root penetration and water infiltration. Field preparation includes tillage, proper soil moisture levels at planting and the optional practice of incorporating green manures or other composted materials. Keeping good field records of the previous year's rotational crop and pest pressures improves planning for field operations.



Read the following statements in order and check all that apply. Refer to the corresponding sections on the following pages for more information.

- ☐ **A.** *Preplant tillage is adequate for potato planting and weed control, but not excessive.*
- ☐ **B.** *Soil moisture levels are near field capacity at planting.*
- ☐ **C.** *Cover crops and/or composts are incorporated to add biomass and increase the soil's organic matter content.*
- ☐ **D.** *The field's rotational and pest history is documented and considered before field preparation.*

## A. Conventional Tillage

Tillage is necessary for loosening the soil prior to planting, managing plant residues, and warming the soil early in the season. Avoid excessive tillage as it increases the cost of production, the likelihood of wind erosion, and the amount of soil compaction.



Pre-plant tillage is often an important part of a potato pest management program. Tillage effectively controls emerged annual weeds and when combined with herbicides, can also manage perennial weeds and volunteer potatoes. However, tillage can increase some perennial weed problems if underground storage organs are spread by tillage. Tillage can also interfere with herbicide uptake by perennial weeds if herbicides are sprayed too soon after a tillage operation.

Water infiltration is influenced by crusting, organic matter, soil aggregation, and macro-pore formation (earth worm tunnels). Tillage can have both positive and negative effects on these factors. Tillage can improve water infiltration by disrupting surface seals or crusts. Deep tillage (> 8-10 inches) disrupts compacted areas formed by field traffic and natural laying pans. Tillage can also break up clods if done at the appropriate time, but may promote clod formation in excessively wet, heavy soils.

Generally, tillage negatively influences soil aggregation, macro-pore formation, and organic matter.

General guidelines for preplant tillage include the following:

- Clean tillage equipment of all soil and plant residue when moving from field to field to prevent the spread of weeds and plant pathogens between fields.
- Vary tillage depth from year to year to prevent the buildup of a hardpan just below the tillage

level. Occasionally, deep tillage operations (deep ripping to 18") may be done if hardpans are a concern.

- When using heavy equipment, distribute the weight over multiple tires and axles to spread the load over as large an area as possible. Adjust speeds, ballast, and tire pressure to minimize tire slippage.

## B. Soil Moisture and Irrigation

Soil moisture level at planting is an important factor contributing to seed piece decay. Plant when the soil moisture is at 70-80% of available soil water. Planting in soil wetter than this promotes bacterial seed piece decay regardless of the temperature.

Planting into hot, dry soil often leads to excessive seed piece decay as well. If the soils are excessively dry, irrigate prior to planting. Avoid irrigation between planting and emergence as this can contribute to seed piece decay.

One method to estimate soil moisture levels is to use the ball test. To do this, simply take a handful of soil and try to form it into a ball. Use the chart on the next page to provide an estimation of soil moisture levels.



## Feel Chart for Estimating Soil Moisture

(Soil Moisture %):

### Sand or loamy sand soil texture

**Below 20:** No ball forms. Single grained soil flows through fingers with ease.

**35-40:** Forms weak brittle balls. Finger print outline not discernible. No soil sticks to hand.

**50:** Forms very weak ball. If soil well broken up it will form more than one ball upon squeezing. Fingerprint outline barely discernible. Soil grains will stick to hand.

**60-65:** Forms weak, brittle ball. Fingerprint outline not as distinct. Soil particles will stick to hand in a patchy pattern.

**70-80:** Forms weak ball. Distinct fingerprint outline on ball. Soil particles will stick to palm.

**100:** Upon squeezing, no free water appears on ball but wet outline of ball is left on hand. Ball has some stickiness and a sharp fingerprint outline is left on it.

### Loam, silt loam, clay loam soil texture

**Below 20:** Powdery, dry, will not form a ball; if soil is crusted, easy to break into powdery condition.

**35-40:** A ball can be formed under pressure, but some soil will fall or flake away when hand is opened. The ball is very crumbly and hardly holds its shape.

**50:** Forms a ball readily, holds its shape. No moist feeling is left on hand nor will any soil fragments cling to palm. Ball is very brittle and breaks readily. Soil falls or crumbles into small granules when broken.

**60-65:** Forms firm ball; finger marks imprint on ball. Hand feels damp but not moist. Soil doesn't stick to hand. Ball is pliable. When broken, ball shatters or falls into medium-size fragments.

**70-80:** Damp and heavy; slightly sticky when squeezed. Forms tight plastic ball. Shatters with a burst into large particles when broken. Hand is moist.

**100:** Wet sticky, doughy, and slick. A very plastic ball is formed, handles like stiff bread dough or modeling clay; not muddy. Leaves water on hand. Ball will change shape and cracks will appear before breaking.

Optimum for potato planting





# Cultural Pest Management Options

## Planting



Cultural control practices at planting are important to the bioIPM production system. Key practices include eliminating sources of disease inoculum, preventing pest introductions to clean fields, and assuring a healthy potato canopy develops.



Read the following statements in order and check all that apply. Refer to the corresponding sections on the following pages for more information.

- ☐ **A.** *Cull piles, storage wastes and seed cutting remnants are buried or destroyed before planting begins.*
- ☐ **B.** *Machinery is cleaned when leaving a field and before entering new fields.*
- ☐ **C.** *Practices to assure a healthy crop and canopy development are followed. These include: proper seed and row spacing, proper canopy development, and following University fertility recommendations.*
- ☐ **D.** *Cultural control strategies are implemented. Some examples include spring trap crops for Colorado potato beetle control or smother crops for weed management.*

## A. Limiting Disease Inoculum Sources

Eliminating inoculum sources is a proven strategy for limiting disease development in the potato system. Several effective strategies for this are described below.

**Late blight:** Cull potatoes that are not properly disposed of often initiate late blight epidemics. Tubers from warehouses dumped in cull piles or seed slivers serve as sources of inoculum for neighboring potato fields. The late blight fungus develops on the plants growing from infected tubers and serves as an inoculum source for nearby potato fields.



Bury cull piles or seed slivers from the seed cutting operation with a minimum of 3 feet of soil over the top of the potatoes. Do not bury cull potatoes or slivers in fields which will be planted to potatoes during the season. Frequently check fields which were used to bury potato waste for vegetative growth above ground. If the potatoes sprout, they should be immediately killed.

**Early blight:** Early blight can be limited by controlling its alternate hosts. Plants such as hairy nightshade, eastern black nightshade and other solanaceous plant species serve as fungal reproductive and overwintering sites. Early blight can also overwinter on dead potato vines. Control the weeds, specifically night-



shades, by cultivation or with herbicides to limit these hosts of early blight.

**Potato Early Dying:** cultural management tactics are described in this handbook's *Preplant/Potato Early Dying Management* section.

## B. Preventing Pest Dispersal by Machinery

If weeds, nematodes, or other soil borne pests are not yet present in a field, preventing their introduction is a cost effective strategy. Soil that is left on equipment traveling from field to field introduces weeds and pathogens to new areas. Thoroughly wash equipment before working in potato production fields and if possible, between fields.

In most cases, the introduction of weeds and/or plant pathogens occurs at the field entrance and tillage then spreads them though the field. Clean tillage equipment before leaving a field. After removing all soil from the implement and tires, spray all equipment parts coming in contact with the soil with a disinfectant. Disinfectant applications can be made with a simple hand sprayer and do not take more than a few minutes between each field.

## C. Plant Health and Canopy Development

Weeds and crops have the same requirements for normal growth, development, and reproduction and therefore are in constant competition. Growers can apply management strategies (proper seed and row spacing and proper plant nutrition) to improve the crop's competitive advantage and reduce negative effects of weeds.

If weeds are controlled early in the season before the potato canopy develops, the potato crop easily competes with weeds later in the season. The options for potato weed management include chemical, mechanical and cultural control or more often some combination of the three. Herbicides are typically used preemergent to the potato crop,

but at currently recommended rates will only give between seven to nine weeks of control. Weed control from herbicides can be enhanced with cultivation; however, excessive cultivation may reduce herbicide efficacy and may reduce yields through root pruning.

Most potato cultivars reach maximum canopy at six to seven weeks after emergence. Once maximum canopy is reached, weed control is provided by the potato crop until the canopy begins to break down later in the season. Some early harvested cultivars such as Superior and Dark Red Norland only shade the soil at about the 90% level which allows for some weed growth. Russet Burbank on the other hand provides shade at 96% or higher. This should prevent any weed growth.

Crop canopy development and maintenance depends on the general health of the potato plant. The canopy may be reduced by water stress, nutrient deficiencies, insect and disease infestation, and other environmental factors.

Field scouting is a critical component of this integrated control program. If the crop canopy is damaged, it may be necessary to apply a post emergent herbicide so weeds can be controlled until the crop is able to recover.

## D. BiolPM Techniques

### INSECTS

**Colorado potato beetles** are vulnerable to various cultural strategies at planting since they walk into the field from overwintering sites in the spring. This limited migration pattern allows for border and trap crop techniques to be used as control methods. Keep scouting and monitoring beetle populations in the field even when these strategies are used since these will not provide 100% beetle control.



Planting **trap crops** can be an effective method for controlling **Colorado potato beetles**. In Wisconsin, trap crops work by congregating adult beetles as they exit overwintering sites and enter newly emerged potato fields. The beetles which congregate in the early planted stand of potatoes are then killed by chemical, physical, or cultural methods. By limiting overwintering adults, fewer beetles will enter the main potato crop, fewer eggs will be laid, and ultimately fewer chemical applications will be necessary, reducing the adverse effects of pesticides.



To implement a trap crop, plant a strip of early-planted potatoes, anywhere from 12-48 rows, along the field's edge. The remainder of the field can be planted at a later date. Once the beetles have congregated in the trap crop area, control them physically or chemically.

Physical control methods that are commercially available include **vacuum suction** and **propane flaming**. Propane flammers are highly effective for Colorado potato beetle control when potatoes are up to 4 inches tall. Two burners per row of potatoes should be directed at an angle at the base of the plants. Adjust the nozzle distance, angle, and tractor speed so that the young foliage is not heavily injured while ensuring that Colorado potato beetles are killed.





**Chemical border treatments** along field edges may also be used as a cultural control strategy. This method is similar to a trap crop but a systemic or foliar insecticide treatment is applied to a strip of potatoes planted along the field edge where Colorado potato beetles are expected to enter. The chemical border method should limit Colorado potato beetle infestations of the main field area. The strip of potatoes can be planted earlier than the rest of the field, or it can be planted at the same time. If beetle populations are expected to be low, border treatments of 24 rows should be sufficient. However, if large beetle populations are expected, a border treatment of greater than 48 rows is needed.

**Barriers**, either natural or artificial, found in or along field edges will limit Colorado potato beetle infestations as well. Barriers are physical obstructions that delay beetle movement into potato fields. Streams, windbreaks, and weeds are among the many natural barriers that already exist. Artificial barriers, such as wheat or grasses, can be planted along field edges prior to beetle emergence to confuse beetle migration.

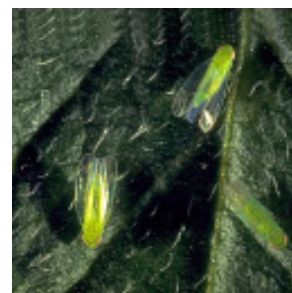
**Trenches** can be dug along field edges to “trap” beetles in the ground where they can be killed before entering the potato fields. Trenches can be an effective, yet costly control measure. Trenches may be used if heavy beetle populations are found or as a resistance management strategy where concerns over beetle resistance are high. Trenches are popular in Long Island due to the beetles’ development of resistance to all chemical control options in that area.



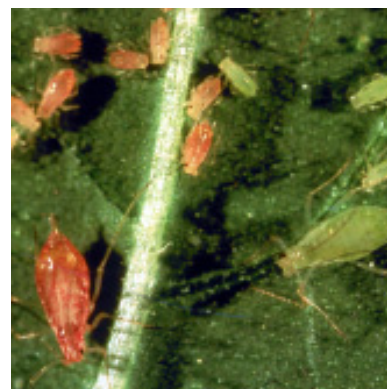
To use trenches for Colorado potato beetle control, follow these steps.

- Check pest pressure and field maps from previous years. Locate the most highly populated areas where trenches will be the most effective.
- Dig trenches along field edges approximately 2½ ft. wide x 1 ft. deep.
- Line the trenches with plastic to create a slippery surface that the adult beetles cannot climb.
- Once beetles have congregated in the trenches, control them physically or chemically. Several physical control methods are commercially available including vacuum suction machines.

Few cultural strategies are effective to prevent **potato leafhopper** infestations, but selecting less susceptible potato varieties may help. A list of the highly to least susceptible varieties can be found in this handbook’s *Preplant/Cultivar Selection* section. When possible, avoid planting potatoes near alfalfa. Alfalfa is a primary source of potato leafhoppers. Leafhoppers will migrate out of alfalfa to other, nearby crops when the alfalfa is cut.



Growers may be able to completely avoid **aphid** concerns at the end of the growing season by altering the timing of planting or the variety planted. Early potato varieties or potatoes which are planted early enough to be harvested by mid-August can avoid aphid problems by being harvested prior to aphid infestations. Since aphids usually infest in mid to late August, varieties which are harvested by that point can be utilized, even if they are susceptible to aphid and viral infections.



## WEEDS

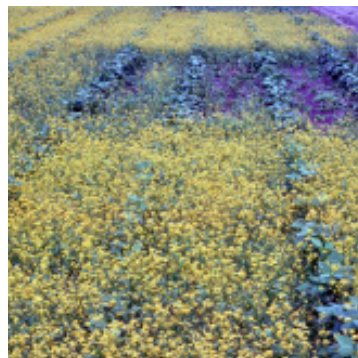
Mechanical, physical, biological, or cultural practices should be utilized in and around the field in the non-potato years to limit the number of weed seeds entering the seed bank.

Minimizing weed competition is critical to improve yield and quality. Potential economic benefits associated with reduced herbicide applications have stimulated interest in alternative and integrated weed management strategies. **Smother crops** seeded at or near the time of potato planting may provide an alternative to conventional weed management by providing a competitive suppression of early season weed growth.

Smother crops are specialized cover crops selected for their ability to suppress weeds. They compete aggressively for light, nutrients, and moisture with the weed species infesting an area. Any highly competitive crop that is well adapted to an area may be suitable for use as a smother crop. If weeds are suppressed during the 4 to 6 weeks after emergence, potato yield reductions are not usually seen.

The fundamental challenge to effectively using smother crops is timely establishment. Smother plants must germinate and grow rapidly to gain a competitive advantage over weeds. Several species have potential for quick establishment and weed suppression. Examples of annual smother crops include rye, buckwheat, and millet. Examples of perennial smother crops include sweet clover and cowpeas.

***Brassica*** species are the most successful smother crops evaluated thus far. Members of the genus *Brassica* include brown mustard, black mustard, field mustard, and white mustard. These mustards are annuals and produce heavy, dense growth. All *Brassica* species contain glucosinolates (commonly referred to as mustard oils) which inhibit weed growth or weed seed germination.



Some guidelines for growing smother crops follow.

- Seed the smother crop at or within 2 weeks of potato planting.
- Suggested seeding rates for mustard are 5-7 lbs/acre for small-seeded cultivars, 10-12 lbs/acre for large-seeded cultivars.
- Seed 3/8 to 3/4 inches deep.
- Drill mustard before planting potatoes or broadcast seed it after planting.
- Mustard species and fast growing plants either die quickly during the potato season or can be easily killed with potato herbicide programs.

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# Resistance Management

## Planting



Resistance management is a critical part of an overall bioIPM program and needs to be considered in all aspects of the production system. Good resistance management strategies should be employed to maintain the reduced-risk, lower toxicity chemistries now available for potatoes.



Read the following statements in order and check all that apply. Refer to the corresponding sections on the following pages for more information.

- ☐ **A.** *Resistance management strategies are considered before applying pesticides.*
- ☐ **B.** *Herbicide classes are rotated between seasons/crops as well as within the season.*
- ☐ **C.** *Insecticide chemistries for Colorado potato beetle control are rotated throughout the farm.*
- ☐ **D.** *Additional bioIPM strategies (cultural options, biological controls, and barriers) are utilized whenever possible to reduce reliance on pesticides.*

## A. Resistance Management for the Current Year's Potato Crop

Resistance of diseases, insects, and weeds to registered pesticides is found in an increasing number of pest species in potatoes. Resistance concerns in Wisconsin potatoes include Colorado potato beetles, early blight, late blight, and several weed species including giant foxtail, green foxtail, velvetleaf, pigweed, and large crabgrass.

Resistance develops through a genetic alteration in the pest allowing it to overcome the toxic effect of pesticides. These resistant genes are transferred through reproduction ultimately increasing the resistant population. Maintaining susceptible populations which will breed with the resistant population is a key to limiting the onset of resistance.

Once resistance occurs, it may be permanent, although occasionally, populations revert back to susceptible levels. These populations, however, have a high probability of quickly becoming resistant again. Therefore, it is still important to practice proper resistance management strategies to prevent the development of resistance. General resistance management strategies should be employed at all times during the production cycle to prevent the onset of resistance by pest species.

General resistance management strategies which should be used include:

1. Avoid consecutive use of a product or other products with similar modes of action against the same target pests. This includes:
  - a. Alternate chemical classes and modes of action within a cropping season.
  - b. Alternate chemical classes and modes of actions between years in the rotation.
2. Only apply pesticides when needed (when problems are seen in a field, when thresholds are met, when forecasting models indicate, etc.)
3. Incorporate various bioIPM techniques when possible to limit pest infestations. This

will reduce the exposure of pest populations to pesticides, ultimately reducing the chance of resistance development.



Remember, there is no chance for resistance developing if pests are not treated with pesticides.

Look in Appendix C for the EPA resistance management groups for insecticides, fungicides, and herbicides. The EPA list is based on the pesticide's mode of action and will help growers determine their pesticide rotational strategies. Resistance management on potatoes can be a challenge because so many of the new, reduced risk chemistries are grouped together. Good resistance management strategies need to be utilized to maintain efficacy for all of the chemistries within the groupings.

## B. Herbicide Class Rotation

Resistance of weed species in Wisconsin is becoming an increasing concern in vegetable production systems. It is important to rotate herbicide chemistries from year to year to limit resistance development by weeds. The key to managing potential weed resistance is to not apply the same herbicide class for the same weed species consecutively whether within a season or between seasons. Herbicide class rotation requires good record keeping from year to year and is complicated by the small number of herbicides that are labeled for vegetable crops.

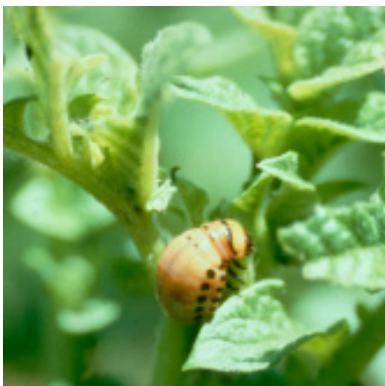
Look in Appendix C for the EPA resistance management groups for herbicides applied to potatoes and rotational crops. There are few herbicides registered for potato weed control and maintaining their efficacy is important. Additional guidelines for herbicide resistance management are covered in this handbook's *Preplant/Resistance Management in Rotational Years* section.



## C. Colorado Potato Beetle Control

The **Colorado potato beetle** is known for its extraordinary capacity to develop insecticide resistance and has already shown resistance to every class of insecticide available. In the Midwest, problems with insecticide resistance are localized, but are increasing and should be monitored.

A good resistance management strategy is to apply insecticides with different modes of action spatially around the farm. Planting is the time to consider these choices since the systemic insecticides (the chloronicotinyls) used at planting are at a high risk for problems developing. If resistance management is not practiced, the Colorado Potato beetle is likely to develop resistance to these insecticides.



Avoid using the same insecticidal control strategy on all the potato fields on the farm. If only chloronicotinyl insecticides are used for Colorado potato beetle control on all fields on the farm, the chance of a resistant beetle being selected greatly increases. This beetle may then breed with susceptible beetles with little consequence, but may also breed with another resistant beetle which could lead to a larger resistant population. How-

ever, if multiple insecticidal classes are applied spatially around the farm, the beetle which may be resistant to the chloronicotinyls, could still be susceptible to other insecticides (such as OP's) and could be killed in a nearby field with that insecticide.

See Appendix C for a listing of EPA resistance management groups. More information on area-wide resistance management is found in this handbook's *Preplant/Resistance Management in Rotational Years* section.



Resistance normally develops by allowing rare individuals that overcome a particular mode of action to survive. Growers "select" these individuals by spraying the same pesticide repeatedly. These resistant species (in our example insects) then mate, and if they mate with another resistant individual, their offspring may all be resistant. This process multiplies if the same insecticide, or similar modes of action is continually applied.

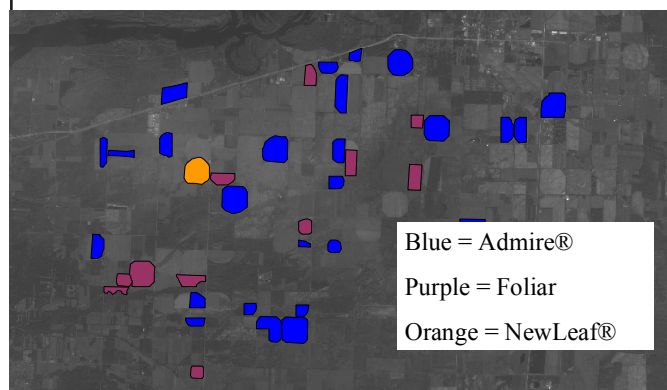
## D. BioIPM Techniques

Implementing various BioIPM techniques to limit pest populations will reduce pesticide applications, therefore decreasing the possibility of resistance developing. Specific bioIPM techniques are discussed in the handbook's *Planting/Cultural Pest Management* section or are found in the pest profiles in Appendix B. Examples include:

### DISEASE

- Late blight: destroy cull piles.
- Early blight: track populations from nearby fields and determine if sensitivity to fungicides may have occurred in populations the previous year. This may be noticed if early blight infection greatly increased toward the end of the previous year's potato growing season. If so, select fungicide options carefully.
- Soil borne pathogens: clean machinery between fields to prevent spread of inoculum.
- Others: utilize resistant cultivars when applicable.

### Management Strategies and Locations- 1998



## **INSECTS**

- Colorado potato beetles: implement an area-wide rotational scheme.
- European corn borer: destroy areas where larval populations can survive and infest potatoes. These locations include corn and snap bean stubble in neighboring fields.

## **WEEDS**

- Till or mow field edges to prevent weeds going to seed.
- Clean machinery between fields to prevent weed seed spread.

### **History of Resistance to fungicides, herbicides and insecticides.**

The development of resistance by any pest species is an evolutionary process in which pests overcome the chemical's effectiveness. Pest populations are filled with genetic diversity, and individuals in the population which may be able to survive a pesticide application spread this genetic potential throughout the population.

The phenomenon of resistance in a pest population was first seen as early as the 1920's, but resistance didn't become a serious problem until the 1950's. Today, it has occurred in insects, weeds and plant pathogens. It is a major problem in agricultural production systems. Resistance to pesticides is seen in over 450 species of insects, over 100 species of plant pathogens, and over 55 species of weeds. These numbers are increasing at a phenomenal rate and new resistance occurrences are found each year. To monitor the total number of resistance occurrences in insect and arthropod populations, Michigan State University has developed a database to track resistance to specific compounds. To check on resistance occurrences nationwide, visit the site at: <http://www.pesticideresistance.org/DB/>

A major concern in resistance management programs is that once a pest develops resistance to one class of pesticides, that pest has the genetic capability to

develop resistance more rapidly to other groups of pesticides that have similar modes of actions or action sites. Knowledge of the modes of action of all registered compounds is necessary. The EPA has developed a resistance management designation code for pesticide classes to aid growers in this determination. This designation can be found in Appendix C.

To maintain the efficacy of the compounds that are currently used in potato production, resistance management strategies need to be implemented. Resistance management is a complement of any bioIPM program and is essential to maintaining the effectiveness of current and newly registered compounds in the system. Strategies that Wisconsin and other potato production systems should implement include:

- Monitoring populations to determine their sensitivity to current products.
- Laboratory testing of populations to determine their sensitivity levels.
- Scouting practices which determine the effectiveness of pesticide applications.
- Monitoring to evaluate the effectiveness of resistance management strategies.
- Utilizing the EPA resistance management designations of pesticides to aid in grower's pesticide choices.



# Planting Process

## Planting



A good stand of potatoes is essential to minimize the effect of plant pathogens and pests. Environmental conditions at planting, accurate equipment and careful planting processes all contribute to the health, quality and emergence of the crop.



Read the following statements in order and check all that apply. Refer to the corresponding sections on the following pages for more information.

- ☐ **A.** *Planter and other transfer equipment are calibrated to reduce the chance of bruising seed pieces.*
- ☐ **B.** *Seed temperatures and soil temperatures are within 5 degrees of each other at planting. Soil is at or below field capacity during the planting period.*
- ☐ **C.** *Planter is calibrated and field checks are taken to ensure accuracy in planting depth, in-row spacing, and fertilizer/pesticide placement.*
- ☐ **D.** *A cup or air planter is used instead of a pick planter. The planter is disinfected many times during the planting process.*

## A. Equipment Calibration

Before planting begins, check for proper operation of the planting equipment by measuring the drop distance and checking for planter skips. At all stages of the planting operation, seed should not drop from heights greater than six inches. Greater seed drops may cause bruising and infection sites for disease. Bruised seed may also alter the physiological age of the seed piece leading to increased stem number. Higher stem numbers increase tuber set and can reduce yields.



## B. Seed and Soil Conditions

Proper seedbed conditions, especially soil temperatures and moisture, are essential in developing a healthy stand of potatoes. Planting in soils which are too hot and too moist may result in a poor stand, excessive seed piece decay, bacterial decay or physiological disorders.



Planting should not occur when soil temperatures are below 50° F. The difference between seed and soil temperatures should be no more than 5°F to prevent condensation forming on the seed piece which can lead to increased seed piece decay.

Soil moisture should be at 70 – 80 % of available soil water. This provides good planting conditions

and adequate soil water for sprout and root development. If the soil is dry, consider irrigating before planting. Do not irrigate between planting and emergence as this increases the likelihood of seed piece decay. A simple method for estimating soil moisture level is described in this chapter's previous section, *Field Preparation*.

### Seed and Row Spacing

Appropriate spacing of rows and seed pieces depends on several factors, including cultivar, fertilization, irrigation, soil type, and intended market. General guidelines are given here.

- Row widths generally range from 30-36 inches.
- In cultivars that generally produce a heavy set, seed pieces should be spaced farther apart in the row, up to 15-18 inches in some areas. If cultivars produce a smaller set, plant seed closer together.
- The row spacing and seed spacing affect the production potential of the crop:
  - ➔ Generally, seed pieces planted closely together will yield smaller tubers and lower quantities.
  - ➔ Conversely, seed pieces planted farther apart will yield larger tubers and greater quantities.



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# Fertility

## Planting



Proper nutrition fertilizer programs at planting are crucial for vigorous early season growth of potatoes. This decreases the potential effects of insects and disease and improves the crop's competitiveness with weeds.



Read the following statements in order and check all that apply. Refer to the corresponding sections on the following pages for more information.

- ☐ **A.** *Soil samples are taken. Test results are used to determine fertilizer rates according to University of Wisconsin recommendations.*
- ☐ **B.** *Starter fertilizer is band applied according to University of Wisconsin recommendations.*
- ☐ **C.** *Surfactants are used to reduce nitrate leaching.*
- ☐ **D.** *Fertilizers are precision applied based on grid sampling and field variation.*



## A. Soil Sampling for Fertilizer Rate Determination

Instructions for soil sampling are included in this handbook's *Preplant/Soil Sampling* section. The UW soil test report combines the soil analysis results with the grower's information on the field, the planned crop, and yield goals to make crop-specific fertilizer and lime recommendations. UW recommendations for nitrogen, phosphorus and potassium are given on the following pages.



## B. Starter Fertilizer

Starter fertilizer enhances early season crop growth and helps the crop compete against early weed infestations. Banding at planting is the most common method of applying starter fertilizer. Place the starter fertilizer two inches to the side and two inches below the seed piece. If the fertilizer touches the seed piece, injury may result. Starter fertilizer may also be applied during row marking operations before planting.

Apply nitrogen in three applications: one quarter to one third banded at planting, one quarter to one third sidedressed at emergence, and the remainder at hilling. Split applications usually reduce nitrate movement out of the shallow root zone. The leaching and the loss of nitrogen can be caused by excessive irrigation or rainfall.



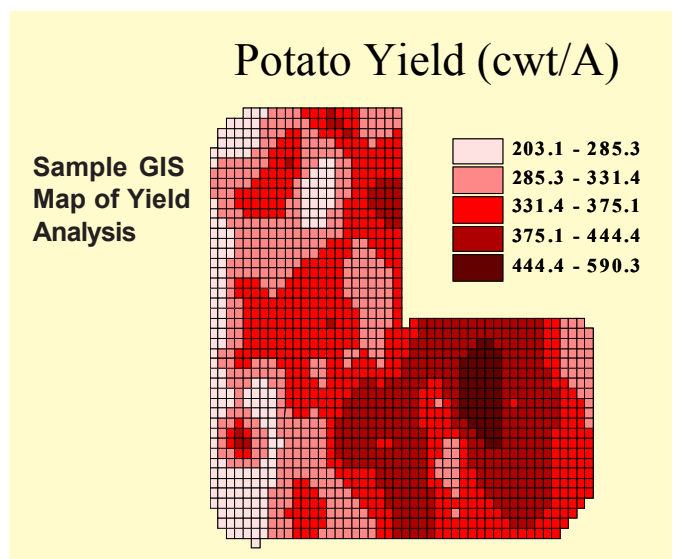
## C. Fertilizer Leaching

Do not apply excessive rates of starter fertilizer because leaching may occur before the potato plant is able to utilize the nutrients.

Some research on side dressed applications has shown that applying a surfactant in furrow can keep the area around the seed piece from drying out and help prevent nitrate leaching.

## D. Precision-applied Fertilizers

On fields that have not been cropped uniformly or have variations in soil type, drainage or topography, it may be profitable to site specifically soil sample and precision apply lime, phosphorus or potassium. Take composite soil samples on a 2-3 acre grid, using GPS to mark the central location for each composite sample. Once the samples are analyzed, computer software can generate maps of the nutrient and pH levels and the grower can determine if it would be economical to variably apply a nutrient or lime. While it is more expensive to conduct this type of testing, it may save money if nutrient or pH imbalances exist across a field.



## Nitrogen applications

Of all essential plant nutrients, nitrogen is often the most limiting to potato production on sandy soils. Plants normally contain between 1-5% nitrogen (N) by weight. Nitrogen helps to build proteins and the main cellular components of the potato. In addition, nitrogen is an integral part of chlorophyll, which is the primary absorber of light energy needed for photosynthesis.

An adequate supply of N is associated with high photosynthetic activity, vigorous vegetative growth, and a dark green color. If a plant lacks N, the entire plant may turn light green, and its leaf margins will roll upward. Young leaves remain green and older leaves turn yellow to light brown as nitrogen moves from the older to the younger.

### Nitrogen recommendations for potatoes grown on irrigated mineral soils\*

Yield Goal Cwt/A	Previous Crop		
	Com Small Grains Potatoes	Soybeans	Alfalfa Clover
	N to apply (lb/A)		
500+	250	230	190
450-499	225	205	165
400-449	200	180	140
350-399	175	155	115
300-349	150	130	90
250-299	125	105	60
200-249	100	80	40
< 200	75	50	25

\*rates should be split into three applications (planting, 1<sup>st</sup> sidedress, 2<sup>nd</sup> sidedress)

### Nitrogen Replacement Credits for Previous Legume Crops

Legume	Credit - non-sandy soils (lb N/acre)	Credit - sandy soils (lb/N acre)
<b>Forage: Alfalfa*</b>		
Good (70-100% alfalfa, more than 4 plants/ft <sup>2</sup> )	<b>190</b>	<b>140</b>
Fair (30-70% alfalfa, 1.5 - 4 plants/ft <sup>2</sup> )	<b>160</b>	<b>110</b>
Poor (0-30% alfalfa, less than 1.5 plants/ft <sup>2</sup> )	<b>130</b>	<b>80</b>
<b>Forage: Red Clover or Birdsfoot Trefoil</b>	<b>80% of alfalfa credit</b> for similar stands.	
<b>Soybeans</b>	<b>40 lb N/acre</b>	No credit on sandy soils.
<b>Vegetable Legumes</b>	<b>20 lb N/acre</b>	No credit on sandy soils
<b>Green Manure: Sweet clover</b>	<b>80-120 lb N/acre</b>	<b>30-60 lb N/acre</b>
<b>Green Manure: Alfalfa</b>	<b>60-100 lb N/acre</b>	<b>10-50 lb N/acre</b>
<b>Green Manure: Red clover</b>	<b>50-80 lb N/acre</b>	<b>0-30 lb N/acre</b>
* If harvesting forage crops after September 10, reduce credit by 40 lb N/a.		

## Potassium Applications

Plant requirements for available potassium (K) are quite high. The concentration of potassium in vegetative tissue usually ranges from 1 to 4% on a dry matter basis.

Potassium plays an important role in enzyme activation and water regulation. Plants that are K deficient are less able to withstand water stress, mostly because of their inability to make full use of available water. K also controls the loss of water. K can affect the rate of transpiration and water uptake through regulating the opening and closing of tiny holes on the leaf surface.

Since K is mobile in the plant, visual deficiency symptoms such as stunted growth usually appear first in the lower leaves, progressing toward the top as the severity of the deficiency increases. Young leaves develop a crinkly surface, and their margins roll downward. Leaves have slightly black pigmentation. Marginal scorching with necrotic spots may occur on older leaves.

K stress can increase the degree of damage by bacterial and fungal stress, insect infestation, and nematode and virus infection.

Water transports potassium very slowly through the soil profile. Applications may be broadcast prior to planting or potassium may be banded below and to the side of seed pieces at planting. Banding near seed pieces ensures more rapid access for the growing roots and improved uptake under adverse conditions. Broadcasting distributes the nutrients more completely throughout the root zone. In general, a greater yield response can be obtained from banded fertilizer than from the same amount applied broadcast.

Use soil test results to determine K application rates as considerable amounts may remain in the soil.

**Potassium recommendations for potatoes grown on irrigated mineral soils**

Yield Goal Cwt/A	Potassium (K) soil test (ppm)*				
	0-50	51-100	101-150	151-200	201+
	K <sub>2</sub> O to apply (lb/A)				
500+	500	400	300	150	75
400-499	400	300	200	100	50
300-399	300	200	100	50	25
200-299	200	150	75	35	20
< 200	150	100	50	25	0

\*ppm x 2 =lb/A

## Phosphorus

Phosphorus (P) occurs in most plants in concentrations between 0.1 and 0.4%. The most essential function of P in plants is energy storage and transfer. Phosphate compounds store energy obtained from photosynthesis or carbohydrate metabolism for subsequent growth and reproductive processes.

A good supply of P is associated with increased root growth and raised tolerance to diseases, especially those affecting the root system. Phosphorus deficient plants are stunted with dark green leaves and upwardly rolled leaf margins with some purpling. Leafroll severity increases as the deficiency increases.

Water transports phosphorus very slowly through the soil profile. Applications may

be broadcast prior to planting or banded below and to the side of seed pieces at planting. Banding near seed pieces ensures more rapid access for the growing roots and improved uptake under adverse conditions. Broadcasting distributes the nutrients more completely throughout the root zone. In general, a greater yield response can be obtained from banded fertilizer than from the same amount applied broadcast.

Phosphorus must usually be applied for potato production. Use soil test results to determine P application rates as considerable amounts may remain in the soil.

**Phosphorus recommendations for potatoes grown on irrigated mineral soils**

Yield Goal Cwt/A	Phosphorus (P) soil test (ppm)*			
	0-10	11-25	26-50	50+
	P <sub>2</sub> O <sub>5</sub> to apply (lb/A)			
500+	175	125	75	25
400-499	150	100	50	25
300-399	125	75	50	25
200-299	100	50	25	0
< 200	75	50	25	0

\*ppm x 2 =lb/A

## Notes:

This image shows a single sheet of white paper with horizontal ruling lines. The lines are evenly spaced and run across the width of the page. There are no margins, text, or other markings on the paper.



# General IPM

## In-season



Integrated Pest Management is a long-term approach to managing pests by combining biological, cultural, mechanical, physical, and chemical tools to combat pests in the most economically and environmentally effective manner.



Read the following statements in order and check all that apply. Refer to the corresponding sections on the following pages for more information.

- ☐ **A.** *Basic IPM approaches are understood.*
- ☐ **B.** *Fields are scouted. Economic thresholds, weather conditions and resistance management are considered in chemical management decisions.*
- ☐ **C.** *Pest life cycles and ecology are known and this understanding is used in management decisions.*
- ☐ **D.** *Biointensive IPM strategies are used that incorporate all available control methods including cultural methods, biological controls, physical and mechanical controls, variety selection, and chemical controls. Pest management is considered in spatial (space) and temporal (time) contexts.*

## A. IPM 101

Integrated Pest Management (IPM) involves various strategies to combat pests, including cultural, physical, mechanical, biological, host-plant resistance, and chemical control methods. Implementing a variety of these strategies is the basis for any biologically based pest management program (bioIPM). Resistance management strategies to maintain chemical classes are also an important component of IPM programs. The principal components of IPM programs are:

- Decision making tools, scouting and economic thresholds.
- Utilization of all available pest management strategies.
- Year round implementation of preventative pest measures.
- Looking at the cropping system as a whole, not just single season pest species management.

This handbook section focuses on the general IPM principals. Other sections detail specific IPM strategies for implementation at various times throughout the production year.

## B. Chemical Management Decisions

Chemical control measures are an important component to an IPM program, but pesticides are not the only control option. IPM programs use economic threshold levels (when pest damage exceeds the cost of control) to determine when chemical measures are warranted. They utilize IPM tools, such as disease forecasting, to provide adequate information on when to initiate spray programs.

When selecting chemical control measures, proper resistance management strategies are also needed. For more information, read the handbook's resistance management sections in the Preplant, Planting, and In-Season chapters and check Appendix C for the EPA resistance management groups for potato insecticides, fungicides and herbicides.

## C. Pest Life Cycles and Ecology

Implementation of IPM programs require growers' knowledge of pest life cycles, IPM, control tactics, and general production practices. Advanced biointensive IPM (bioIPM) systems call for a more extensive understanding of pest life cycles and targeting control measures to specific times during pest's vulnerable stages. A combination of control techniques including available biologically based pest management tools should be incorporated when possible.

General pest life cycles for key pests in Wisconsin potatoes are described below. See the Pest Profiles in Appendix A for more information.

### DISEASES

**Early Blight** is a common foliar disease of potatoes. The pathogen overwinters in crop debris, infected tubers, and on other solanaceous plants. Spores are carried primarily by wind and infect potatoes under wet and warm conditions. Most disease development occurs during periods of alternating wet and dry weather conditions accompanied by periods of high relative humidity.



Germinating spores penetrate susceptible tissue directly or through wounds. Lesions are typically small and sunken with slightly raised margins. Early blight is more prevalent on older, senescing tissue and infection increases when plants have been predisposed by injury, poor nutrition, insect damage or other types of stress. Tuber infections occur mostly through wounds inflicted during harvest.

**Late Blight** is a serious disease on potatoes. There are two mating types of the fungus, the A1 and A2 strains that are found worldwide. If only one mating type is present, the fungus spreads through asexual reproduction by sporangia. When both

mating types are present, sexual reproduction may occur resulting in oospores. Oospores have thick walls and are able to overwinter in Wisconsin in association with potato tubers and germinate using a germ tube that grows directly into mycelium (a fungal mass).

In spring, late blight grows on plants which develop from infected tubers, including cull piles, volunteer potatoes, and infected seed. The fungus is prevalent under moist conditions and it is dispersed by wind, water, machine, or human activity. During wet periods, zoospores (fungal spores mobile via water) are formed that increase infection. High

humidity conditions (91-100%) and temperatures between 37-79° F (with optimal temperatures from 64-72° F) favor development of late blight. Temperatures above 86° F are not favorable for late blight development.



## Powdery Scab

**Powdery Scab** was first found in Germany in 1841 and in North America since 1911-1913. Although it is widespread and occurs in most potato producing areas, it was first found in Wisconsin in 2003. The disease develops best under cool, moist conditions. Powdery scab symptoms occur only on belowground parts of the plants. Symptoms on tubers are raised purplish brown lesions. Mature lesions on tubers have a scab like appearance and are filled with fine, brown colored resting spores. In storage, powdery scab infection sites also serve as entry points for other tuber rotting organisms.

Infection can occur on roots and stolons and first symptoms are small lesions or necrotic spots. These infection sites develop into milky white to tan galls. As galls mature they turn dark in color and eventually break down releasing resting spores into the soil. Powdery mildew infection sites often serve as entry points for other pathogens.

Powdery scab survives in the soil in the form of resting spores which can survive for up to six years and can survive passage through animal digestive tracts. Inoculum can be transported from field to field through the spread of infected seed, soil, and manure and perhaps on wind-borne particles. Soil temperatures of 52-64°F and alternating periods of wet and dry soil favor disease development. Powdery scab is often associated with poorly drained soils.

Few cultivars have true resistance to powdery scab, but russet skinned varieties have more resistance to tuber infection though they still may be susceptible to root infection.

Guidelines for Powdery Scab Management:

1. Ensure a powdery scab free seed source.
2. Avoid planting tubers infected with powdery scab.
3. Avoid fields with a history of scab infection.
4. Rotate out of infested fields for 3-10 years.
5. Control weed hosts of powdery scab.
6. Carefully manage irrigation.



**Common scab** overwinters in the soil and survives indefinitely. It is distributed on infected tubers by wind and water or through animals' manure. Warm, dry soils and early season stress favor scab development. Scab infection occurs through natural openings in the plant such as through lenticels and stomata, as well as through wounds.



**Rhizoctonia** infection occurs when cool wet weather is encountered. *Rhizoctonia* overwinters in the soil as sclerotia on plant debris. Spores germinate in the spring and infect potatoes through wounds. High moisture, cool soil temperatures, pH less than 6, and high soil fertility levels favor *Rhizoctonia* development.



## **INSECTS**

**Colorado potato beetles** overwinter in Wisconsin about 6-8" underground in areas adjacent to fields. They begin to infest potato fields in the spring by walking into the fields. Females lay up to 500 bright yellow eggs on the lower leaf surface and larvae hatch in 4-9 days, depending on temperatures. There are 4 larval stages of the beetle, with the large larval stage (3<sup>rd</sup> and 4<sup>th</sup> instar) being the most damaging. Fourth instar populations burrow into the ground and pupate for 7-10 days and



then emerge as adults. Summer adults can be damaging when present in high numbers. In the fall, adults head out of the field toward overwintering sites adjacent to field edges.

**Potato leafhoppers** do not survive the winter in Wisconsin. Populations are found in the Gulf Coast States and migrate northward in April and May on warm southerly winds. Large migrations of potato leafhoppers into Wisconsin occur in June and early July. Damage occurs through the sucking of the plant sap. Damage occurs when the phloem movement of plant nutrients and water is limited.



**Potato aphids** overwinter as eggs on wild and cultivated roses. Eggs hatch in the spring and several generations live on plants in the rose family before winged aphids develop. Winged aphids migrate to susceptible plants in late June and July. Potato aphids are primarily important as vectors of viruses, particularly potato virus Y.

Potato aphids have an elongated body with a long pointed tail. The body color is usually pale green to yellow green and sometimes pink. Adult potato aphids are two to three times the size of adult green peach aphids, and when disturbed are highly mobile.







### Interesting Fact:

Female, non-winged aphids have the ability to give birth to 50-100 live young with 5-10 generations per year.

**Green peach aphids** are the most serious pest of seed potato production because they transmit the potato leafroll virus and potato virus Y. The green peach aphid overwinters in Wisconsin as eggs on the bark of peach, plum, apricot, or cherry trees. Some green peach aphids migrate in from southern states. Nymphs hatch when the fruit trees are in bloom and reproduce parthenogenetically, giving birth to live young for 2-3 generations. Winged green peach aphids then develop and migrate to susceptible weeds and crops where they once again reproduce parthenogenetically.



Green peach aphids have an egg-shaped body that has a plump, rounded back abdomen. They are usually creamy white to light peach in color with an almost translucent appearance.

The **European corn borer** (ECB) is a sporadic pest of potatoes. In years when the first generation of the European corn borer occurs early, the preferred egg-laying sites in corn are not yet available and the pest moves to potatoes. Damage in potatoes occurs



when ECB larvae feed on potato foliage. ECB larvae rarely occur in numbers substantial enough to cause economic damage, but if ECB larvae exist at high enough levels, feeding may cause enough defoliation to warrant a control. Additionally, stem damage may open up the plants to secondary disease infection.

**The looper and cutworm complex**, which are commonly known as “worms”, are not serious pests of potatoes but may cause problems if they are present in high numbers. **Black cutworms** migrate into Wisconsin in late May and lay their eggs on low-growing vegetation such as chickweed, curly dock, mustards, or plant residue from the previous year. **Variegated cutworms** overwinter in the soil as mature larvae or soil encased pupae. Adults emerge in June. Cutworms are large larvae that characteristically curl up into a tight C-shape if disturbed.



**Cabbage loopers** have a greenish body that tapers at the head with a thin white line along each side. They overwinter in Wisconsin in small numbers but the majority migrate in from the south in mid-July through September.



### **Tarnished plant bugs**

are occasional pests of potatoes in Wisconsin. Tarnished plant bugs overwinter as adults under leaf mold, stones, tree bark, and among clover and alfalfa. Adults begin to emerge in late April to early May. After feeding for a few weeks, they migrate to lay eggs in a variety of hosts, including potatoes.



Tarnished plant bugs cause injury to potatoes by inserting their piercing-sucking mouthparts into the plant and removing sap. In addition to the direct damage caused by feeding, the bug also injects a salivary secretion, which is toxic to the plant. This toxin will produce small, circular, brown areas at the point of feeding. Feeding causes leaves to curl, new growth to wilt, and destruction of the flowers.

Adults are ¼ inch long and half as broad. Coloration is variable, but they are generally brown with splotches of white, yellow, reddish-brown, and black. There is a clear yellow triangle tipped with a smaller black triangle on the posterior end of the abdomen.

**Flea beetles** are commonly found in Wisconsin potatoes but are rarely a serious pest. Potato flea beetles overwinter as adults in the field soil. Beetles become active when temperatures reach 50°F



and emerge in late May and June. They begin feeding on weeds or volunteer potato plants until the crop emerges. Eggs are laid in the soil and larvae feed on potato roots and tubers. The adults are small, shiny black beetles with enlarged hind legs, which allow them to jump from foliage when disturbed. The second-generation adults emerge in July-August.

Adult flea beetles feed on both sides of the leaf, but usually on the underside where they chew small, circular holes through the tissue. The circular holes give the plant a shotgun appearance, which is characteristic of flea beetle feeding. Heavy feeding on young plants may reduce yields. Larvae feed on the roots and tubers but do not cause economic damage.

**Aster leafhoppers** are occasional pests of potatoes because of their ability to transmit a phytoplasma-like organism that carries aster yellows. Infected plants are generally stunted and have small tubers. Infected tubers will be dark in color when fried. The aster leafhopper must probe and feed on a host for eight hours before passing its phytoplasma-like organisms into the salivary glands where they are able to be transmitted.



The adult aster leafhopper is olive-green, wedge-shaped, and about 3/8 inches in length. They have three pairs of spots on their head. Nymphs are similar in shape to adults, but are cream-colored and lack fully developed wings.

Aster leafhoppers do not overwinter in Wisconsin but migrate from the Gulf States on warm southerly winds. Early migrants are female and arrive in May and early June. Infestations may occur in June and July as local populations develop.

**White grubs** are white-bodied larvae, ½ -1½ inches in length, with brown heads and six prominent brown legs. Adults are June beetles seen in the spring and early summer. Most species have a three-year life



cycle in Wisconsin. Adults emerge and mate in late May to early June. Females search out grassy areas, burrow into the soil and deposit eggs. Eggs hatch in 2-3 weeks and grubs begin feeding on roots and underground plant parts. With the onset of cold weather, the grubs move beneath the frost line.

It is during the second year that the most damage is done. Therefore damage is most severe in years following peak adult flights and continues throughout the growing season. In potatoes the grubs eat large, shallow circular holes in the tubers. The above ground portions of affected plants do not reveal the injury. As a result, serious tuber damage can occur before the grower realizes there is a grub problem.

The **armyworm** is generally not a problem on vegetable crops; it prefers grasses and grains. However, grass weeds in potato fields will attract moths. Outbreaks are more common following cold, wet, spring weather. The moths usually appear in late April and early May. Grasses and small grains are the preferred host and blades are often folded and sealed to protect the eggs. There are 3 generations per season, with each generation lasting 5-6 weeks. The first generation is small and does little damage, however the success of this generation, produces later, more injurious, generations of armyworms. The second larval generation which appears in July is the largest and most damaging generation to Wisconsin crops. The fall generation is typically not injurious and is often heavily parasitized by beneficial insects, fungi and viruses.



## WEEDS

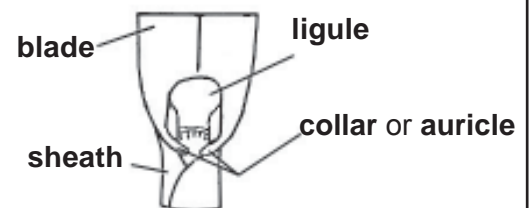
The term **broadleaf weed** pertains to dicot weeds with broad leaves and 2 cotyledons, or seed leaves. Seed leaves or cotyledons are usually the first pair of leaves to appear as the plant emerges through the soil and generally have a different shape and appearance than true leaves.

One key that aids in the identification of broadleaf weeds is the leaf arrangement. Some broadleaf weeds have leaves arranged alternately on the stem, some have leaves arranged opposite each other, and some have leaves arranged in a whorl about the stem.

Both annual and perennial broadleaf weeds affect potato production. Annual species live only a single year and reproduce by seed. They die naturally at the end of the season after they have produced their seed crop. Perennial species live several years and reproduce by various types of vegetative structures in addition to seed. Perennials can regenerate shoots each year using food reserves stored in vegetative structures in the soil, and thus they are not dependent on seed germination for their survival. They can also re-sprout when their top growth has been removed mechanically or by other means, as long as the underground storage organ is intact.

**Grass** weeds are monocots and most **annual grasses** have narrow leaves with parallel veins. To ensure proper control measures, it is important to correctly identify grasses found in the field. Seedling grasses are more difficult to identify than seedling broadleaf weeds, but as grasses grow, they develop distinguishing features that aid in proper identification. The four basic parts of the

### Monocot Anatomy





grass plant leaf that are commonly used for identification are described here. More information is contained in the Pest Profiles (Appendix A).

The leaf of a grass plant is composed of four basic parts:

- The **blade** is the flattened portion of the leaf.
- The **collar** or **auricle** is the junction between the blade and the sheath.
- The **sheath** is the portion of the leaf surrounding the stem.
- The **ligule** is a short tube that extends out of the collar. Not all grasses possess this structure.

## D. BiolPM Systems

Biologically based IPM (bioIPM) systems include numerous components based on the potato system's ecology and incorporates more than field level IPM programs. Progress along the Integrated Pest Management (IPM) continuum toward biointensive IPM is made possible by greater reliance on pest management skills and practices that are inherently **prevention-oriented**. This will ultimately reduce the reliance on pesticides or practices that are primarily reactive and designed to kill pests when populations exceed prescribed thresholds.

Field data on crop status and pest population levels are the backbone of IPM systems. In making day-to-day operational decisions, it is critical to incorporate the use of scouting data with knowledge of the pest life cycle, economic damage, other pest complexes, and beneficial species to make informed decisions and properly design the pest management strategy. A challenge for all IPM systems is accurately recognizing and responding to changes in the status of crops, pests, and beneficial insects triggered by agronomic systems, weather patterns, and a range of living and non-living factors.

In general, as IPM systems become more complex and prevention-oriented, pest managers will need routine access to both more kinds of data and greater data resolution in time and space. Several

tactics which are commonly found in biologically based IPM programs include:

- Information management systems for long-term assessment of pest, crop and production systems.
- Resistance management strategies to maintain reduced-risk, low toxicity compounds in the production system.
- Area-wide management strategies (multi-field and multi-grower pest control).
- Prevention based strategies using cultural, host plant resistance, physical, mechanical and other non-chemical strategies.
- Beneficial species management.

## Notes:

[illegible]



## IPM Components\*

**IPM is a long-term approach to managing pests by combining biological, cultural, and chemical tools in a way that minimizes economic, health and environmental risks. In our program, there are five essential components to an IPM program.**

- 1. Understanding the ecology and dynamics of the crop.** It is important to gather all of the available knowledge about the crop we are growing. Most, if not all, pest problems can be directly related to the condition of the crop. The more we know about the ecology of the crop, the better pest management decisions we can make.
- 2. Understanding the ecology and dynamics of the pest(s) and their natural enemies.** It is not only important to know what pests are present but also to know the details of their life cycles, what makes their populations change, whether any natural controls are present, and what effects these may have on the pests. By knowing as much about the pest as possible we may find some weak point that we can exploit.
- 3. Instituting a monitoring program to assess levels of pests and their natural enemies.** It is vitally important to continually monitor the pest levels in the field. This is a crucial aspect of the IPM approach. By knowing how many pests are present we can make the best decision about how much damage they might cause to the crop. If natural enemies are present we need to know how many are present as well because they may take care of the pest problem for us.
- 4. Establishing an economic threshold for each pest.** Effective monitoring and use of economic thresholds make up the core of any IPM program. What is an economic threshold? It is the level of a pest population above which, if a control action is not taken, the amount of damage caused by the pest will exceed the amount it costs to control that pest. In other words it is the level of the pest population at which the control measure used pays for itself.
- 5. Considering available control techniques and determining which are most appropriate.** A wide range of control techniques are available for crop pests. They can be divided into 5 broad categories: chemical controls, such as pesticides; cultural controls, such as controlling plant vigor or rotations; biological controls, such as natural enemy releases or conserving natural enemies; behavioral control, such as the use of insect pheromones; and genetic control, such as the use of resistant varieties.

It is very important to choose the right control technique based on the economic nature of the pest problem, the cost of the particular control technique, and the effects of this technique on the environment and people's health.

### **IPM is an 'Approach' and Changes with Time**

IPM is not a technique or a recipe, but rather an approach to identifying and solving pest problems. Particular techniques for pest management may vary from field to field, year to year, crop to crop, and grower to grower but the overall approach is always the same, using the 5 essential components of an IPM program. It is important to point out that an IPM program is not a cookbook approach. It would be nice if we could tackle a pest problem the same way every time, but history has shown us that this will not work.

An IPM program is never complete and is a process of continuous improvement. The reason for this is that over time we learn more about our crop, our pests and their natural enemies, and refine our monitoring programs. We also improve our economic thresholds, and develop new control strategies. Furthermore, we periodically get new pests. As we gain more knowledge, we need to use it to refine our IPM programs to make them more effective and to ensure they will work in the long-term. This is the best way to minimize the economic impacts of pests in our vineyards and minimize the risks to our health and to the environment.

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## Notes:

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# Scouting

## In-season



Effective scouting during the growing season will ensure that pests are controlled only when they reach economically damaging levels, will ensure efficacy of the applied control measure, and will provide information regarding pest population changes over time and space.



Read the following statements in order and check all that apply. Refer to the corresponding sections on the following pages for more information.

- ☐ **A.** *Fields are only occasionally scouted during the growing season*
- ☐ **B.** *Fields are scouted weekly for insects, diseases, and weeds starting at crop emergence and continuing until harvest. Fields are scouted utilizing the university recommended methods (sweeps, plant counts, leaf counts, etc.).*
- ☐ **C.** *Management strategies are monitored for their effect on target pests and non-target organisms. Information gathered from this monitoring is used to alter and/or improve management decisions in the future. Written records are kept for long-term comparisons of pest pressures. Pest pressures are tracked over time to check for changes in each field.*
- ☐ **D.** *Field maps of pest "hot spots" are created to observe general patterns of changes in pest populations over time within a field. These may be maintained in a geo-referenced manner so that management plans can be implemented site specifically.*

## A. Crop Scouting 101

Crop scouting provides information on pest population dynamics that allows growers to exploit the pests' most vulnerable stages and to accurately time pesticide applications. Field scouting should occur at least weekly from crop emergence until harvest.

The number of scouting locations should be determined by field size. One scouting site per 10 acres is recommended. To ensure that the entire field is represented in the scouting process, a W-shaped pattern should be followed across the field. If that is not feasible, the scout should walk the pivot tracks, and should make sure that a reasonable amount of the field is scouted, including the edges. Increasing the number of scouting locations provides better information to the crop manager for more informed management decisions.

Specific areas of the field should be scouted to look for certain pest problems. For example, scout the field's edge for early season Colorado potato beetles as the beetles leave overwintering sites. Completely inspect areas prone to disease development as well. These areas include locations near windbreaks, woodlots, low spots in the field, near irrigation pivots, or areas where fungicide applications are difficult to make such as underneath power lines or utility poles and near highways or residential areas. Scout these disease-prone areas throughout the growing season until harvest is completed.

Individuals who are interested in becoming scouts should take the University of Wisconsin Vegetable Crop Scouting class. Crop scouts must be able to properly identify pests, scout using the proper techniques, and provide an accurate analysis of field pest concerns and overall crop health. Crop managers should employ certified crop scouts or IPM trained farm employees to scout fields and provide accurate information for decision making.

For the scout training class schedule or scouting manuals, contact Wisconsin's IPM Coordinator: Bryan Jensen at Entomology Department, UW-Madison, 1630 Linden Drive, Madison, WI 53706  
Phone: 608-263-4073 Fax: 608-262-3322  
e-mail: Bmjense1@wisc.edu

## B. Crop Scouting Methods

Implementing the University of Wisconsin recommended scouting procedures will help growers receive an accurate account of pest populations found in their fields. Complete and accurate field diagnosis also provides information to improve the timing of chemical treatments. Specific instructions for scouting the important potato pests are provided below.

### DISEASES

**Early Blight:** Scouting should occur when weather conditions are favorable for early blight development - at 300 P-days (P-day calculations begin at crop emergence). Scout at least weekly through-

### HORSFALL-BARRATT DISEASE RATING SYSTEM

Foliar disease infections can be monitored using the Horsfall-Barrett disease rating scale. This scale, which runs from 0 to 11, takes into account the percentage of the field which exhibit disease symptoms. The scale should be recorded on the scouting form.

0= no infection

1=2-3% infection

2=3-6% infection

3=6-12% infection

4=12-25% infection

5=25-50% infection

6=50-75% infection

7=77-88% infection

8=88-94% infection

9=94-97% infection

10=97-100% infection

11=all foliage infected

out the growing season until the vines have completely died. Pay specific attention to older senescing leaf tissue where early blight symptoms tend to appear first. Assess early blight incidence based on the Horsfall-Barratt disease rating system.

**Late Blight:** Scouting should occur just before crop emergence in sites where overwintering inoculum (such as near cull piles) may be present. After emergence, scouts should record disease symptoms at each scouting site weekly throughout the growing season until vines are completely dead. Scouts should look for late blight lesions as they are casually walking through the field as well. Scout additional sites which could be prone to late blight infections weekly. These include areas near windbreaks, woodlots, near the irrigation pivot, or near power or utility lines. Assess late blight incidence based on the Horsfall-Barrett disease rating system.



Scout weekly from emergence until vines are completely dead.

## **INSECTS**

Scout weekly during the growing season unless otherwise noted in the instructions below.

### **Colorado potato**

**beetles:** Begin scouting in early May when adults emerge from overwintering sites along the field edges. Start scouting for bright yellow egg masses by looking at the lower sur-



faces of all leaves on a plant. Record numbers of adults, eggs, small larvae (1<sup>st</sup> and 2<sup>nd</sup> instars), large larvae (3<sup>rd</sup> and 4<sup>th</sup> instars), and estimate the percentage of defoliation per 10 plants at each site.

**Potato leafhoppers:** Scout for potato leafhoppers by taking 25 sweeps per sample site. Record the number of adult PLH found in the net. Potato leafhopper nymphs are less mobile and are best scouted by leaf samples. Carefully turn over 15 leaves per sample site. Select the leaves from the middle portion of the plant. Record the number of nymphs found on the leaves.



**Potato aphids:** Aphids can be sampled by sweeping, but if aphids are found in the sweep net, than leaf counts should be taken to ensure the proper analysis of aphid numbers. Sample for aphids by examining 15 leaves at each sampling site. Leaves should be taken from the middle of the plant. Record the total number of adults and nymphs. Potato aphids tend to reside on the upper, newer leaves of the potato plant.

**Green peach aphids:** Sample for aphids by looking at 15 leaves at each sampling site. Leaves should be taken from the middle of the plant. Record the total number of adults and nymphs. Green peach aphids reside on the mid to lower, older leaves of the plant so samples from the middle to lower portions are recommended to determine green peach aphid populations.

## **Aphid Scouting**

Take leaf samples from the middle of the potato plant to ensure an accurate account of the aphid populations. Potato aphids reside toward the upper portion of the plant, while green peach aphids reside toward the lower portion of the plant.



**European corn borer:** Begin scouting procedures at 500-degree days (around mid-June) and continue through 700-degree days (based on a developmental base 50°F threshold for degree day accumulation). Since the ECB is a sporadic pest, monitoring should be done before beginning any control program. To detect potentially damaging levels of egg-laying; adult moth flights can be monitored using a black light trap.

Pheromone traps are another way to monitor male moth activity. These traps are specific to individual moth species, which makes identification easier. Contact your local UW-Extension agents who have access to statewide monitoring programs for plant trap numbers.



Once adults are found in field, scouting for ECB egg masses and larval damage should occur. To scout, look for white eggs that overlap like fish scales on the lower leaf surface. There can be as many as 30-40 eggs in each mass.



### **Looper and Cutworms:**

Sample by shaking the foliage of a five-foot section into the furrow and counting the larvae on the soil surface. Worm populations (combining loopers and cutworms) can



also be sampled using the sweep net method and counting the number of worms per 25 sweeps.

**Tarnished Plant Bugs:** Scout using a sweep net beginning in early to mid-July. Take 25 sweeps per site and count the total number of tarnished plant bugs in the sample.

**Flea Beetles:** Scout using a sweep net beginning early in the season when flea beetles are the most active. Look for damage on smaller plants where defoliation will likely be more prevalent. Flea beetles are not a pest later in the season. To scout, take 25 sweeps at each site and count the number of flea beetles present.



**Aster leafhoppers:** Scout when plants are newly sprouted in the spring and the leafhoppers begin infesting Wisconsin. Take 25 sweeps per site. Count the total number of aster leafhoppers present per sweep.

## **WEEDS**

Begin scouting when the potatoes emerge and continue until harvest.

- At each sampling site, note any weed infestations.
- Properly identify the weed species since this will dictate the control method.
- Record the numbers of weed species present and their locations within the field.
- If GPS is available, map weedy areas within a field by walking around the weed patch for long-term monitoring.



## C. Information Gathering and Mgmt

Field scouting has many advantages beyond the simple determination of pest species and numbers. Scouting can provide information on the effectiveness of current management programs (including cultural, biological, mechanical and chemical control methods) and can aid in future management decisions. By tracking scouting data with management information, growers can determine the most effective, economical, and environmentally sustainable control method. It is recommended that pest population numbers and control strategy information be kept for 10 years for long-term analysis. If data is discarded, the information cannot be used to guide better management strategies in the future.

## D. Field Maps of "Hot Spots"

Long-term pest averages and numbers should be kept by the grower to watch the trends and changes in pest populations. Usually, there are areas within a field which are prone to pest infestations, especially with weeds and diseases. These areas of the field are known as “hot spots” and geo-reference mapping of such areas could provide valuable information from year to year. Mapping these areas using GPS systems can be done to assess the patterns and changes in these pest “hot spots” over time. Specifics on using GIS and GPS technologies can be found in the handbook’s *Preplant/Rotational Pest Management* section.

## Notes:

This image shows a single sheet of white paper with horizontal ruling lines. The lines are evenly spaced and run across the width of the page. There are no margins, text, or other markings on the paper.

# Potato Pest Scouting Form

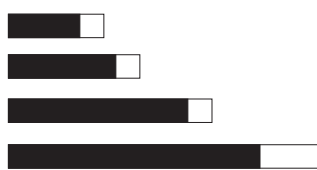
Grower \_\_\_\_\_ Field # \_\_\_\_\_ Field Location \_\_\_\_\_  
 Field Size \_\_\_\_\_ Date \_\_\_\_\_ Hour \_\_\_\_\_  
 Plant Height \_\_\_\_\_ Growth Stage \_\_\_\_\_ Scout \_\_\_\_\_

Insects	Thresholds	Field Average	Field Tally
1. PLH	25/25 sweeps	___/25 sweeps	_____
2. PA	25/25 sweeps	___/25 sweeps	_____
3. PLHN	1.5/15 leaves	___/15 leaves	_____
4. GPA	1.5/15 leaves	___/15 leaves	_____
	(seed potatoes)		
	15/15 leaves (table stock)	___/15 leaves	_____
5. CPBA	25/5 ft. row	___/5 ft. row	_____
6. CPBL	75/5 ft. row	___/5 ft. row	_____
<b>Cutworms and Loopers</b>			
7. Instar 1&2		___/5 ft. row	_____
8. Instar 3	20/5 ft. row	___/5 ft. row	_____
9. Instar 4	20/5 ft. row	___/5 ft. row	_____
10. Instar 5&6		___/5 ft. row	_____

**Cutworm head**  
capsule gauge

■ Instar 3  
 ■ Instar 4  
 ■ Instar 5  
 ■ Instar 6

**Cutworm body**  
length gauge



**Field Map / Comments:**

## Diseases

- Early Blight \_\_\_\_\_
- Late Blight \_\_\_\_\_
- Other \_\_\_\_\_

## Horsfall-Barratt Disease Rating System:

- |                         |                           |
|-------------------------|---------------------------|
| 0 = no foliage infected | 6 = 50-75%                |
| 1 = 0-3%                | 7 = 75-88%                |
| 2 = 3-6                 | 8 = 88-94%                |
| 3 = 6-12                | 9 = 94-97%                |
| 4 = 12-25               | 10 = 97-100%              |
| 5 = 25-50               | 11 = all foliage infected |

# Disease Management

## In-season



An integrated disease management program which incorporates cultural, physical, mechanical, biological, and chemical control strategies should be utilized during the potato growing season.



Read the following statements in order and check all that apply. Refer to the corresponding sections on the following pages for more information.

- ☐ **A.** *Fungicides are applied according to a calendar schedule.*
- ☐ **A.** *Protectant fungicide applications begin at 300 P-days and/or 18 severity values.*
- ☐ **A.** *Good growing practices produce a healthy crop that limits disease infestations.*
- ☐ **A.** *Cultural control strategies are added to the potato disease management system. Growers and neighboring home gardeners control late blight as a community-wide disease.*



## A. Calendar Applied Fungicides

Traditionally fungicide applications for potato disease control began early in the growing season and continued at least weekly until harvest. Regular, frequent fungicide applications were the basis of many disease management programs. Today, new bioIPM techniques, including disease forecasting models and cultural, biological and reduced-risk chemical options, have advanced disease management strategies. Using these new strategies will assure a more effective fungicide program.

### Disease Forecasting Model

“Blitecast”, developed at Penn State University, is a program module that has been adapted for Wisconsin and is part of the WISDOM and SureHarvest software systems. The model uses the duration of high relative humidity along with the corresponding range of temperatures to calculate severity values. Severity values represent the extent to which the daily environment has been favorable for disease development and sporulation. Calculation of severity values begins at crop emergence, and when 18 severity values are accumulated, environmental conditions are favorable for disease development and fungicide control measures should be initiated. There is an approximate two week window from the time 18 severity values are accumulated and the anticipated onset of disease symptoms.



## B. Disease forecasting models

Disease forecasting models are useful tools to predict when disease incidence may occur as a result of weather and environmental conditions. The predictive models alert crop managers to start protectant fungicide applications. Disease forecasting models for early blight and late blight are an integral part of the disease management programs for Wisconsin potatoes.

To view current season's P-day and severity value accumulations at various locations throughout Wisconsin, visit the UW Vegetable Pathology website at <http://www.plantpath.wisc.edu/wivegdis/>

Calculations from data collected at monitoring sites in Antigo, Grand Marsh, Hancock and Plover can be found there.

For more accurate values, on-farm weather stations can be used and models can be run in the WISDOM or SureHarvest software systems.

**Early blight** infestations are forecast with predictive models that calculate the physiological age of potatoes. Physiological days (P-days) calculate the age of potatoes using high and low temperatures. When 300 P-days accumulate, sporulation of the pathogen is likely to increase, potatoes become vulnerable to the disease, and protectant fungicide sprays should be initiated.



Calculations for P-day values are based on potato developmental temperatures. The potato plant grows at temperatures above 45° F and below 86° F (optimal potato growth occurs at 70°F). Outside this range no P-day accumulations occur. The



## Severity Value Accumulations based on Environmental Conditions

Average	----- Severity values and hours of > 90% relative humidity -----				
temperature range*	0	1 (trace)	2 (slight)	3 (moderate)	4 (severe)
45 - 53°F	15 hours	16-18 hours	19-21 hours	22-24 hours	25-27 hours
54 - 59°F	12 hours	13-15 hours	16-18 hours	19-21 hours	22-24 hours
60 - 80°F	9 hours	10-12 hours	13-15 hours	16-18 hours	19-21 hours

\*Average temperature of period when relative humidity > 90%

At 45-53°F and >27 hrs of relative humidity >90%, total severity values =  $((\text{Total hours} - 1) \div 3) - 4$

At 54-59°F and >24 hrs of relative humidity >90%, total severity values =  $((\text{Total hours} - 1) \div 3) - 3$

At 60-80°F and >21 hrs of relative humidity >90%, total severity values =  $((\text{Total hours} - 1) \div 3) - 2$

maximum P-day accumulation in one day is 10, and that occurs with a continuous temperature of 70° F for 24 hours.

**Late blight** infestations are forecast using the severity value model. Fungicide sprays should be initiated when 18 severity values have accumulated. Historically, 18 severity values accumulate in Wisconsin between mid-June and mid-July. The early accumulation of 18 severity values usually predicts a high risk of late blight infection if there is a local inoculum source.

Severity values are numbers that can be calculated each day based on two factors:

- the number of hours the relative humidity is at or above 90%
- high and low temperatures during the high humidity period



Calculations of severity values begin at crop emergence and continue throughout the growing season.

### Notes:

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### IMPORTANT FACT

Protectant fungicides applications should begin when 300 P-days and/or 18 Severity values have accumulated. Fungicides should be applied with the correct equipment, nozzles, and pressure to ensure complete plant coverage. If aerial applications occur, field edges should be ground sprayed to provide adequate coverage.

## C. Reduce plant stress and increase potato health

Many pathogens are opportunistic and attack plants that are already stressed by malnutrition, water, heat, or by insects, weed competition or other diseases. Good healthy potatoes will aid in the reduction of disease pathogen infestations.

**Early blight** is more prevalent on older, senescing tissue and particularly when plants have been predisposed by injury, poor nutrition, insect damage or other types of stress. Tuber infection does not occur before harvest because the spores do not percolate in the soil. Most tuber infections occur when the periderm is damaged during harvest operations. The spores will not penetrate intact periderm.



should be used when the prediction models indicate disease development is possible.

Tubers left in the field during harvest will be winter killed if they are exposed, even briefly, to temperatures below 28° F. However, some tubers may survive the winter and will need to be controlled in rotational crops during the growing season with herbicides and tillage.



*Late blight on nightshade.*

Since late blight is a community disease discuss disease control strategies with neighboring growers and home gardeners. Neighbors can have a direct effect on the late blight pressure on nearby farms, and therefore, growers should ensure that their neighbors are properly applying fungicides when disease forecasting models indicate, and that they will destroy plants which exhibit symptoms.

## D. BiolPM Techniques for Disease Management

Alternate host species provide reproductive and overwintering sites for late blight and early blight pathogens and commonly serve as inoculum sources for both the early and late blight fungus. These hosts include tomato, eggplant and most plants in the *Solanaceae* (nightshade) family. Volunteer potatoes, cull piles and other waste tubers that sprout can also be sources of late blight inoculum.

Control strategies for alternate hosts should be employed during the growing season and include their direct control by cultivation or herbicide applications. Completely destroy any alternate hosts on field edges or in adjacent fields. Protectant fungicide applications for host crops

If late blight is found in a field, apply fungicide to the uninfected portion of the crop first, and then apply fungicide to the infected area. Exercise caution when re-entering the uninfected portion of the field and sanitize all equipment completely before entering the un-infected portion of the field and again before entering the next field. Vine desiccate the infected potatoes and include dessicant on a 20 foot border from each edge of the infected patch. Once vines are desiccated, re-apply fungicides until no green tissue remains. Plow down the infected areas and monitor the plants for any re-growth or lesions. If re-growth or lesions are found, reapply vine desiccant and fungicide. Continue monitoring areas near the infected sites (within the field and neighboring field) for the entire growing season.

# Insect Management

## In-season



An integrated insect management program that incorporates cultural, physical, mechanical biological, and chemical control strategies should be utilized during the potato growing season.



Read the following statements in order and check all that apply. Refer to the corresponding sections on the following pages for more information.

- ☐ **A.** *Insecticides are applied according to a calendar schedule.*
- ☐ **B.** *Insecticides are applied when populations reach economically damaging levels.*
- ☐ **C.** *Cultural control strategies such as spot treatments, flaming, or targeted scouting are also used for insect management.*
- ☐ **D.** *Management decisions consider beneficial insects and beneficial species are part of the pest control strategy.*

## A. Calendar Spray Program

In traditional pest management systems, insecticides were the sole means of insect control and these chemicals were applied according to a calendar schedule. Field scouting did not occur and the actual number or species of insects present was not taken into consideration.

Current insect management programs include both scouting and precise timing of insecticide sprays targeted at the vulnerable stages of the pest's life cycle. Using insect threshold levels assures more effective insecticidal sprays and less adverse environmental impact.

## B. Threshold Program

Control strategies should only be used when insect populations have reached or exceeded economic threshold levels. Threshold levels are set to limit yield loss from insect damage to the potatoes. The control strategy managers wish to employ is their choice, and does not necessarily have to be a chemical application. Cultural, biological, physical, and chemical options are available to combat insect pests. For specific control options, see the pest profile area in Appendix A or try one of the bioIPM strategies discussed throughout this handbook.

When the following insect thresholds are met, control strategies should be implemented.

### Colorado potato beetle

are most vulnerable during the 2<sup>nd</sup> to 3<sup>rd</sup> instar stages, and chemical controls should be applied when they are in the 2<sup>nd</sup> and 3<sup>rd</sup> larval stages. Growth and development is dependent on heat unit accumulations (see text box at the end of this section).



Threshold levels of defoliation and adult numbers have also been set. Adult threshold levels are as follows:

<u>Plant Stage</u>	<u>Allowable Defoliation</u>
Pre-flowering (6-8")	20 to 30% defoliation
Flowering	5 to 10% defoliation
Tuber bulking	30% defoliation

Economic threshold levels for Colorado potato beetle adults are:

1<sup>st</sup> generation 20 adults/ 5 plants

2<sup>nd</sup> generation 15 adults/5 plants

Colorado potato beetle larvae can cause significant damage and defoliation, and the degree day model should be used for precise, accurate timing for larval control. See the text box on pg. 82 for details.

**Potato leafhoppers** feed on plants using their piercing/sucking mouthparts resulting in stunted plants with yellow, triangular-shaped burned areas on leaf tips called "hopperburn".



Severe yield reductions have already occurred when this symptom appears in the field. Therefore, proper scouting needs to be done to ensure management at the threshold levels.

Potato leafhopper adults: 25/25 sweeps

Potato leafhopper nymphs: 1.5/15 leaves



**Go to the page 82 for the text box:**

***Colorado Potato Beetle degree days accumulations***



**Aphids** are primarily a concern on potatoes toward the end of the growing season. They can be a serious problem for seed potato production. In production fields, aphids can also be a concern when they reach threshold levels. However, if these levels occur late in the growing season (within 1-2 weeks of vinekill) sprays are not needed. Thresholds for aphid control are as follows:



#### **Fresh Market or Processing**

Early Season: 50 wingless aphids/25 leaves (all species)

After Bloom: 100 wingless aphids/25 leaves (all species)

#### **Fresh Market or Processing Potatoes Grown in Seed Production Areas**

7.5 green peach aphids/25 leaves

50 aphids of any species/25 leaves

#### **Seed Potatoes**

2.5 green peach aphids/25 leaves on virus susceptible varieties

5.0 potato aphids/25 leaves on virus susceptible varieties

7.5 green peach aphids /25 leaves on virus resistant varieties (Katahdin, Kennebec, Norgold, Norland, Red Pontiac, Shepody)

If **European Corn Borer** counts exceed 25 moths per trap per night, egg laying in potatoes may be high enough to result in larval feeding causing economic damage. European corn borers prefer corn, and therefore, there is no need to treat unless egg masses and/or European corn borer larvae are present within the potato field. Spot treatments may be effective in localized areas within a field.

**Looper and Cutworm:** The following thresholds have been established:

Prior to July 25: 20 larvae/5 foot section. Minimal defoliation will not cause yield losses.

After July 25: 40 larvae/5 foot section. Larger plants can sustain more defoliation without the threat of yield losses.

## **C. Cultural Management Strategies**

Advances in bioIPM techniques for insects, including cultural, biological, mechanical, and host plant resistance strategies provide many ways to combat pests in an integrated insect management program. Various cultural management strategies which limit or prevent pest levels should be included in the insect management program. Some of these strategies are described in the following paragraphs.

#### **Spot treatments**

(only chemically treating the part of the field where pests are located) can be very effective for insect control. Spot treatments greatly limit the amount of pesticide used.

This limits the adverse affects of pesticides and beneficial insect populations can be preserved in non-treated areas. Spot treatments can be effective at preventing full field infestations. Spot treatments are most effective for insects that are not greatly mobile. Unlike highly mobile or flying pests, insects that walk or are in worm stages are more likely to remain in the area where they originate.

Examples of effective spot treatments are Colorado potato beetle control along field edges in the spring and spraying localized infestations of European corn borers.

**Flaming** using propane torches can be an effective cultural control for **Colorado potato beetles** and provides more than 75% control of adult



beetles. Propane flamers are especially effective for early season control of adults on plants up to 4 inches tall. Use flaming as an edge treatment to kill adult beetles when they are exiting overwintering sites and moving into the field early in the season.



Flaming should occur daily during the first 2 weeks of beetle infestations and can be done by placing two burners on a rig on either side of the potato row and directing the burners at an angle toward the base of the plants. Adjust the nozzle distance, angle, and tractor speed so that the young plant foliage is not seriously injured but Colorado potato beetles are killed. The potato plants' stunted growth and appearance caused by flaming is temporary and will not adversely affect potato growth or yield.

**Potato leafhoppers** are found extensively in alfalfa fields. Once the alfalfa is cut, potato leafhoppers rapidly migrate to the nearest host crop, including nearby potatoes. A cultural management strategy for potato leafhoppers in alfalfa stands is to cut the alfalfa prior to leafhopper damage. If your potato crop is near an alfalfa field, be aware of when the alfalfa is cut and scout the potato field immediately after cutting to determine if potato leafhoppers reach threshold levels.



Cultural controls for **loopers and cutworms** can be successful and greatly help in keeping looper populations down. To control overwintering looper larvae, spring plow debris. Keep weeds controlled in and around fields to reduce egg laying environments.



Preserve beneficial insects by using a pest specific insecticide that won't kill the beneficial insects. Use of a broad spectrum foliar insecticide will kill the beneficial populations.

## D. Beneficial Insects

Beneficial insect and fungal species within a field can greatly decrease pest populations. General insect predators may feed on the larval stages of Colorado potato beetles and other pest species to reduce populations. Biological control will not entirely suppress these populations, but may aid in an integrated control program.

Aphid species usually sustain high levels of mortality from natural enemies. **Parasitic wasps** frequently attack aphids. The

wasps (which are microscopic and not seen by the human eye) lay their eggs in the aphid's body. The wasp's larva grows by feeding on the aphid and after it is done feeding, it breaks away and leaves an aphid mummy. An **aphid mummy** looks like a petrified aphid body and is usually stuck to the underside of leaves. To determine if parasitic wasps are located in a field, scout and



Maintaining habitat for beneficial populations is important so that predatory and parasitic insects have a place to survive when no prey is available. For specifics on beneficial releases and maintenance, see the *Biological Control* section later in this *In-season* chapter.

[illegible]

## Colorado Potato Beetle degree days accumulations

Degree days provide a means of predicting an insect's development and activity by monitoring time and temperature. Since insects are cold blooded, their body temperature is related to the temperature of the surrounding environment. As a result, the physiological activity of many insects is determined by environmental temperatures. Degree day calculations of Colorado potato beetle growth and development help to determine the most effective timing of pesticide applications.

Below 50° F, Colorado potato beetle growth is limited. In the Colorado potato beetle degree day accumulation model, growth starts at a base temperature of 52° F. Calculation of degree days begins when the first egg mass is found in the field and continues according to the following equation.

### Calculating Degree Days for Colorado potato beetle growth and development.

Use the high and low temperatures for the day to calculate an average temperature, and subtract 52.

Example: High temperature = 80° F

Low temperature = 60° F

Average temperature:  $(80 + 60) \div 2 = 70^{\circ}\text{F}$

$70 - 52 = 18$

The degree days for this particular example are 18.

If the average daily temperature is below 52° F, no degree days are accumulated

### Degree day accumulations for the Colorado potato beetle are as follows:

Life Stage	Degree Day	Cumulative Degree Days
Egg	120	120
*First Instar	65	185
**Second Instar	55	240
**Third Instar	60	300
Fourth Instar	100	400
Pupae	275	675

\* the most susceptible life stage for Btt foliar applications

\*\*the most susceptible life stage for foliar insecticide applications

Important point to remember - do not treat fields unless scouting reports **verify** that Colorado potato beetles are present at or above economically damaging levels.



# Weed Management

## In-season



An integrated weed management program which incorporates cultural, mechanical, biological, and chemical control strategies should be utilized during the potato growing season.



Read the following statements in order and check all that apply. Refer to the corresponding sections on the following pages for more information.

- ☐ **A.** *Weeds are controlled solely by chemical means.*
- ☐ **B.** *Herbicides are applied at reduced rates where possible, and herbicide modes of actions are rotated. Tillage practices are timed for weed control.*
- ☐ **C.** *Overall plant health is encouraged through proper fertility, insect and disease control. The canopy closure module is utilized in weed control decisions. Chemical controls are not applied after canopy closure.*
- ☐ **D.** *Advanced cultural management strategies are utilized when possible. These include the use of smother crops, tilling and mowing field edges, and using propane torches for weed control.*

## A. Chemical Weed Control

Traditionally, weeds were controlled solely through the use of herbicides and often no other cultural or mechanical control methods were used. With the advancement of bioIPM strategies, growers can now manage weeds in a more comprehensive, year-round program.

## B. Reduced Rate Herbicides and Tillage Practices

Reducing the herbicide application rate can significantly diminish the potential for groundwater contamination. Reduced rates provide good weed control when coupled with



timely tillage operations. Tillage is very effective in controlling small, shallow rooted annual weeds early in the season and less effective later in the season when weeds are larger. Don't cultivate in overly wet soil or irrigate after cultivation, as wet

conditions allow weeds to re-root.

Annual broadleaf seedlings are generally very susceptible to uprooting by cultivation. They are also susceptible to specific soil and foliar herbicides that provide excellent control when properly applied. Optimal application timing is important in controlling annual broadleaf weeds with foliar sprays as many of these herbicides will not control larger annual weeds. Annual broadleaves that reach larger size are generally more difficult to manage.

As with broadleaf weeds, annual and perennial grasses infest potato fields. Young grass seedlings are easily controlled with cultivation, but as they get older, they may re-root after a cultivation.

Most annual grasses are easily controlled with preemergent herbicides. Emerged annuals and perennials can also be controlled to varying degrees with postemergent herbicides. Do not use postemergent herbicides as the only control for grasses. These herbicides are all in the same chemical family and resistance may develop rapidly. Control perennial grasses outside of the potato crop, or treat with a systemic herbicide before potato crop emergence.

Perennials can also re-sprout when the top growth has been removed as long as the storage organ is intact. Avoid planting into fields heavily infested with perennials.

### Benefits and Disadvantages of Tillage

#### Benefits:

- Not restricted by windy weather
- Does not increase toxicity values
- Aerates the soil
- Effectively controls annual weeds

#### Disadvantages:

- May damage potato roots and foliage
- Increases soil compaction
- May require repeated operations
- Only effective early in the season

In addition to reducing the herbicide rate, think about what herbicides are available later in the season to control weed escapes not controlled by tillage. Postemergent herbicide applications should include chemical classes not used in a preemergent application. For example, if metribuzin is used in a preemergent application, it should not be applied in a postemergent application unless it is tank mixed with a chemical from a different herbicide class that will augment metribuzin's efficacy. For help in rotating herbicides, refer to Appendix C which lists all the potato herbicides by their chemical class.

## C. Canopy Closure Module

An additional tool to use when reducing herbicide rates and utilizing cultivation is the canopy development model in the WISDOM program. The model has options for early and late season cultivars and predicts canopy closure using P-Day accumulation. Maximum shading from the canopy will occur at approximately 7-8 weeks for most cultivars depending on row and seed spacing.



At that time full season cultivars like Russet Burbank will provide approximately 97-100% reduction in light reaching the soil surface which is enough shading to prevent growth of most weeds. Earlier maturing varieties such as Superior will only provide approximately 90% shade which greatly slows, but does not stop weed growth. Full season cultivars will typically maintain that shade until late in the season which prevents weeds from growing and limits the need for any further herbicide application. Weed growth that occurs with early maturing varieties is usually not enough to interfere with potato growth or harvest.

The key to understanding the canopy in weed control is knowing that a combination of herbicides and cultivation is needed for only 7-8 weeks (when maximum canopy shading occurs).

An important factor to remember in utilizing the canopy is that the plant's overall health must be maintained through proper fertility and irrigation as well as insect and disease control. Any canopy breakdown can allow weed growth, and a rescue herbicide application may become necessary.

## D. Advanced Cultural Management

Advanced cultural or mechanical weed management methods should be used when possible and

when the situation dictates. These alternative strategies will help in weed control and may limit the need for herbicide application.

One of these methods is to inter-seed **smother crops** between the potato rows. This technology provides a rapidly growing crop that will shade between the rows providing weed control before the potato crop is able to fully shade the soil surface. Crops that have been used as smother crops include dwarf brassica and some of the mustard crops. Ensure that the inter-seeded crop does not act as a weed itself, competing with the potato crop. Provide the potatoes with adequate nutrition and water and use only short-lived smother crops which will die before competing with the potatoes.

Weeds need to be controlled in and around the field as well and in areas adjacent to but not in the potato crop. This prevents the spread of weed seeds, increases to the weed seed bank and controls alternate plant hosts for disease and insect pests. **Mow ditches** and corners of pivots and till headlands or any other bare soil where weeds are growing.

The use of a **propane flamer** for early season weed control is another cultural method for weed control. In this technique, two burners per row are directed at weeds growing between the rows.

The intense heat and length of exposure causes sap in the weeds to expand resulting in plant cell rupture. Flaming needs to occur when the weeds are no more than 1-2 inches tall as older weeds are much less succulent and the time of exposure to kill larger weeds may also damage the potato crop. The flamer is generally tractor mounted and the typical fuel used is propane although other fuels may be used. Adjust the nozzle distance, angle and tractor speed across the field according to the size and shape of the hill and the location of the weeds.



## Herbicide resistance in weeds

To be effective, herbicides must come into contact with and be absorbed by plants. Once in the plant, the herbicide must travel to a specific site of action which disrupts some critical growth process resulting in weed death. The term mode of action refers to the specific growth process that is disrupted by the herbicide. The mode of action also dictates how the herbicide is applied.

An understanding of how herbicides kill weeds is necessary for selecting and applying the correct chemical for a given weed problem and for preventing herbicide resistance.

In general herbicides fall into three different types depending on how the weed uptakes the herbicide and how the weed is killed.

- Soil applied herbicides are taken up by the weed as it germinates and begins to grow.
- Foliar applied which acts as a contact and burns the foliage to kill the plant.
- Foliar applied systemic in which the chemical travels into the plant tissue and is transported to its site of action.

Some chemicals can be used in more than one way. For instance, metribuzin can be used preemergent or it can be used as a postemergent foliar spray.

The repeated use of herbicides with similar modes of action on the same site over a period of years has resulted in weed biotypes that are resistant. Weed resistance may be defined as those plants which grow normally with an herbicide dosage that usually kills the weed.

Characteristics of herbicides or herbicide families that contribute to the development of herbicide resistance are:

- Specific mode of action with a single target site
- Effective in killing a wide range of weed species
- Long soil residual activity
- Frequent use in season and from year to year without rotating, alternating or tank mixing with other herbicide classes

Prevention is important to avoid the development of herbicide resistant weed populations. Preventative measures are designed to break the cycle of constant pressure that selects for herbicide resistance.

- Rotate herbicide modes of action.
- Rotate between years.
- Plan 4 - 5 year crop rotation that addresses herbicide rotation.
- Avoid sequential applications of high risk herbicides (ALS, ACCase).

### Within years

- Use multiple modes of action.
- Choose herbicide families that pose a low risk of developing resistance.
- Follow all label instructions.
- Spot spray weed escapes using different modes of action.
- Use scouting information to determine the location of weeds.
- Eliminate weeds before they go to seed.
- Tank mix herbicides with different modes of action.



# Plant Nutrition

## In-season



Crop nutrient applications should follow research-based, University of Wisconsin recommendations. Excessive nitrogen is both economically and environmentally damaging.



Read the following statements in order and check all that apply. Refer to the corresponding sections on the following pages for more information.

- ☐ **A.** *Fertilizer rates are based on past experience.*
- ☐ **B.** *Nitrogen fertilizer programs follow the University recommendations for 2-3 split applications.*
- ☐ **C.** *Petiole nitrate samples are taken to justify supplemental nitrogen.*
- ☐ **D.** *Hill shape is modified to ensure optimal water and nutrient use efficiency.*

# A. Rates 101

University of Wisconsin recommendations and yield goals should be used in determining nitrogen rates. Applying nitrogen without regard to cultivar and in season growing conditions may lead to excessive applications which are both costly and may leach into groundwater.

# B. University Recommendations

Fertility rates and requirements should only be determined after field soil test results are available. Supplemental nitrogen should be applied in split applications. Rates need to be adjusted according to varietal needs. Specific varietal recommendations can be found in varietal profiles available through your seed dealer.

The first application of nitrogen should be made at or near emergence and follow with a second application 10 to 14 days later. If three split applications are made, space applications from 7 to 10 days apart, starting at emergence. Consider the individual cultivar needs when determining nitrogen rates. Excessive nitrogen may stimulate excessive top growth leading to delayed tuber maturity and lower solids content in the tuber.

### General Nitrogen Recommendations for Potatoes

Yield Goal	Soil organic matter (%)			
	<2	2-9.9	10-20	>20
cwt/a	Amount of N to apply, lb/a*			
250-350	115	90	70	30
351-450	150	125	100	45
451-600	200	150	125	60

\*These amounts assume some additional nitrogen (about 30 lbs/a) was applied as starter fertilizer. Reduce nitrogen rate by 25% if petiole nitrogen test is used to guide in-season nitrogen applications.

## Calcium Use for Potatoes

Recent Wisconsin research has shown that potatoes may benefit from added calcium when grown on sandy soils with low calcium levels. High rates of potash applied to potatoes depress calcium uptake. Additional calcium improves resistance to bacterial soft rot and internal brown spot and consistently improves potato grade.

Limestone applied to correct soil acidity is the predominant source of applied calcium. The limestone quarried in Wisconsin contains 300-400 lbs/ton of calcium. The amount of calcium normally added in limestone applications, combined with the relatively large amounts of exchangeable calcium in Wisconsin soils, far exceeds the 25-100 lbs/a annually removed by crops.



## Notes:

## C. Petiole Nitrate Sampling

Petiole nitrate samples are a diagnostic tool used to determine nutrient status. Use petiole nitrate testing to determine additional nitrogen needs later in the season. Visual estimates of crop health are not adequate to determine additional crop needs.

Petiole sampling should be started approximately 30 days after emergence and continue at 7-14 day intervals until approximately 65 days after emergence. Potatoes absorb little or no nitrogen after 70 days, so continued sampling is unwarranted.

Samples should be taken before noon because petiole nitrate concentrations can fluctuate greatly as plants grow throughout the day and internal moisture levels change. Sample the newest fully mature leaves only. This is typically the fourth or fifth leaf down from the growing point. Older or younger leaves will not accurately represent the plant's nutritional status. Sample forty to fifty petioles from a given area and take samples

following the same pattern used for soil samples. Sample field areas that differ in soil type or in cropping history separately. If the samples are going to be sent to a lab for dry tissue analysis, the petioles can be put into a paper bag and be "sun dried" before sending to the lab.

When analyzing nitrate-N in the petiole sap, the test should be conducted immediately. However, samples can be stored on ice or in a refrigerator for 24-48 hours without affecting the results. Samples should be stored as cold as possible in airtight zip-lock bags to avoid moisture loss and incorrect readings.

The tables below list optimum petiole  $\text{NO}_3\text{-N}$  levels for several varieties and stages of growth. If levels are below optimum and the crop has at least 45 days to vine kill, apply 30-50 lb N/a. Early season supplemental N rates can be reduced by 25-30% if N levels will be monitored through petiole nitrate testing.

### Optimum Ranges of nitrate-nitrogen concentrations

(dry weight in potato petiole at various stages of growth)

Growth Stage*	<u>Potato Variety</u>		
	Norland	Shepody	Onaway
	Atlantic	R. Burbank	
	Kennebec	Snowden	Superior
	----- % $\text{NO}_3\text{-N}$ -----		
30	2.5 - 2.8	2.0 - 2.3	2.3 - 2.5
40	2.3 - 2.5	1.7 - 2.2	2.0 - 2.3
50	1.8 - 2.3	1.2 - 1.6	1.5 - 1.9
60	1.3 - 1.9	0.8 - 1.1	0.9 - 1.2
70	0.8 - 1.1	0.5 - 0.8	0.4 - 0.6

\*days after emergence

### Optimum Ranges of nitrate-nitrogen concentrations

(sap basis in potato petiole at various stages of growth)

Growth Stage*	<u>Potato Variety</u>		
	Norland	Shepody	Onaway
	Atlantic	R. Burbank	
	Kennebec	Snowden	Superior
	----- ppm $\text{NO}_3\text{-N}$ -----		
30	1900-2100	1600-1800	1800-1900
40	1800-2000	1600-1700	1600-1800
50	1400-1800	1000-1300	1200-1500
60	1100-1500	700-900	500-1000
70	700-900	500-700	400-600

\*days after emergence

## D. Hill shape

Hill shape can influence water and nitrogen use efficiency. When hills are round-topped or pointed, more water runs off into the furrow than percolates through the hill and root zone. These hill types do not hold nitrogen well because the water carries nutrients into the furrow. Implements that create flat topped hills with a small ridge on either side have recently become available. Hills formed in this manner allow better water use efficiency by forcing more water to flow through the hill rather than running off the side of the hill. These flat topped hills also provide better nitrogen use efficiency as less of the nitrogen is washed down the side of the hill. It is possible that the improved water use efficiency may result in improved nitrogen use efficiency and reduce the loss of nitrogen in the groundwater.



## Notes:

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# Irrigation

## In-season



Irrigation management strategies which provide adequate water without over watering should be used to ensure proper growth and development of the potato crop.



Read the following statements in order and check all that apply. Refer to the corresponding sections on the following pages for more information.

- ☐ **A.** *Irrigation is applied to ensure proper water to the crop.*
- ☐ **B.** *Irrigation scheduling tools are used to determine irrigation timing and amounts.*
- ☐ **C.** *Disease management and stress concerns play a key role in irrigation decisions.*
- ☐ **D.** *Water is applied efficiently throughout the crop cycle to reduce physiological stress and adverse environmental effects.*

## A. Irrigation

The goal of water management is to maintain adequate soil moisture throughout the growth of the crop, while avoiding extremes and excessive fluctuations. Water constitutes approximately 90-95% of the foliage and 75-85% of the tubers. For potatoes, the soil moisture status becomes critical when water levels reach 60-65% of available soil water. Plants become stressed when only 35-40% of the available soil water is used. At the other extreme, excessive soil water can cause plant stress as well as leach nutrients.

### Available Soil Water

The **available soil water** is the difference between a soil's field capacity (total amount of water that can be held by a soil) and the permanent wilting point (point at which plants wilt and die). As potatoes show stress and loss of yield and quality before the permanent wilting point is reached, there is a critical amount of available soil water that can be depleted. That critical depletion amount is called the **allowable depletion**.

The maximum allowable depletion for the potato crop is at 60-65% of available soil water. Although the allowable depletion is 60-65% of the available soil water, most growth stages of the potato crop require at least 70-75% ASW for optimal growth. See section D for further explanation of water use efficiency. If the field is allowed to go below the allowable depletion, significant stress will occur and yield and quality will suffer.

The majority of Wisconsin growers use center pivot overhead irrigation systems but some of the crop is irrigated with traveling gun or linear systems. A small percentage of the crop is irrigated through solid set systems. Regardless of the system used, it is critical that the application rate be matched to soil infiltration rate and crop use.

Advantages of overhead irrigation include uniform water distribution, good control of the amount of water applied, and the capacity to apply fertilizer and pesticides without making additional trips across a field.



A major disadvantage of overhead irrigation is the high energy required to pressurize the systems. Energy costs can be reduced by using low pressure nozzles which also increase water use efficiency.

Some smaller-scale, fresh market growers use drip irrigation systems. The high cost of equipment and the labor required to lay drip tubes prohibits this technology's use on larger commercial fields.

## B. Irrigation Scheduling Tools

Whatever the type of irrigation system, use irrigation scheduling to balance crop use with irrigation and rainfall. The simplest tool to use is a check-book method to track water use and irrigation needs. In this approach, crop water use is calculated using evapotranspiration. When calculations show that the allowable depletion is reached, irrigation is applied to bring the available soil water back to desired levels.

The amount of available soil water can be derived from the WISDOM or SureHarvest computer irrigation scheduling tools, which are based on the Wisconsin Irrigation Scheduling Program (WISP).



## Evapotranspiration (ET)

Irrigation schedules are based on an estimation of the amount of water the plants require each day. Crop water use is referred to as **evapotranspiration**. This is the sum of two forms of water loss- evaporation from the soil surface and transpiration from the plants.

Evapotranspiration (ET) is affected by several climatic factors and plant characteristics. It increases as sunlight, temperature, and wind increase and as the size of the plant canopy increases. It decreases as the relative humidity increases and as stomata on the leaves close in response to water stress.

Various methods have been developed for estimating daily ET. ET numbers for production areas in Wisconsin and Minnesota can be viewed by accessing the WI-MN cooperative extension agricultural weather page at <http://www.soils.wisc.edu/wimnext/weather.html>. The Wisconsin Irrigation Scheduling Program (WISP) is a part of the WISDOM and SureHarvest programs. It uses daily ET to determine the current percentage of available soil water, the frequency of irrigation, and the amount of water to be applied.

The irrigation-scheduling module requires the input of the following parameters for successful and effective operations:

- Allowable depletion value for the soil
- Initial allowable depletion balance at crop emergence
- Amount of rainfall and irrigation applied to the field
- Daily evapotranspiration estimate
- Percent canopy cover to adjust the ET when the crop is less than full cover

These inputs are used in a simple checkbook-like accounting format in which water deposits and water withdrawals are used to derive the allowable depletion balance. The allowable depletion balance

reflects the current amount of soil water storage and can be used to determine irrigation frequency and amounts.



## C. Disease Management

Irrigation often plays a crucial role in managing various diseases and physiological disorders. For instance, late blight development is favored by long periods of uninterrupted leaf wetness. During times of late blight concern, keeping leaves drier is preferred. Contrarily, water stress can also lead to disease concerns. Stressed plants are vulnerable to certain diseases, such as potato early dying.



## D. Efficient Water Use

The following guidelines describe optimum water management at various stages of the potato crop.

### Growth Stage I: Vegetative

Irrigation management should be moderate and designed to promote optimal plant stands and canopy development. If the field is very dry before planting, the field should be pre-irrigated to field capacity before planting. After emergence, keep the field at 75-85% available soil water (ASW). By

keeping the soil below field capacity, some soil water storage holding capacity is available to absorb rains. Early applied nitrogen could leach if rains fall on a soil at field capacity.

### Growth Stage II: Tuber Initiation

Irrigation should again be moderate with the goal of preventing moisture fluctuations. Irrigation should maintain soil water levels from 75-85% ASW. Avoid excess irrigation that can lead to nitrogen leaching. Increasing ASW to 80-90% during tuber initiation and early bulking is important for reducing scab on susceptible cultivars.

## Plant Stress

Growth Stage	Excess Soil Moisture	Deficient Soil Moisture
I - Vegetative	Stands will be reduced from increased seed piece decay. <i>Rhizoctonia</i> infection may be a problem especially if soils are also cold.	Can result in poor stands from the decreased healing of seed pieces. Will increase susceptibility to soft rot decay especially if the soil temperature is 10 or more degrees higher than the seed piece.
II - Tuber Initiation	Shown to result in increase in brown center, hollow heart and <i>Verticillium</i> .	Inhibits plant growth and fertilizer uptake. Soil water deficits increase tuber susceptibility to scab.
III - Tuber Bulking	Hollow heart may increase from fluctuations in soil water. Excess irrigation will increase diseases such as early and late blight and may leach nitrogen leading to nutrient deficits.	Slows tuber development and reduces yield. Knobs and other tuber malformations will increase. Premature plant senescence may occur which leads to increased problems with early blight and early dying.
IV - Tuber Maturation	Leads to enlargement of lenticels which may increase bacterial infection. Also favors development of pink rot, <i>Pythium</i> leak and late blight in tubers.	Dry soils will dehydrate tubers and increase likelihood of stem-end vascular discoloration. May also hinder skin set.
Harvest	Increases susceptibility to shatter bruise. Soil clings to tubers and may increase likelihood of tuber rot in storage.	Increases blackspot bruising during harvest. Increases clods in soil which will increase bruising.



### Growth Stage III: Tuber Bulking

Soil water should be maintained at 75-85% ASW during early tuber bulking to minimize hollow heart and nitrogen leaching. As tuber bulking continues, increase the soil moisture to 80-90% ASW to help reduce the potential for scab. Care must be taken during this period as excessive moisture can result in disease problems such as hollow heart. Minimize soil moisture fluctuations if possible.

### Growth Stage IV: Tuber Maturation

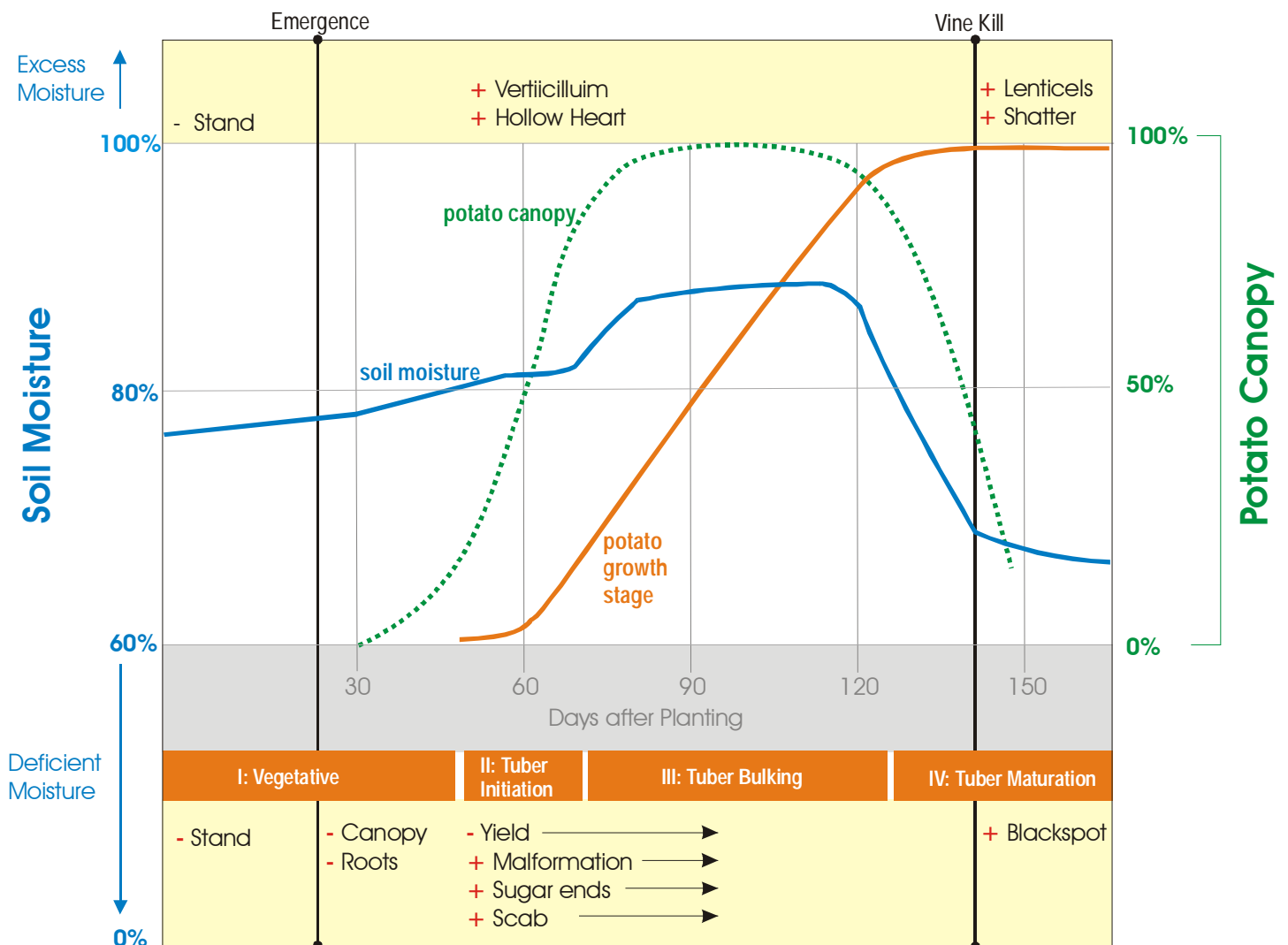
Irrigation should reflect declining water use by the crop and declining canopy. As the canopy

senesces, irrigation management should lower to 60-65% ASW. This will help weaken vines and aid in vine kill.

### Harvest:

If soils become excessively dry after vine killing but before harvest, irrigate to bring the ASW back to the 65-70% range. Apply this irrigation about one week prior to harvest. This will allow the tuber to re-hydrate and become more resistant to blackspot bruising. Avoid over irrigating as this may enlarge lenticels and increase storage problems and tuber decay from several different pathogens.

## Soil Water Management and Potato Productivity



### Notes:

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# Resistance Management

## In-season



Resistance of pest populations to pesticides is an increasing problem in Wisconsin potato production. Proper resistance management strategies should be used to maintain the efficacy of available pesticide chemistries in the potato production system.



Read the following statements in order and check all that apply. Refer to the corresponding sections on the following pages for more information.

- ☐ **A.** *Pest management decisions consider pesticide modes of action and classes.*
- ☐ **B.** *Similar insecticide chemistries are not applied in succession and single-site fungicides are not used in consecutive sprays. Pesticides are only applied at pest threshold levels or when weather conditions dictate that controls measure should be utilized.*
- ☐ **C.** *If systemic insecticides are applied at planting, foliar versions of that chemistry or similar chemistries are not used later in the season.*
- ☐ **D.** *The resistance management program considers the field's past history and future crops.*

## A. Pesticide Modes of Action

Pesticides have a specific way in which they control pests known as the pesticide's mode of action, or target action site. Growers need to know these modes of actions so they can implement proper resistance management strategies. Ultimately, applying these strategies will minimize the likelihood that resistance to the various chemistries will occur and will maintain more options for potato pest management.

The Environmental Protection Agency (EPA) has developed a voluntary pesticide labeling proposal that groups pesticides with similar modes of action and designates them with a number. Look in Appendix C for the EPA resistance management groups for insecticides, fungicides, and herbicides.

Pesticide resistance develops in pathogens, insects and weeds a variety of ways. In general, the pest species become resistant through natural selection of biotypes exposed to a particular family of pesticides over a period of years. These pests have the genetic potential to pass along the resistant traits through reproduction. Many times the resistant traits are irreversible in the populations, and once resistance occurs, the pesticide will never work in the system again. Occasionally resistance is reversed in new populations when the pesticide is not used for a length of time. For example, certain fungal populations may exhibit a form of "resistance" in one growing season, but are susceptible to the fungicides in the following years.



## B. Non-consecutive spray

The genetic alterations that create resistant populations occur most rapidly when growers repeatedly apply pesticides with similar modes of action in consecutive sprays. Therefore, it is essential to not spray the same product or similar products against the same target pest in consecutive applications.



Single-site fungicides, including the new, reduced-risk Group 11 strobilurin fungicides, are prone to the development of resistance by pest populations. Recommendations for Group 11 fungicides are to completely avoid consecutive sprays of any Group 11 fungicide. This includes pre-mixed products which include a Group 11 material and tank-mixed applications with other, non-Group 11 materials.

Resistance management programs should incorporate bioIPM approaches which limit pest infestations, limit the number of applications needed, time the products appropriately, and target the vulnerable life stages. Specific strategies are listed in the text box at the end of the section, *Strategies to prevent resistance development*.



## C. Systemic and Foliar Insecticides

To limit the possible exposure of Colorado potato beetles to chloronicotine active ingredients (Group 4 materials), it is recommended that these products only be used as a systemic (an at-planting or seed treatment) OR foliar treatment. Do not use a Group 4 insecticide both systemically and foliarly in the same year. Products in this class include the imidacloprid materials (Admire, Gaucho, Genesis, Provado, Leverage) and the thiamethoxam materials (Platinum, Actara). Refer to Appendix C for insecticide resistance management classifications.

## D. Rotational Resistance Management

Successful resistance management programs incorporate an area-wide management approach and consider the field's pesticide history and pest populations from previous years as well as future

plans and projections. The movement of pest populations, specifically for Colorado potato beetles from overwintering areas and early blight spores from the previous year's field, can have a major impact on the resistance management program. If localized populations develop resistance, using the chemistries where resistance is found will only increase the problems. Therefore, if there are resistance concerns, alternating different chemical classes with different modes of actions is extremely important.

Rotational resistance management strategies are most effective when field maps with locations of pest populations and the types of management strategies are kept from year to year.

Growers should think of their programs in an area-wide framework and alternate chemical classes on adjacent fields one year to the next. Growers should also consider the projected applications for following years. More information on resistance management in rotational crops can be found in the *Preplant* chapter.



**Go to the next page for the text box:**

***Strategies to prevent resistance development***

## Strategies to prevent resistance development

Growers should consider the following resistance management strategies and evaluate all chemical applications (fungicides, insecticides, and herbicides) as part of a comprehensive IPM program.

### Fungicides

- For the strobilurin group of fungicides (Group 11 in Appendix C):  
  
Always alternate any Group 11 compound with another mode of action, specifically a multi-site compound group. Do not apply Group 11 compounds twice in a row, even if they are tank mixed with combinations of other fungicide classes.  
  
Do not exceed six applications of strobilurin fungicides per crop per acre per year. In Wisconsin, three applications are recommended.
- Use disease forecasting programs and IPM approaches to target fungicides to when control is most needed.
- Integrate lower risk fungicides into a season-long, seed to market disease management program.
- Use bioIPM strategies which limit inoculum sources and disease potential whenever possible.

### Herbicides

- Rotate crops.
- Rotate herbicide families and use herbicides with different modes of action in the growing year and between years.
- Use herbicide mixtures with different modes of action.
- Control weedy escapes and practice good sanitation to prevent the spread of resistant weeds.
- Integrate cultural, mechanical, and chemical weed control methods.

### Insecticides:

- Rotate crops and select field locations to avoid high, early season pest pressure.
- Scout pests using the correct method to get an accurate count.
- Treat only at economic thresholds.
- Time application to target the most vulnerable life stage (e.g. 1<sup>st</sup>, 2<sup>nd</sup> instar Colorado potato beetle larvae).
- Obtain good spray coverage.
- Spot treat when feasible.
- Take all pests into consideration to maximize sprays.
- Preserve natural controls by using selective insecticides (e.g. Spintor, Btt) and by using selected uses of materials (timings, rates).
- Use cultural control to reduce populations.
- Rotate potatoes 1/4 mile from previous crop.
- Treat edges as trap crop in spring and fall.

# Biological Control

## In-season



Strategies that promote beneficial species should be utilized whenever possible. Maintenance and augmentative releases of beneficial species may have an effect on limiting pest populations within the field.



Read the following statements in order and check all that apply. Refer to the corresponding sections on the following pages for more information.

- ☐ **A.** *Beneficial insects and biological controls are considered part of the potato production system.*
- ☐ **B.** *Insecticides that are safe to beneficial insects are selected when possible.*
- ☐ **C.** *Beneficial habitat is maintained and beneficial insects and/or fungi are occasionally released.*
- ☐ **D.** *The potential for pest control by beneficial insects is known and considered in management decisions.*

## A. Biological Control

Biological control uses naturally occurring organisms to control pests. Using biological control methods as part of a comprehensive IPM program can reduce the adverse environmental and public safety hazards of pesticides.

Beneficial organisms, also called “natural enemies”, fall into three categories: general predatory insects, parasitic insects, and insect pathogens (fungi, bacteria or nematodes). To implement biocontrol strategies, it is critical to first properly identify beneficial populations and then determine if biological control is a feasible control option for the field area and crop.



For beneficial management to be effective, adequate prey (food) for the insect needs to be present at all times. If pest populations are too low the beneficials may starve to death. If pest populations are too high, the natural enemies may be unable to act quickly enough to protect the crop.

Maintenance of habitat in or around the field may increase beneficial species and may aid in biological control. Maintained areas may include non-agricultural areas which are ecologically diverse and have multiple species with a diversity of floral color, shapes and sizes. These areas attract beneficial species and also serve as an area for them to reside when little prey (food) is available in the field.

## B. Pesticide Selection

The choice of pesticides may have a large effect on beneficial populations. Broad spectrum insecticides and fungicides kill or eliminate pest species, as well as potential biological control agents found

in or around fields. Therefore, carefully select pesticide options to protect biological control organisms. New, reduced-risk options which target pesticide applications to pest species should be used when possible because these materials do not adversely affect beneficial populations. The pesticide toxicity calculation found in Appendix B



### QUICK FACT:

When selecting pesticides choose insecticides that preserve natural enemies. Pesticides that are pest specific help to maintain beneficial populations whereas broad-spectrum pesticides eliminate both pests and beneficial insects.

includes in its scoring system each chemical's effect on beneficial organisms. Review this section to determine the reduced-risk options that do not adversely affect beneficial species.

Scouts should properly identify and count beneficial populations during normal scouting activities. If few to no beneficials are found, biocontrol will not be effective. If many beneficial species are detected, it is critical that only pesticides which do not harm beneficials are chosen.

## C. Beneficial Insect Management

If beneficial populations are found, growers can maintain them by protecting or enhancing their habitats. To keep beneficial species in and around fields, maintain the overwintering areas and field edges for natural enemies. To improve habitats, plant a variety of plant species that attract both beneficial organisms and non-pest hosts of the beneficial insects. Providing a variety of floral colors and plant types also aids in survival of beneficials.

Augmentative releases of biological control agents may be utilized. Biocontrol companies routinely sell predatory insects, such as lady bugs and lacewings, which can be put directly in the field.



These agents may be effective if large quantities are released and they are in their life stage where they attack pests the most, normally in the feeding larval stages.

## Common natural enemies of the potato insect pests



## Parasitic wasps

- Microscopic predators
- Feed on aphids and leave a characteristic mummy on the underside of leaves



## Predaceous stink bugs

- Shield-shape and distinctive odor
- Preys on larvae



## Tachnid flies

- Adult species are robust, dark and look like houseflies, except that tachnids have stout bristles at the tips of their abdomens
- Internal parasites of larvae - lay eggs inside of larvae



## Ten-spotted ladybird beetle

- Dome shape with distinctive color patterns
- Generalist predators that attack larvae

## Notes:

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## D. Biocontrol potential

When insecticides are used which do not adversely effect beneficial species, many microscopic parasitic wasps are able to survive.

These parasitic wasps feed extensively on aphid populations and it is possible for these natural enemies to control aphid populations. Broad spectrum insecticides will kill the parasitic wasp populations, but certain specific, targeted materials will not harm the wasps. To determine if natural enemies are attacking aphids, look for aphid mummies stuck to the leaf undersides. Parasitic wasps feeding on aphids result in the mummies. If a high number of aphid mummies are seen, insecticide applications may not be necessary.



Certain pathogens also have biocontrol potential. *Beauveria bassiana* is a naturally occurring fungi which can attack insect populations in the field. However, necessary protectant fungicide sprays usually limit its effectiveness in insect control. If you find Colorado potato beetles which are dead due to a fungal infection, this means that *B. bassiana* is present in the field and providing biological control.



## SPECIFIC PREDATORS OF THE CPB

Predatory stinkbugs are voracious and can kill a large number of Colorado potato beetle larvae and other pest species in a short time. However, they are rarely present in numbers great enough to be of much practical value.

The carabid beetle is an aggressive predator and can cause high levels of mortality in Colorado potato beetle eggs. Larvae of the beetle feed exclusively on Colorado potato beetle larvae. This beneficial insect is very sensitive to most insecticides commonly used in potato fields and therefore may be of little value in commercial fields.



Parasitic flies can cause up to 80% mortality in the prepupal stage of the Colorado potato beetle, especially in second generation pests. This beneficial insect is a strong flier and appears able to rapidly colonize new potato fields at the same time as Colorado potato beetle adults.

The ten-spotted ladybird beetle is a generalist predator. It can cause as much as 35% mortality in first-generation Colorado potato beetles larvae and up to 60% in the second generation larvae. Both larvae and adults ladybird beetles also feed on aphids. Adult ladybird beetles overwinter in undisturbed habitats around the edges of fields.

# Pest Management Decisions

Harvest



Pest management changes throughout the growing season. Late in the season, there is little economic benefit to be gained from controlling insects. It is essential, however, to maintain a proper disease management program until stems and leaves are completely dead.



Read the following statements in order and check all that apply. Refer to the corresponding sections on the following pages for more information.

- ☐ **A.** *The late blight fungus is controlled by utilizing protectant sprays until the potato vines are completely dead. Other diseases are monitored late in the season.*
- ☐ **B.** *Insect pests such as aphids and Colorado potato beetles are not controlled late in the season. NOTE FOR SEED POTATO PRODUCERS: aphids are controlled until vinekill.*
- ☐ **C.** *Cultural control strategies, such as a fall trap crop for Colorado potato beetle, are utilized.*
- ☐ **D.** *Fields are mapped to record the number of Colorado potato beetles entering overwintering sites. Other pest "hot spots" are mapped for future potato seasons.*

## A. Late Blight Control Measures

Vine killing prevents the spread of early and late blight fungal spores from foliage to tubers at harvest. After applying the desiccant, continue fungicide applications until the vines are completely dead. This minimizes the development of the late blight spores which can infect tubers during harvest and cause serious storage disease problems.



Maintain a preventative fungicide program until potato stems and leaves are completely dead. This includes treating any vine regrowth that may occur during warm periods after vinekill.

Tubers should be harvested only after the skins are well set (see the handbook's *Harvest/Environmental Conditions* section for more discussion of skin set). Handle tubers gently at all times during the harvesting process to avoid damage and abrasions. Any damage to the potato skin opens the tuber to infection by pathogens including late blight and bacterial soft rot.

## B. Late Season Insect Control Considerations

Late in the season, many insect pests found in the field at or above threshold levels may not need to be treated. Insecticide applications close to vinekill or harvest may not be beneficial because insect populations found in high numbers at vinekill will not severely limit yield. The vinekill operation immediately stops tuber bulking; therefore, insecticide applications may be an unnecessary expense.



Insects which may not need to be controlled include aphids, potato leafhoppers, and Colorado potato beetles. The potential damage done by these insects will not severely limit yields since the vine kill operation will kill living tissue anyway. For example, mature potato plants can withstand up to 30% defoliation without a yield loss, and the beetles can aid in the plant destruction process by feeding on green foliage and vines. Consider the following recommendations when determining late season insect control.

- In fresh market or processing potatoes, insecticides are not needed for leafhopper or aphid control anywhere from 2 weeks prior to vinekill. Control beetle populations only if heavy defoliation is found. There is no need to treat for beetles within 3 days of vinekill.
- For seed potato production, continue insecticide applications for aphid control until vinekill to prevent viral transmission. Stop insecticide applications for potato leafhoppers 1 week prior to vinekill. Control beetles only if significant defoliation is found. No application is needed within 3 days of vinekill.

White grubs can cause damage to the tubers and should be carefully monitored during harvest operations. White grubs are distinctive, C-shaped, fat white larvae, approximately ½ -1½ inches long, with brown heads and six prominent brown legs. The adult stages of white grubs are commonly known as June beetles. These are seen in the spring in Wisconsin, but do not damage potato plants.

In general, white grubs are only occasional pests in potatoes, and chemical control is rarely recommended. However, if white grubs are present in a field during harvest, keep accurate records and implement cultural control strategies to reduce populations in the next potato cropping season (see *Planting/Cultural Pest Management* section).





## C. Cultural Control Strategies

### INSECTS

Colorado potato beetles exit fields in the fall to enter overwintering sites. A fall trap crop should be used to attract adult beetles moving toward overwintering sites. Fall trap crops are strips of



non-vine killed potatoes. These sections can be in the middle of the field or along one of the field edges. Colorado potato beetles congregate in the area of living potato plants where the insects can be easily killed before they move to overwintering sites.

- Leave approximately 24 rows of non-vinekilled potatoes along the field's edge or as a single strip anywhere in the field.
- Manage late blight in the trap crop potatoes.
- Once the beetles have congregated into the trap crop area, control them chemically or physically.

Usually beetle feeding will be extensive and no further vine killing is needed. However, if the trap crop remains vigorous, apply a desiccant with the insecticide.

The use of flaming strategies and propane torches at the end of the season may also reduce any remaining Colorado potato beetles while also providing another method for vine desiccation.

### WEEDS

Continue late-season weed control measures to limit weed populations before seed formation increases the weed seed bank. Chemical or mechanical vine-killing procedures should be targeted to kill weeds along with potato vines.

After vine desiccant application, monitor weeds along with potato vines to see how the dying is

proceeding. Harvest operations are more difficult if green weeds or vines are moving with potatoes through the harvesting chains and equipment. Therefore, all weeds and vines should be dead before harvest begins.



## D. Development of Field Maps for Colorado potato beetle and other pest populations

Harvest is the ideal time to map pest populations within potato fields. Use the maps to determine rotational sequences, control measures, and bioIPM strategies for the following years.

Map Colorado potato beetle populations to record which field edges have the highest number of adult beetles entering the adjacent overwintering sites. Simply take a field map and mark beetle populations on a scale of high, medium, or low. Use the maps to more accurately predict where high beetle populations will be found the following spring. Use this information in an area-wide rotational strategy determining the following year's field locations and selecting management strategies for beetle control.

During harvest note other pest populations (specific weed species, wireworm or white grub populations, and disease concerns) that were seen in the field. Use the information gathered during harvest to plan rotational cropping systems and consider pesticide and cultural options to manage these pests during the non-potato cropping years.



## Notes:

[illegible]

# Environmental Conditions

## Harvest



Conditions during the harvest operations can have a great impact on potato storability as well as quality characteristics. Careful handling and optimum environmental conditions can reduce potato damage and the potential for storage problems.



Read the following statements in order and check all that apply. Refer to the corresponding sections on the following pages for more information.

- ☐ **A. Potatoes are harvested.**
- ☐ **B. Potatoes are harvested at the correct temperature and soil moisture.**
- ☐ **C. Tarps are used on trucks and wagons during transportation to prevent tuber heating, cooling or sun burning.**
- ☐ **D. Care is taken to limit bruising throughout harvest and transportation operations.**

## A. Harvest Considerations

Harvest is a busy time of year, yet proper harvesting decisions can prevent damage to the crop during the storage and handling process. Harvesting normally occurs after an efficient vinekill and once there is an assurance that the tubers have formed the proper skin set.

Killing potato vines before harvest aids in tuber maturation and skin set. Mature tubers with well set skin prevent tuber injuries which may lead to infection from bacteria and fungi. Vine killing should occur at least two weeks prior to harvest to allow proper skin set. Avoid vine killing during hot, dry periods because a rapid kill can cause stem end browning in tubers. To prevent the spread of early and late blight, continue fungicide applications after vine killing until no green tissue remains.



Proper vine kill will:

- Stop the spread of foliar disease
- Help to separate vines from tubers during harvest
- Protect the tuber from skinning and bruising
- Help to prevent infection by disease organisms

Skin setting is an essential part of controlling diseases and maintaining tuber viability and quality. Bruising and skin breaks may occur if tubers are harvested too soon after vine kill or the skin is not properly set. Damaged tubers are susceptible to infection by many disease pathogens including late



blight, early blight, bacterial soft rot, and *Pythium* leak.

For best skin setting:

- Vine kill at least 14 days prior to harvest.
- Make sure vines are completely dead prior to harvest.

Dig up a few hills to check for tuber size and skin setting before harvesting. The skin should not move when it is rubbed with a finger.

Harvest at 60-65% soil moisture levels and when tuber pulp temperatures are between 50-65°F. When soil moistures are too high or pulp temperatures are too low, skin set can be delayed.

### Skin Set Biology

The periderm is critical for protecting the tuber from storage diseases. The periderm is the specialized layer of cells that lies just under the tuber surface. It prevents the entrance of pathogens, regulates gas exchange and water loss, and protects against chemical damage.

The skin of the potato tuber is the phellem layer of the periderm. The phellem consists of a tough, brick shaped matrix of cells with no intercellular spaces. Cultivars vary in the number of layers and other phellem characteristics.

Tubers become more resistant to wounding as the phellem matures because it is bound more tightly to adjoining tuber tissue. This maturation process produces a sturdy skin set. Skin set cannot occur until the potato tuber stops bulking. Immature potatoes have a loose skin for tuber expansion and growth. As potatoes begin to senesce, the skin thickens and suberin is deposited inside the periderm, forming a much "tougher" skin.



## B. Temperature and Soil Moisture

Environmental conditions during harvest are critical for maintaining a quality product through the storage and marketing season. Do not harvest potatoes with any free water on the surface or with pulp temperatures above 70°F. High temperatures and free water promote infections by fungi and bacteria and can lead to large areas of decay in storage.

Harvest potatoes with a pulp temperature between 50-65° F. Potatoes harvested with pulp temperatures above 70° F are very susceptible to breakdown in storage. Potatoes harvested at temperatures below 50° are susceptible to shatter bruise.



Optimal conditions for harvest are when tuber pulp temperatures are between 50-65° F and when the soils contain 60-65% available soil water moisture levels.

Moisture content of the soil directly relates to moisture content of the potato. Maintain soil moisture 65-70% of available soil moisture (ASW). Soils wetter than 70% ASW carry large amounts of soil onto the harvester which may increase bruising and result in excessive soil being carried into storage. Wet soils may also increase lenticel size and predispose tubers to infections by fungi and bacteria. Dry soils will lead to dehydrated potatoes and an increase to blackspot bruising.

During harvest skip any areas that were infested with late blight to prevent infection of healthy tubers. Also skip low wet spots in the field as these areas may be predisposed to decay. Harvest these areas last and store them at the end of the building. If any decay does occur, these tubers are



more easily removed from storage to prevent further decay.

## C. Transportation Conditions

Sometimes potatoes are transported long distances from the field to storage which increases the risk of tuber damage. To avoid harmful temperatures during transport, trucks and wagons should be covered with a tarp.

On warm sunny days pulp temperatures can increase rapidly during transport which may lead to problems removing that heat in storage. Increasing pulp temperatures above 70° can lead to decay in the pile and problems later in the storage season.

Exposed tubers can also be sunburned in a short period of time. Sunburn interferes with wound healing in storage which may promote disease infection and decay. During cool weather, tubers become chilled which will increase susceptibility to bruise.



## D. Minimizing bruising during harvest

Maintaining a quality bruise free product starts with the harvester and continues through all equipment that comes in contact with the tubers. General guidelines for harvesting equipment are described below.

To prevent bruising, keep the amount of tubers and soil at capacity on all harvester chains and conveyers. Less material leads to excessive bouncing and bruising of the tubers as they roll along the chains. Overfilling chains leads to increased bruising from excessive rollback. As the yield

changes across a field, adjust the ground and chain speed to keep the harvester at capacity. When filling trucks or wagons, do not drop tubers more than six inches except when the steel is adequately padded.



The chain speed is equal to the chain length (in feet) divided by the time for one revolution (in seconds). To express the speed in miles per hour, multiply the number of feet per second by 0.68. Using this formula will help keep harvesting equipment at its appropriate capacity.

Inspect bulk trucks and repair or pad any rough or jagged areas. Equip the trucks with tarps or mechanical covers to protect potatoes from wind, rain, or sunburn during transport. Low temperatures may increase bruising. Sun exposure during transport may warm tubers excessively or cause sunburn.

Conveyors and pilers can contribute significantly to tuber bruising. As with all other equipment, repair or pad rough or jagged edges and limit any drops to six inches. The piler angle should not exceed 45° to prevent rollback of tubers. Use a stepped bin piling procedure to minimize rollback on the pile face.

## Bruising: Description and Conditions

**There are two types of tuber bruising.**

1) Blackspot bruise results in discolored areas about ¼ inch below the skin and is detectable only by peeling the potato. These internal bruises do not develop immediately. It takes from 6-8 hours for symptoms to occur and up to 24 hours for full development.

2) Shatter bruise can penetrate deeply into the tuber depending on the severity of the injury. The tuber tissue ruptures and discolored flesh forms on the edges of the damage.

**To minimize bruising, aim for the optimum handling conditions described below.**

- Maintain soil moisture at 65-70% available soil moisture to properly hydrate the tuber. Higher soil moistures result in more soil carried on the harvester and this can lead to increased shaking and bruising. Lower soil moisture dries out the tuber which may increase the tuber's bruise susceptibility.
- Tuber condition is important at harvest. Vines should be killed two weeks before harvest for proper skin set (three weeks may be required for certain varieties). Proper hydration of the tuber is important as well. Hydrated tubers are susceptible to shatter bruise but resistant to blackspot bruise. Dehydrated tubers are resistant to shatter bruise but susceptible to blackspot bruise.
- Ideal tuber temperature is about 60° F. For tubers dropped 6 inches bruising increases 1% for each degree of temperature drop below 60°. For example, a 10% increase in bruising will occur when the tuber temperature drops from 60° to 50° F.
- During harvest and transport all drops should be less than 6 inches unless steel is adequately padded. Keep maximum volume on all chains and conveyers to prevent tubers from bouncing and rolling.

# Storage Conditions

Post-harvest



The proper environmental conditions should be utilized to optimize potato storability



Read the following statements in order and check all that apply. Refer to the corresponding sections on the following pages for more information.

- ☐ **A.** *Conditions are monitored during the storage period.*
- ☐ **B.** *The crop is stored at the optimal temperatures and relative humidity levels during curing, storing and removal.*
- ☐ **C.** *Sprout inhibitors are appropriately applied to maintain tuber dormancy.*
- ☐ **D.** *Storage records are kept to document storage conditions, disease, quality and shrinkage.*

## A. Storage Conditions

Potatoes need to be stored in an environment that keeps their internal and external quality from deteriorating. Because tuber quality does not improve once potatoes are placed in storage, use optimum production and harvest practices to assure that high quality potatoes enter the storage phase.

Proper storage conditions for maintaining tubers will enhance their storability, maintain their quality, and will aid in the disease management during the storage period. Monitor temperatures, humidity, quality, and disease characteristics in each bin. Assess the bin's conditions to determine which tubers and which bins should be cleared out first due to various storage concerns.

## B. Temperature and Humidity

The potato tuber is a living organism that uses oxygen and gives off heat, moisture and carbon dioxide. Proper conditions are necessary to control respiration, water loss and sprout inhibition. Maintaining proper storage conditions is crucial in promoting tuber health and wound healing while preventing pressure bruise, disease and the accumulation of sugars. The storage operation is divided into three stages; curing, holding and removal. Optimum conditions for each stage are described below.

### Curing

Curing promotes suberization (healing of bruises, cuts and skinned surfaces) over a 2-4 week period immediately after harvest. Cure potatoes at 50-55°F and a relative humidity of 90-95%. Cure tubers that are stressed from disease at slightly lower



*Bacterial soft rot infected tubers*

temperatures and at 85% relative humidity. Maintain proper airflow during this period to provide the oxygen needed for wound healing. Avoid free water on the potato surface because this interferes with oxygen exchange and promotes the development of bacterial soft rot.

### Holding

Long term storage temperatures are based on the intended use of the potato as follows:

- Seed and table stocks – 38-40°F
- Frozen and dehydration stocks – 42-45°F
- Chip stock and potatoes stored 3 months or less - 50°F

Once the curing phase is completed, slowly lower the temperature 1° every 5-7 days to prevent accumulation of reducing sugars. Relative humidity should be maintained at 90-95% to minimize weight loss and pressure bruising.

Monitor temperatures at both the top and bottom of the pile. The top of the pile should be 1-3°F higher than the temperature at the bottom of the pile. If the temperatures are the same, too much air is moving through the pile.

Monitor relative humidity as well. A drop in outside temperature can cause condensation on the ceiling that then drips on the potatoes. This surface moisture increases the potential for tuber breakdown by soft rot bacteria.

Long term storage of potatoes requires using a sprout inhibitor. The current sprout inhibitors are applied either in the field (MH30) or in storage after curing has been completed (CIPC).



*Late blight infected tuber*



## Removal from Storage

As the tubers are being removed from storage, continue to monitor and manage conditions. Rough handling of tubers under unfavorable conditions can result in a high incidence of shatter bruise or internal blackspot. It may also cause potatoes to accumulate significant quantities of reducing sugars within a few hours, resulting in an unmarketable product. General guidelines are given below.

- Gradually raise pulp temperatures to 55 - 65°F over a period of two to three weeks. This is essential for reconditioning potatoes for quality chips and french fries. Warming also reduces the possibility of tuber injury. Cold potatoes are easily bruised. Use some fresh air to keep carbon dioxide levels low.
- Clean and sanitize all the handling equipment to prevent the spread of bacterial infections.
- Keep the dumping heights of hoppers and trucks to 6 inches or less.
- Maintain the flow of potatoes at capacity on all conveyors. Pad sharp and rough surfaces on all equipment.

## C. Sprout Inhibitors

Sprout development in storage significantly decreases tuber quality, accelerates water loss, and may make tubers unmarketable. If potatoes are going to be stored for long periods of time, a sprout inhibitor will be needed. The two commonly used sprout inhibitors are maleic hydrazide (MH) and chlorpropham (CIPC). MH is used during the season and translocates into the tubers. CIPC is applied in storage to control sprouting.

The chemical CIPC interferes with cell division so it should only be applied after all wound healing is complete. If applied before wounds are healed, excessive losses will occur from water loss and disease. CIPC is applied as an aerosol through the plenum into the air ducts and up through the pile. When CIPC is applied to storage, residues can remain up to a year after application. Do not store seed potatoes in treated buildings until the chemical residue is thoroughly cleaned from all surfaces including fans, ducts and plenum and the building is allowed to air out for at least six months.

### General Recommendations for CIPC Applications to Stored Potatoes

1. Only store potatoes for long-term storage in structures insulated to withstand outside temperature extremes.
2. Ensure all potatoes in the storage have had adequate time to heal by waiting 14 to 21 days (depending on the storage temperature and the potato variety) after the last potatoes are placed into storage before treating with CIPC.
3. Follow the commercial applicator's pretreatment storage preparation requirements.
4. CIPC should not be applied after potatoes have broken dormancy and started to sprout.
5. Do not store potato seed in a building treated with CIPC within the previous year until it is thoroughly cleaned, or in a structure near a storage that will be treated with CIPC.

## D. Storage Records

Maintain records of temperature, relative humidity and potato condition while storages are being loaded and throughout the storage process. This can aid in diagnosing storage related problems. Proper documentation of environmental conditions during the growing season can also help determine what field conditions or practices used on the field during the growing season may have led to storage problems.

When storages are initially being filled, record which fields and which field areas are being placed in specific storage areas. Lines on the walls and streamers from the ceiling work well to designate areas in the storage. As the storage is emptied, keep records on tuber quality. Keeping good records of temperatures, relative humidity and any problem areas will assist in correcting the problems during the non-storage months. If problems in storage can be traced to problems in the field, good storage and field records can be used to diagnose and correct the problem in future years.



Storage Research Facility, Hancock, WI

## Notes:

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# Pest Management Decisions

Post-harvest



An Integrated Pest Management program which utilizes cultural, biological, and mechanical methods should be used during the winter season to minimize pest population survival for the following season.



Read the following statements in order and check all that apply. Refer to the corresponding sections on the following pages for more information.

- ☐ **A.** *Potential late blight sources are eliminated.*
- ☐ **B.** *Cover crops are planted for weed and disease management and erosion control.*
- ☐ **C.** *Colorado potato beetle overwintering site management and winter mortality rates are considered as a pest management option.*
- ☐ **D.** *An IPM storage program is utilized whenever possible.*

## A. Late Blight Sources

During harvest, storage, and removal from storage, waste potatoes and cull piles can accumulate and become potential sources of the late blight infection. Proper removal and disposal of these tubers should occur as soon as possible. Winter disposal can help eliminate late blight sources since the fungus does not survive the harsh, cold temperatures of severe Wisconsin winters.

To properly dispose of waste and culled potatoes, spread them sparingly during the winter months on the surface of fields not intended for potatoes the following spring. Spread potatoes so they are exposed to several cycles of freezing and thawing throughout the winter months. Tubers exposed to temperatures below 28°F, even briefly, are killed. However, at temperatures above 30°F, tubers will survive. Do not till tubers into the ground in late fall or early winter months since burying protects them from the freezing process.



Culled potatoes and waste potato products may be fed to livestock during the winter months as long as the tubers are completely consumed. Do not apply the livestock manure to fields where potatoes may be grown since the manure can contain late blight spores and the scab organism.

## B. Cover Crop Considerations

Cover crops or other green manures (rye, wheat, barley, oats, forage grasses) should be planted soon after the harvesting operations so that the crops have enough time to establish themselves before the winter begins. Cover crops provide many benefits including improving crop and soil productivity, reducing disease potential, adding organic matter, reducing soil erosion, and providing a competitive weed control strategy.

To provide soil cover during the winter, a cover crop is usually planted within one week after harvesting in late summer or fall. In Wisconsin, the crop selected needs to possess enough cold tolerance to survive hard winters. Rye is one of the few selections that meet this requirement. The cover crop can be established by aerial seeding into maturing cash crops in the fall, or by drilling or broadcasting seed immediately following harvest.



Winter-annual legumes established in the fall usually produce most of their biomass in the springtime. In many regions, winter-annual legumes must be planted earlier than cereal crops in order to survive the winter.

## C. Colorado Potato Beetle Overwintering Mortality

Winter mortality of adult, overwintering beetles can be enhanced by habitat disruption. These practices kill beetles by decreasing the soil temperature where the Colorado potato

beetles are overwintering. The adult beetles overwinter in underground sites adjacent to field edges. If temperatures in these overwintering areas are reduced to 23°F at the depths that beetles are overwintering (about 6-8 inches), the adults will die, reducing the emerging spring populations.



Habitat disruption will be most successful during



the coldest period of the year, typically during January. Remember that snow and mulch remaining on the soil surface keep the soil temperatures around 32°C, which suits beetle survival. Removing the snow and mulch when the temperature is 23°F or colder can decrease the soil temperatures and may allow temperatures at the beetles' depth to be cold enough to cause death.

## D. IPM Storage Program

IPM strategies, especially for disease management, should continue until potatoes are sold and off the farm. Implementation of IPM strategies in storage will greatly aid in storage disease management. To maintain healthy tubers in storage;

1. Inspect, repair, and sanitize the storage facility and storage equipment before putting potatoes in storage.
2. Properly dispose of waste potatoes. Do not put cull piles near the storage facility.
3. Ensure bruise free potatoes by not dropping potatoes from heights of more than 6 inches. Install padding on all potential bruise sites and maintain padding through harvest and storage operations.
4. Remove as much mulch, soil, and debris as possible during loading of storage bins.
6. Isolate damaged or diseased lots in separate bins for immediate grading, marketing or processing.
7. Monitor carbon dioxide levels in storage. Carbon dioxide buildup slows healing, favors bacterial soft rot, and in the most severe cases, causes blackheart.



## Cover Crops

Cover crops may be a non-legume, a legume, or a combination grown together. Most of the commonly used non-legume cover crops are grasses. These include:

- Annual cereals (rye, wheat, barley, oats)
- Annual or perennial forage grasses such as ryegrass
- Warm-season grasses like sorghum-sudangrass

Commonly used legume cover crops include:

- Winter annuals, such as crimson clover, hairy vetch, field peas, subterranean clover and many others
- Perennials like red clover, white clover and some medics
- Biennials such as sweetclover
- Summer annuals (in colder climates, the winter annuals are often grown in the summer)

Growers should determine which cover crop works best in their production system. To find a suitable cover crop or mix of covers, consider these steps:

- Clarify the primary needs of the potato system.
- Identify the best time and place for a cover crop in the system.
- Test a few options.
- Determine the cost of cover crops and economics of the system, but also estimate the cost benefit they may provide (such as reduced disease management costs).

## Notes:

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# Personal Recuperation Practices

Post-harvest



Revitalization of the mind and relaxation techniques should be part of your whole farm strategy. This will allow one to be in the right frame of mind to begin the next cropping season.



Read the following statements in order and check all that apply. Refer to the corresponding sections on the following pages for more information.

- ☐ **A.** *Stay in Wisconsin and enjoy the Packers and Badgers.*
- ☐ **B.** *Enjoy the Packers and Badgers while traveling to an exotic location to see the sights.*
- ☐ **C.** *Enjoy the Packers and Badgers while traveling to an exotic location to see the sights and enjoy a beverage or two while planning a fishing trip.*
- ☐ **D.** *Enjoy the Packers and Badgers while traveling to an exotic location to see the sights and enjoy a beverage or two while planning a fishing trip. Begin to strategize about your biointensive IPM plans for the next growing season.*

## A. Sports Therapy

We all love the Badgers and the Packers. Have a nice beverage or two while watching.



## B. Sports Therapy with Environmental Considerations

A nice trip to a warm location during the cold months is great for mental recuperation.



## C. Sports Therapy with Environmental Considerations and Proper Hydration

An ice fishing adventure, or a deep sea fishing trip may result in a new wall decoration if you are particularly skilled at it.



## D. Sports Therapy with Environmental Considerations, Proper Hydration and Biointensive IPM.

Remember that during the winter months exchanging or seeking ideas about how to run your upcoming potato season can result in a more biologically based production system. In a bioIPM production system, a year round integrated strategy, with various cultural, biological, mechanical, ecological, and chemical strategies, needs to be utilized during each time of the production season which lasts the entire year, not just the few months of the growing season. The winter months are the time for educational meetings and learning opportunities, so attend the various educational functions and contact the University specialists for more information on developing your bioIPM programs.



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# Insect Pest Profiles

## Armyworm

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**Scientific Name:** *Pseudaletia unipunctata*

**Order:** Lepidoptera

**Family:** Noctuidae

### General Information

#### Biological Description:

The armyworm is generally not a problem on vegetable crops; it prefers grasses and grains. However, grass weeds in potato fields will attract moths. Outbreaks are more severe following cold, wet, spring weather. The sand colored moths have a wing span of 1.5" with definitive white dots in the center of each forewing and dark markings on the hind wings. The brownish green larvae are hairless, have alternate dark and light stripes down their backs and are about 2" long when fully grown. The head is pale brown with dark markings. Pupae are dark brown and approximately 3/4 inch in length. They are sharply tapered at the tail end with a much more rounded head end. The greenish white eggs are laid in rows or clusters on leaves. Moths often seem to congregate in certain locations. Armyworms often are confused with the variegated cutworm and other related species.

#### Economic Importance:

Damage is sporadic and dependent on heavy flights of southern moths reaching Wisconsin.

#### Life Cycle:

It is not known if the armyworm overwinters in Wisconsin. The moths usually appear in late April and early May. Most of the early season moths are immigrants from southern states. Once they arrive, they immediately mate. Eggs are laid in the evening and at night and eggs are laid in rows or clumps of many eggs. Grasses and small grains are the preferred host

and blades are often folded and sealed to protect the eggs. One week to 10 days after the eggs are laid, the larvae emerge and begin to feed. After feeding for 3-4 weeks, the full-grown larvae pupate for an additional 2 weeks and emerge as adults. There are 3 generations per season, with each generation lasting 5-6 weeks. The first generation is small and does little damage, however the success of this generation produces later, more injurious, generations of armyworms. The second larval generation, which appears in July, is the largest and most damaging generation to Wisconsin crops. The fall generation is typically not injurious and is often heavily parasitized by beneficial insects, fungi and viruses.

#### Host Range:

Armyworms attack all grasses, particularly wheat, oats, corn barley and rye and some legumes; but when under stress armyworms will attack neighboring vegetable crops and seedling alfalfa. Additionally, the presence of grass weeds in vegetable fields will attract moths for egg laying.

#### Environmental Factors:

Cold, wet spring weather precipitates armyworm outbreaks.

#### Damage/Symptoms:

Larvae tend to feed at night or on cloudy days and hide in the soil or under foliage during the day. There are two types of infestations that can occur in sweet corn. Infestations may occur throughout a corn field in July if grassy weeds such as foxtail, quackgrass, goosegrass, and nutsedge are present for oviposition in the field. In this case, plants in scattered areas of the field will have ragged leaves from larval feeding. The other type of infestation results when armyworms migrate from pastures, oats, or grassy pea or alfalfa fields, to destroy the outside rows of corn. Damage is usually highest along the field edge or in grassy spots.

#### Scouting Procedure and ET:

Timely detection is critical if post emergent insecticidal treatment is to be effective. If you find signs of armyworm feeding, check 5 sets of 20 plants at random. Record the number of damaged plants and the number of worms per plant. Repeat in several locations within the field since infestations may be restricted to certain areas. Damage usually begins along field edges and moves inward as the insects migrate. Treatment is suggested if worms are ¾ inch long or less, and two or more worms per plant can be found on 25% of the stand; or if one worm per plant can be found on 75% of the stand. Spot treat when possible. When armyworms migrate from adjoining areas, treat only border rows.

## Integrated Control

### Non-Chemical Control:

**Natural Control:** A number of braconid wasps and tachinid flies help keep armyworm numbers down, as do birds, toads, skunks and some domestic fowl. Armyworms are only problematic in grassy areas.

**Cultural Control:** Since female moths prefer to lay eggs in grassy areas, keeping grassy weeds controlled will lessen the possibility of problems. Avoid planting susceptible crops in low wet areas or in rotations following sod. If this is unavoidable, be sure to plow in the fall of the previous season to decrease early spring egg-laying sites. Killing grass with a herbicide or tillage may drive armyworms to the susceptible vegetables.

**Biological Control:** Several natural enemies exist which may keep armyworm populations low. The red-tailed tachinid fly (*Winthemia quadripustulata*) is one such biocontrol agent. It lays its eggs on the armyworm's back and the tachinid larvae bore into larval armyworms to feed. In addition, several ground beetles and parasitic hymenoptera prey upon the armyworm. There is also an egg parasite (*Telenomus minimus*) that is effective in preventing egg hatch and subsequent larval feeding damage.

### Chemical Control:

Carbaryl, esfenvalerate, and methomyl are foliar treatments which are labeled for the control of armyworms. Refer to the product label for more information on specific application instructions and precautions.

Insecticide Resistance: None.

### References:

R. H. Davidson and W. F. Lyon (1987) *Insect Pests* 8th Ed. of Farm, Garden, and Home. John Wiley & Sons, New York 640 pp.  
C. L. Metcalf and R L. Metcalf (1993) *Destructive and Useful Insects, Their Habits and Control* 5th Ed. McGraw Hill Book Co., New York.

## Aster Leafhopper



**Scientific Name:** *Macrostelus fascifrons*

**Order:** Homoptera

**Family:** Cicadellidae

## General Information

### Biological Description

The adult aster leafhopper is olive-green, wedge-shaped, and about 4 mm in length. They have three pair of spots on the vertex of their head. Nymphs are similar in shape to the adults, but are cream-colored and lack fully developed wings. Adults are extremely active and jump, fly, or crawl sideways or backwards when disturbed. Nymphs are less active but crawl rapidly, often seeking to regain the lower leaf surface when dislodged.

### Economic Importance

The aster leafhopper is an occasional pest of potatoes because of its ability to transmit the mycoplasma-like organism (MLO) that causes aster yellows. On potatoes, this disease is called purple top.

### Life Cycle

The first aster leafhoppers that appear in May and June do not overwinter in Wisconsin. This insect overwinters in the Gulf states and migrates northward each spring on warm, southerly winds. The first migrants are primarily female. Large influxes may occur in June and early July as local populations develop. Eggs are laid under the epidermis of leaves of susceptible hosts. The leafhoppers progress through five nymphal instars and require 20-30 days for development. There are normally two to five generations per year.

### Host Range

Both the aster leafhopper and the aster yellows disease have broad host ranges of over 200 plant species in many different families. The leafhopper prefers lettuce and small grains for feeding and breeding, while other crops such as potatoes, tomatoes, and onions provide a temporary source of food and refuge. These temporary sites are utilized only by the adults as the nymphs fail to develop on these plants.

### Damage/Symptoms

Leafhopper feeding alone does little damage to the plant. However, it is the transmission of the aster yellows pathogen that causes problems. Newly sprouted potatoes are the most susceptible stage; mature plants are almost totally resistant to aster yellows. If young plants do become infected, symptoms may not be expressed for 30 days or more. General aster yellows symptoms on potatoes include yellowing and reddening of mature foliage, and aerial tuber formation. Infected plants are generally stunted and have small tubers. Infected tubers which are processed, will result in a dark-colored product. An infective leafhopper transmits the pathogen to a plant during its feeding activity. The pathogen is carried in the insect's saliva and is transmitted to the phloem vessels when the leafhopper feeds on plant sap. On average, the leafhopper must probe and feed on a host for eight hours before the pathogen is transmitted. The aster yellows MLO can multiply in both the plant and in the insect vector. The pathogen must



multiply in the vector for at least three weeks before it is passed into the salivary glands and is able to be transmitted. After the incubation period, the leafhopper is infective for the remainder of its life.

## Scouting Procedure/ET

Begin scouting for aster leafhoppers early in the spring when plants are newly sprouted. Scout for adult aster leafhoppers by taking 25 sweeps per sample site with an insect sweep net. Sample at least five sites per 30 acres and add one sample site for each additional 20 acres. The need for treatment is determined by an index which is based on the number of leafhoppers per 100 sweeps times the percent infectivity of the migrant population. Treat potatoes at an index of 200. For example: if the percent of infectivity is 1%, treatment would be necessary at 200 leafhoppers per 100 sweeps. The percent of infectivity is available from the UW Extension.

## Integrated Control

### Non-Chemical Control

**Natural Control:** There are no effective natural controls for aster leafhoppers, although there will be fewer migrants in the absence of southerly winds in May.

**Cultural Control:** Elimination of infective weed reservoirs can reduce the spread of aster yellows to vegetable crops. Compared with other vegetables such as carrots and lettuce, potatoes are quite resistant to aster yellows.

**Biological Control:** There are no effective biological control agents to use to reduce aster leafhopper populations.

### Chemical Control

**Commercial:** Current pest management for aster leafhoppers on potatoes calls for insecticide treatment when populations exceed the economic threshold level or index of 200. If systemic insecticide was used, no further treatment should be necessary. If foliar treatments are required, the highest recommended labeled rate is suggested to achieve control. Asana, Lannate, Monitor, Ambush, and Pounce are registered for control of aster leafhoppers on potatoes. Refer to the product label for specific application instructions and precautions.

**Homeowner:** Sevin will effectively control aster leafhoppers in small gardens. In areas where leafhoppers and aster yellows are routinely a problem, increasing the size of the crop to account for crop loss to disease may be useful.

**Insecticide Resistance:** None.

## References:

- C.L. Metcalf and R. L. Metcalf (1993) Destructive and Useful Insects, Their Habits and Control. 5th Ed. McGraw-Hill Book Co., New York.
- R.E. Foster and B. R. Flood ed. (1994) Midwest Vegetable Insect Management. Purdue University Agricultural Experiment Station. West Lafayette, IA.
- L.N. Chiykowski and R. K. Chapman. 1965. Migration of the Six-spotted

Leafhopper in Central North America. Research Bulletin 261, University of Wisconsin - Madison.

# Cabbage Looper



**Scientific Name:** *Trichoplusia ni*

**Order:** Lepidoptera

**Family:** Noctuidae

## General Information

### Biological Description

The cabbage looper adult is a grayish-brown, night-flying moth with a wing span of 1.5". The mottled brown forewings are marked near the middle with a small silver-white figure-8 or letter-Y. Hind wings are uniformly brown. The caterpillar (larva), is called a looper because of the way it arches its body while moving. Mature larvae are up to 1 1/2 inches long, have a greenish body which tapers at the head end with a thin white line along each side, two longitudinal white lines on the middle of the back. There are three pair of prolegs at the distal end of the abdomen. Eggs are small, round and white in color and laid singly under the leaves near the edge. Pupae, which are enclosed in a loosely woven silken covering, are brown and 1/2-3/4 inches long.

### Life Cycle

Cabbage loopers probably do not overwinter in large numbers in Wisconsin, but migrate in from the south mid-July through September. Overwintering pupae give rise to the first generation adults in spring. White eggs are laid singly on the lower leaf surfaces in June. Larvae mature through 5 successively larger instars over the next 4-5 weeks before leaving the plant to pupate. Adults emerge in 10-14 days, mate, and lay eggs which give rise to the second generation. Second generation cabbage loopers cause the most damage in

August and September.

### Host Range

Host plants include beets, cole crops, celery, lettuce, mint, peas, potato, spinach and tomato.

### Damage/Symptoms

Larvae feed high on the plant and are usually easily seen. They chew large holes in the foliage, but are rarely present in damaging numbers in potatoes. Most damage is caused by the second generation of larvae in August.

### Scouting Procedure/ET

Shake the foliage of five foot sections of two adjacent rows into the furrow and count the larvae on the soil surface. Divide the number of larvae counted by five. The resulting number is the number of worms per row foot. Sample at least five sites per 30 acres and add one additional sample site for each additional 20 acres.

Prior to July 25: Control measures are recommended if the cutworm and looper counts exceed four per row foot as a field average.

After July 25: Control measures are recommended if the cutworm and looper counts exceed eight per row foot as a field average.

### Integrated Control

#### Non-Chemical Control

**Natural Control:** Natural controls are frequently quite effective in holding looper populations down. An egg parasite (trichogramma), several larval parasites and an egg-larval-pupal parasite (copidosoma) may become numerous. Several general predators attack the egg and larval stages. An NPV wilt disease kills most of the looper population in late summer.

**Cultural Control:** Spring plowing of debris and clean culture are good insurance against potentially overwintering cabbage looper pupae.

**Biological Control:** There are no commercially available biological control agents which are cost effective to use to reduce looper populations.

#### Chemical Control

**Commercial:** Current pest management recommendations for loopers and cutworms calls for insecticide treatments when populations exceed threshold levels. Spot treatments can be effective when "hot spots" exhibit high numbers and yet the field average remains below threshold. Insecticides registered for control of loopers include endosulfan, esfenvalerate, permethrin, methomyl, methamidophos. Refer to the product label for specific application instructions and precautions.

**Homeowner:** Chemical treatment is seldom necessary. Handpick larvae or treat with *Bacillus thuringiensis* if necessary to reduce the impact on beneficial insects.

**Insecticide Resistance:** None.

### References

R. H. Davidson and W. F. Lyon (1987) Insect Pests 8th Ed. of Farm, Garden, and Home. John Wiley & Sons, New York 640 pp.

C. L. Metcalf and R. L. Metcalf (1993) Destructive and Useful Insects, their Habits and Control 5th Ed. McGraw-Hill Book Co., New York.

## Colorado Potato Beetle



**Scientific Name:** *Leptinotarsa decemlineata*

**Order:** Coleoptera

**Family:** Chrysomelidae

### General Information

#### Biological Description

Adult Colorado Potato beetles are hard-shelled, broad (3/8 by 1/4 inch), convex, yellow beetles with 10 black longitudinal lines on the wing covers, and black spots behind the head. The larvae are fat, red-orange, hump-backed, worm-like insects with black legs and head, and black spots along the sides of body. Eggs are bright yellow and laid in clusters on the underside of foliage.

#### Economic Importance

If left unchecked, feeding activity of the Colorado potato beetle larvae and adults can completely defoliate potato plants, resulting in reduced tuber size or plant death.

#### Life Cycle

Colorado potato beetles overwinter as adults in the soil 2-8 inches deep, often at field margins. Adults become active in the spring, about the time the first shoots of early season potatoes or volunteer plants appear. Females will lay up to 500 bright yellow eggs in clusters of 15-25 on the lower leaf surfaces before dying. Eggs hatch in 4-9 days and larvae

begin feeding immediately. After passing through four instars over the course 2-3 weeks, larvae return to the soil to pupate. Within 10-14 days, adult beetles emerge. There are 2 generations/year in most of Wisconsin.

### Host Range

Potato is the preferred host but beetles also feed on eggplant. Weeds such as nightshade, groundcherry, jimsonweed, horsenettle, and mullein can also serve as hosts.

### Environmental Factors

Cool weather tends to slow insect activity and development thereby reducing the amount of damage that occurs. Conversely, warm spring weather may accelerate insect growth so that a complete second generation will develop before the end of the season.

### Damage/Symptoms:

Both adults and larvae are voracious leaf feeders. Large holes, larger than 1/8 inch in diameter, are chewed into potato leaves. Often, entire leaves on the terminal parts of plant are consumed. Larvae typically feed in groups and may completely defoliate plants. The late larval instars do the most feeding damage. Heavy defoliation will severely affect plant yields, particularly if it occurs when potatoes are in the flower stage.

### Scouting Procedure/ET

Egg Masses Start scouting for bright yellow egg clusters in early May by examining the lower surfaces of all leaves on a plant. Sample five consecutive plants per sample site.

Sample at least five sites per 30 acres and add one sample site for each additional 20 acres.

Overwintered Adults Overwintered adults are normally found on newly emerging plants in May and are frequently concentrated on field edges close to overwintering sites. Due to low average temperatures in May, overwintered adults normally do not feed enough to cause severe defoliation. Chemical treatments are also ineffective at this time because of the continued beetle migration into fields and the rapidly growing potato foliage. Sprays should be avoided at this time. If temperatures are high, feeding will increase and a treatment should be made to reduce beetle numbers if defoliation exceeds 20-30% on infested plants. Spot treatments are very effective in controlling overwintering or migrating adults.

First Generation Larvae First instar larvae are small, blackish-brown and frequently congregate on expanding terminal foliage where feeding damage is inconsequential. Second instar larvae begin to assume the more typical brown-red larval coloring, and although feeding damage on terminal growth is more evident, damage from second instars will not be severe enough to require treatment. Third and fourth instar larvae are reddish-brown and foliage consumption increases

rapidly as larvae enter the third instar. Accurate counts of small larvae are difficult to obtain due to the clustering of larvae in expanding terminal foliage and a count of the proportion of infested plants (those with 10 larvae/plant or more) per sample unit is a more accurate measure of infestation. Treatments should be delayed whenever possible until larvae reach the third instar to allow as many eggs as possible to hatch and still avoid potential damage by third instar larvae.

Degree day accumulation can be used to accurately predict the occurrence of third instar larvae. A base temperature of 52°F is used and accumulation is begun when the first egg mass is found in the field. Begin scouting for egg masses in May. Degree day accumulations for Colorado Potato Beetles are as follows:

Life Stage	DD <sub>50</sub>	Cumulative DD <sub>50</sub>
Egg	120	120
First Instar	65	185
Second Instar	55	240
Third Instar	60	300
Fourth Instar	100	400
Pupae	275	675

When 240-250 DD<sub>50</sub> have accumulated from the first egg deposition, the first larvae will be entering the third instar stage and the bulk of larvae will be in the second instar. A treatment should be applied at this time if larval infestation is greater than 2 infested plants/25 on a field average. Since larvae are normally clustered near field edges, spot treatments are very effective and should be used to control Colorado Potato Beetles in high infestation areas even though field averages may be lower than the threshold.

Fields should be scouted regularly during egg laying and if egg-laying is prolonged, a second insecticide application should be made 100-150 DD<sub>50</sub> after the first to control larvae which were in the egg stage when the first application was made.

Selection of sample sites should depend on the infestation pattern. Full coverage of the fields is necessary to ensure that overall infestation patterns are identified, but since infestations are frequently clumped near field edges, sampling may be concentrated in these areas to allow spot spraying recommendations to be made. Plant samples of 25 consecutive plants should be used in egg, larvae, and adult samples. Larvae and adults can be counted visually but to accurately determine egg numbers, leaves must be overturned.

### Second Generation Adults

Second generation adults normally appear in mid-July and may cause severe defoliation. When temperatures are above normal in June and July, second generation adults may produce a second generation of larvae. Under normal conditions, these adults produce only a partial second

generation and then seek overwintering sites. Defoliation pressure from second generation Colorado Potato Beetle adults is estimated from counts of adults on plants in each of the sampling areas. Count the number of Colorado Potato Beetle adults on a total of 25 plants in each sampling location in the field. Divide the total number of insects by 25 to determine the average number of adult beetles per plant. If the average exceeds 3 beetles per plant, control measures are recommended.

## Integrated Control

### Non-Chemical Control

**Natural Control:** A number of predaceous bugs, two species of parasitic tachinid flies, and some birds may reduce populations of Colorado Potato beetle however, none of these are particularly effective.

**Cultural Control:** Colorado potato beetles have limited host ranges and thus crop rotations which avoid solanaceous plants, in conjunction with the removal of alternate host weeds, will reduce populations effectively. Trap crops consisting of strips of early-planted potatoes on field edges next to overwintering sites may be used to concentrate beetles for physical control. Propane flamers and vacuum suction have been used for beetle removal. Plastic-lined trenches located between fields and overwintering sites have also been effective.

**Biological Control:** There are no commercially available biological control agents which are cost effective to use to reduce populations of the Colorado potato beetle

### Chemical Control

**Commercial:** Systemic recommendations for the control of Colorado potato beetles fall into one of three options:

Option 1 Thimet/Phorate applied at 2 lb ai/A at the time of plant emergence on irrigated crops or in the furrow at planting on dry land. This rate may be increased to 3 lbs ai/A on heavy soils. Do not use on muck soils. Thimet/Phorate will only provide early season control.

Option 2 Disyston applied at 3 lbs ai/A at planting or plant emergence on irrigated crops or in the furrow at planting on dry land. Do not use on muck soils. Only provides suppression of the Colorado potato beetle so the crop should be scouted regularly and a foliar spray program initiated when needed.

Option 3 Admire applied in the furrow at 0.2 to 0.3 lbs ai/A will provide virtually season long control. A 12 month plantback restriction prevents planting crops other than potatoes for 12 months following application.

Foliar sprays are generally the most effective means of controlling the Colorado potato beetle and can be used alone or in combination with systemic insecticides. Two considerations are critical when planning a spray program: 1) Avoidance of insecticide resistance - Resistance is a very serious threat to continued effective Colorado potato beetle control.

Wisconsin populations are still susceptible to a wide range of insecticides, but repeated use of any one material can rapidly lead to loss of efficacy. 2) Timing of applications - Application timing allows growers to accurately target needed sprays against only vulnerable life stages. This strategy keeps sprays to a minimum and avoid excessive selection of resistant beetles.

The most vulnerable life stages of the Colorado potato beetle are the larval instars resulting from eggs laid by overwintered adults. These stages normally occur during June with maximum damage caused by fourth instar larvae in late June. Degree day accumulations can be used to predict development of larvae. Foliar sprays should be timed as follows:

Overwintered adults which are continually moving onto the emerging crop in May are hard to control on small, rapidly growing plants. Defoliation is limited by cool temperatures and plants are tolerant at this stage. Controls should only be attempted if defoliation approaches 20-30%. Infestations are often limited to the field edges of "hot spots" and spot treatments should be used when feasible. If a spray is needed, an organophosphate, carbamate, or organochlorine should be used in preference to pyrethroids which should be reserved for the main larval control spray. Eggs are not susceptible to chemical control. Larval instars are the most easily controlled stages. Of the four instars, 1st and 2nd instars do very little damage and growers should delay larval sprays until 3rd instar larvae are present. Delaying the main larval spray until this point will allow as many eggs as possible to hatch into susceptible larvae and at the same time, avoid the damaging 4th instar where most larval feeding occurs. Consult defoliation thresholds to make sure damage does not surpass the threshold while larval treatment is delayed. If thresholds are approached, an earlier spray should be considered. Larval sprays must be applied before the 4th instar leaves the plant and enters the soil to pupate. Pyrethroid insecticides should be used for the main larval control sprays.

If egg-laying continues after the main larval spray is applied, it may be necessary to apply a late larval spray about 150-200 DD after the main spray. An organophosphate, organochlorine, or biological insecticide should be used for this spray. An additional strategy to control larvae and avoid resistance is to incorporate a biological insecticide early into the program. These bacterial insecticides are only effective against first and second instar larvae and thus they should be utilized as an early spray at 150 DD or as a late spray applied 150 DD after the first pyrethroid application. Bacterial insecticides have short persistence (1-2 days) and should be applied weekly for 2-3 applications if used alone.

Pupae reside in the soil and are not susceptible to chemical control.

Second Generation Adults which emerge in July are mobile and can cause serious damage when potatoes are still susceptible (at flowering). Use adult sprays at defoliation thresholds and consult scouting reports for other insect



control needs.

#### Defoliation Thresholds

Varying levels of defoliation due to Colorado potato beetle feeding can be tolerated by potato plants without yield loss depending on the plant growth stage:

When plants are 6-8 inches (preflowering),  
treat at 20-30% defoliation.

If plants are flowering, treat at 5-10% defoliation.

If plants are mature, treat at 30% defoliation.

Chemical classes should be alternated. The following insecticides have demonstrated good efficacy in UW trials: pyrethroids - Asana, Ambush, Pounce; organophosphates - Guthion, Imidan; organochlorines - Thiodan; carbamates - Furadan; nicotinyls - imidacloprid (Provado); biologicals - Foil, Mtrak, Novodor; others - Cryolite, Kryocide. Pyrethroid synergists (piperonyl-butoxide; Butacide) may increase pyrethroid efficacy. If the population of second generation adults is large, and a significant amount of egg-laying occurs, it may be necessary to treat for second generation larvae. For specific foliar insecticide recommendations, consult UWEX publication A3422 "Commercial Vegetable Production in Wisconsin". Refer to the product label for specific application instructions and precautions.

**Homeowner:** Treat with carbaryl when larval populations exceed 1/plant in mid-season. Larvae and adults are large and easily identified and may be hand picked or removed with a net in small plantings.

**Insecticide Resistance:** Colorado potato beetles exist which are resistant to every class of insecticide currently registered for control.

#### **Life Cycle:**

The European corn borer overwinters as mature 5th instar larvae in corn stalks and stems of weedy hosts. Spring development begins when temperatures exceed 50 degrees F. Pupation occurs in spring with the first moths emerging shortly thereafter. Peak emergence occurs at 600 degree days (base 50). Adult moths are nocturnal and spend most of their daylight hours in sheltered areas along field edges. Female moths lay egg masses in the evening. The eggs hatch in 3-7 days depending on the temperatures and young larvae feed on leaves and in the midrib of the leaves for 5-7 days (125 DD<sub>50</sub>) before boring into stems. Boring usually begins with the second and third instars. The larvae pass through five instars and complete their feeding and development while boring inside stems. The earliest larvae to mature embark upon a 12 day pupal period within the stalk after which time the adult moths emerge. This begins the second generation. In northern areas, late-maturing larvae may go into diapause (a pause in development) and overwinter. Second generation moths peak in mid-summer when approximately 1700 DD<sub>50</sub> have been reached and may lay eggs in potatoes or other crops. All mature 2nd generation larvae enter diapause in northern states and overwinter. In

## References

- C.L. Metcalf & R.L. Metcalf (1993) Destructive and Useful Insects, Their Habits and Control 5th Ed. McGraw-Hill Book Co., New York.
- S. E. Rice Mahr, J. A. Wyman, E. B. Radcliffe, C. Hoy and D. W. Ragsdale. 1995. Potato: Chapter 5 in Midwest Vegetable Insect Management. R. Foster and B. Flood, Eds.

## European Corn Borer



**Scientific Name:** *Ostrinia nubilalis*

**Order:** Lepidoptera

**Family:** Pyralidae

### General Information

#### **Biological Description:**

Eggs are white, overlap like fish scales, and are deposited on the lower leaf surface of leaves and near the midvein. There can be as many as 30-40 eggs in each mass. As they develop, the eggs change to a creamy color. Just before hatching, the black heads of the larvae become visible inside each egg. This is referred to as the black-head stage and each egg reaching this stage usually hatches within 24 hours. Full grown larvae are 3/4-1 inch in length and grey to cream-colored with numerous dark spots covering the body. The pupae are brown, 3/4 inch long and cigar-shaped with segmentation evident on one-half of the body. The adults are nocturnal, straw-colored moths with a 1 inch wing span. Males are slightly smaller and distinctly darker than females.

#### **Economic Importance:**

The European Corn Borer is a sporadic pest of potatoes and is generally more severe in southern states. In years when the first generation of the European corn borer adults occurs early, the preferred egg-laying sites in corn are not yet available and oviposition can be heavy in potatoes. Certain varieties are more susceptible to damage with Norgold, Norchip, and Norkota varieties being most affected.

seasons with unusually warm spring and summer temperatures, some of the second generation larvae will pupate, emerge as moths and lay eggs for a late-season, third generation of larvae. These larvae do not have a chance to become fully grown before cold weather arrives and ultimately will perish. In southern states, three generations may occur.

### European Corn Borer Development (DD base 50)

<u>First Generation</u>	<u>Accumulated DD</u>
First moth	375
First eggs	450
Peak moth flight	600
Larvae present	800-1000

### Host Range:

Corn borers attack over 200 different kinds of plants including corn, vegetables, field crops, flowers and some common weeds. Serious damage may occur on sweet corn, peppers, snap beans and potatoes.

### Environmental Factors:

Cool weather and drought delay spring insect development due to the desiccation of eggs and young larvae. Conversely, warm weather and moisture may accelerate insect development. Excessive heat and drought in spring may cause increased mortality of all stages. The number of eggs laid is affected by the availability of drinking water of which, dew is considered an important source. Heavy rainfall will decrease moth activity and drown newly-hatched larvae in whorls and leaf axils, or even wash them from the plant.

### Damage/Symptoms:

When the European corn borer attacks potatoes, larvae can feed on foliage as well as inside stems. Larval feeding on the lower leaf surface results in small feeding scars when all of the leaf tissue except the transparent upper epidermis is eaten. Stems which sustain boring damage show an entry hole, 1/8 inch in diameter, typically surrounded by frass. Above the entry hole the stem may be wilted and the leaves flagged. Older, larger larvae create larger entry holes than do smaller larvae, and tissue around older entry holes is often discolored, whereas tissue is usually still healthy around recently-made holes. Most damage is caused by larvae which develop from eggs laid by moths flying in early summer. Secondary bacterial infection may invade the stems and cause stalk death.

### Scouting Procedure/ET:

Egg mass counts are made to detect damaging levels of oviposition. The best procedure for determining when damaging levels of oviposition are likely is to operate a black light trap in the field and count trapped moths daily. Adult European corn borer moths congregate in dense weedy areas on field edges prior to egg laying. Traps should be

operated in the grassy edge or corner of the field and should be far enough from buildings to avoid interference. Catches will vary with location, but when an increase in catch occurs on 3 consecutive nights the flight is severe enough to warrant treatment on susceptible crops. If moth flights are greater than 25 moths/trap/night anytime during the early summer flight, oviposition may be high enough to cause economically important levels of crop damage. By referring to light traps in other fields or areas, and by following statewide black light trap catches, growers can follow the general population and predict local areas more effectively.

Degree day accumulation may also be used to predict moth flights. Using a base temperature of 50°F, peak flights will occur at 600 DD<sub>50</sub> and 1700 DD<sub>50</sub>. Action sites along field edges can be walked regularly to gauge the level of European corn borer populations close to an individual field. For the first generation, scouting should begin at 500DD<sub>50</sub> and continue through 700DD<sub>50</sub> or until egg counts drop off. Sample for egg masses from the mid to lower portion of the plant by examining the lower leaf surface of 25 leaves per sample site. If greater than 4% of the leaves (one out of 25 leaves) are infested with eggs as a field average, control is recommended. Because Norgold, Norkota and Norchip varieties are particularly susceptible to damage, control is recommended if greater than 2% of the leaves are infested with egg masses.

### Integrated Control

#### Non-Chemical Control:

**Natural Control:** Weather conditions greatly influence European corn borer survival, particularly during the egg stage and while young larvae are feeding on the leaves. Heavy rains wash the egg masses and young larvae off the plants and thus can greatly reduce borer numbers. In addition, very hot, dry weather causes desiccation of the eggs and young larvae. These climatic variables will kill 22-68% of freshly hatched larvae. Predators, parasites, and diseases also take their toll on European corn borer populations, however, there is no way to predict the impact of these factors.

**Cultural Control:** Plowing under crop stubble in the fall, thereby destroying overwintering larvae, has long been an effective method of reducing borer populations. This is especially important in nearby corn fields, where the majority of corn borers are produced. European corn borer moths rest in weedy, grassy areas at field edges during the day and then fly into nearby crops to lay eggs at night. Cleaning up such areas around fields can reduce borer pressure. Certain varieties of potatoes are annually attacked by the European corn borer and may result in economic damage. Norgold, Norchip, and Norkota are attractive to oviposition, with Norgold and Norkota being especially susceptible to damage. Russet Burbank can sustain moderate to heavy damage without yield reduction, although quality may be affected.

**Biological Control:** *Bacillus thuringiensis* var. *Kurstaki*

formulations can be effective if timed to target young larvae.

## Chemical Control:

**Insecticide Resistance:** None.

## References:

C.L. Metcalf & R. L. Metcalf (1993) Destructive and Useful Insects, Their Habits and Control 4th Ed. McGraw-Hill Book Co., New York.  
S. E. Rice Mahr, J. A. Wyman, E. B. Radcliffe, C. Hoy and D. W. Radsdale. 1995. Potato: Chapter 5 in Midwest Vegetable Insect Management. R. Foster and B. Flood Eds.

# Green PeachAphid



**Scientific Name:** *Myzus persicae*  
**Order:** Homoptera  
**Family:** Aphididae

## General Information

### Biological Description

Wingless forms are 1/8 inch in length, pear-shaped, soft-bodied, and commonly yellow-green in color but may be darker green or salmon. Winged forms are dark green on the head and thorax and have a dark patch on the abdomen. All forms have piercing/sucking mouthparts. When compared with the potato aphid, the green peach aphid has shorter legs and is broader. Green peach aphids are relatively immobile.

### Economic Importance

The green peach aphid is the most serious pest of seed potato production due to its capacity to transmit potato leafroll virus and potato virus Y.

### Life Cycle:

The green peach aphid overwinters as black, shiny eggs on the bark of *Prunus* spp: peach, plum, apricot, or cherry trees. Some aphids migrate into Wisconsin from overwintering sites in the southern states. Nymphs hatch at about the time *Prunus* spp. are in bloom. After 2-3 generations, winged forms are produced. The aphids then migrate to susceptible weed and

crop plants and begin producing nymphs asexually. Infestations often begin in the field margins and many generations of wingless forms are produced during the summer. A single female can produce 50-100 live young with a complete generation requiring less than 10 days under ideal conditions. In response to adverse conditions, such as crowding, winged, asexual forms are produced and further dispersal occurs. In the fall, winged sexual forms are produced which mate and lay eggs on trees in the genus *Prunus*.

### Host Range

The green peach aphid has an extremely wide host range which includes most vegetables, some fruit trees, ornamental shrubs, flowering plants, and weeds.

### Environmental Factors

Heavy rain can rapidly decrease aphid populations as well as produce ideal conditions for the rapid spread of several fungal diseases which can rapidly reduce populations.

### Damage/Symptoms

Green peach aphids possess extremely fine, needle-like, piercing mouthparts which are inserted between plant cells, and into the vascular tissue. Typically, this causes little direct morphological damage. When present in high numbers, enough sap may be extracted to cause plant wilting, particularly on hot, dry days. Eventual plant death may occur under extreme conditions and usually occurs in small circular patches which enlarge as aphids move. Excess sap is excreted as "honeydew" and falls on leaves, giving them a shiny appearance and sticky texture. Indirect damage caused by the transmission of plant viruses is extremely serious. The green peach aphid is an extremely efficient vector of many plant viruses and is known to transmit several important potato viruses including potato leafroll virus and potato virus Y. Winged forms of the aphid are generally more important in virus transmission.

### Scouting Procedures/ET

Remove leaves from the mid to lower half of 25 potato plants per sample site. Count the total number of adult and nymphs. Sample at least five sites per 30 acres and add one sample site for each additional 20 acres. Since aphid species identification is difficult in the field, the following thresholds should be followed for all aphids.

### Control measures are recommended when counts are as follows:

#### **Fresh Market or Processing:**

Early season—> 50 wingless aphids/25 leaves (all species)

After bloom—100 wingless aphids/25 leaves (all species)

#### **Fresh Market or Processing Potatoes grown in Seed Production Areas:**

7.5 green peach aphids/25 leaves

50 aphids of any species/25 leaves

### **Seed Potatoes**

2.5 green peach aphids/25 leaves on virus susceptible varieties

5.0 potato aphids/25 leaves on virus-susceptible varieties

7.5 green peach aphids/25 leaves on virus resistant varieties

*Katahdin, Kennebec, Norgold, Norland, Red Pontiac, and Shepody have been identified as having potato leafroll virus tolerance.*

## **Integrated Control**

### **Non-Chemical Control**

**Natural Control:** Green peach aphids are susceptible to both biotic and abiotic mortality factors which can drastically affect population levels. Abiotic factors such as heavy rain can rapidly decrease populations or produce ideal conditions for the rapid spread of several fungal diseases which can reach epidemic proportions and decimate high populations very rapidly. Several predators including ladybird beetle larvae and adults, lacewing larvae and syrphid fly larvae are active particularly in conjunction with high aphid populations. Parasitic wasps are also common, leaving characteristic swollen hard shelled "aphid mummies" adhering to plant leaves. In general, however, the enormous reproductive potential of the green peach aphid is sufficient to override the effects of parasites and predators and economic levels of control cannot be expected.

**Cultural Control:** Due to the extremely large host range of this insect, cultural practices do not effectively reduce infestations. Geographic isolation in northern areas will delay onset of infestation and some states have been successful in removing overwintering sites.

**Biological Control:** Practices which conserve naturally-occurring natural enemies will help keep aphid populations down. However, because of the high reproductive potential of the aphids, sufficient control may not be achieved.

### **Chemical Control**

**Commercial:** Systemic and foliar insecticides provide good control of the green peach aphid. Insecticides registered for systemic control of aphids on potatoes include Thimet, Disyston and Admire. Systemics are prophylactic and use should be dictated by several considerations such as risk of groundwater contamination, efficacy against target pest, efficacy against other potato pests, and persistence of control. Systemic insecticides are recommended for green peach aphid control in all seed potatoes. On table stock or processing potatoes, the use of systemic compounds is usually unnecessary and foliar sprays may be substituted. Systemic

control of the green peach aphid is not normally required on short season processing or table stock potatoes. Thimet or Disyston may be applied at plant emergence on irrigated crops, or in the furrow at planting time on dry land. Do not use on muck soils. These materials should provide 70-80 days of protection, but scouting is recommended. Another option is to apply Admire in the furrow at planting time which will provide 80-100 days protection. Use this material only if there is no risk of groundwater contamination.

Foliar insecticides can also provide good control of the green peach aphid. Monitor provides the most effective green peach aphid control with Thiodan, Asana and Provado also providing protection. Please refer to the product label for specific application information and precautions.

**Homeowner:** Pyrethroids and insecticidal soaps are effective in controlling aphid populations in small garden situations.

**Insecticide Resistance:** Applications should only be made when thresholds are reached in order to minimize selection pressure. Chemical classes should be rotated when possible. Repeated use of methamidophos should be avoided to preserve its effectiveness. Limit sprays of other classes

## **References**

- R.H. Davidson & W.F. Lyon (1979) *Insect Pests of Farm, Garden, and Home*. 7th Ed. John Wiley & Sons, New York. 596 pp.
- C.L. Metcalf & R.L. Metcalf (1993) *Destructive and Useful Insects, Their Habits and Control*, 5th Ed. McGraw-Hill Book Co., New York.
- S. E. Rice Mahr, J. A. Wyman, E. B. Radcliffe, C. Hoy and D. W. Ragsdale. 1995. Potato: Chapter 5 in *Midwest Vegetable Insect Management*. R. Foster and B. Flood Eds.

## **Potato Aphid**



<b>Scientific Name:</b>	<i>Macrosiphum euphorbiae</i>
<b>Order:</b>	Homoptera
<b>Family:</b>	Aphidae



## General Information

### Biological Description

Winged and wingless forms occur in high numbers on the lower leaf surfaces of terminal leaves and on young stems. Wingless forms are medium sized aphids, up to 1/8 inch long with elongated, smooth, soft, spindle-shaped bodies. Cornicles are long and parallel with the body. Antennae are held sideways and are longer than the body. Coloration varies from green to reddish-pink. Both color forms may be present at the same time. Winged forms are a pale green. When compared with the green peach aphid, potato aphids appear more slender and have longer legs. Wingless forms may drop from the plant if disturbed.

### Economic Importance

The potato aphid is a sporadic pest of potatoes in Wisconsin and is primarily important as a vector of virus diseases, particularly potato virus Y.

### Life Cycle

Potato aphids overwinter as black eggs on wild and cultivated roses. Eggs hatch in the spring and several generations are produced asexually on the succulent, developing tissue of the rose before winged forms of the aphid are produced. Winged aphids migrate to susceptible host plants in late June and July. On potatoes, aphids give birth to live young asexually and one female may produce 50 nymphs within a two week period. Aphid nymphs become mature in two weeks. The short generation time, along with the high numbers of offspring, result in rapidly exploding populations. As conditions become adverse or crowding occurs, the aphids disperse to new hosts. In late fall, winged forms return to roses, undergo sexual reproduction and lay overwintering eggs prior to frost.

### Host Range

The potato aphid is primarily found on roses in the spring but migrate to a wide variety of plants including vegetables, flowers and weeds.

### Environmental Factors

Heavy rain can rapidly decrease aphid populations as well as produce ideal conditions for the rapid spread of several fungal diseases.

### Damage/Symptoms

Like other aphids, the potato aphid possesses a fine, needle-like stylet which is inserted between plant cells into the vascular tissue. Typically, this causes little direct injury to adjacent tissues. Extremely large populations may extract enough sap to cause leaf curling and wilting or eventual plant death under extreme conditions. Excess sap is excreted as honeydew and falls onto leaves, giving them a shiny appearance and sticky texture. Sooty mold fungi may grow on copious honeydew secretions. The potato aphid transmits some potato virus diseases but it is not as efficient a vector as

the green peach aphid.

## Scouting Procedure and ET

If potato aphids are found in the sweep net while sweeping for potato leafhoppers, then a leaf sample should be taken to get an accurate estimate of the potato aphid population present in the field. Remove the leaves from the terminal parts of 25 plants per sample site and count the total number of adult and nymphal potato aphids. Sample at least five sites per 30 acres and add one sample site for each additional 20 acres. Since aphid species vary in vector efficiency and may not be easily identifiable in the field, the following thresholds may be followed for all aphid species.

### *Fresh Market or Processing:*

Early season—> 50 wingless aphids/25 leaves (all species)

After bloom—100 wingless aphids/25 leaves (all species)

### *Fresh Market or Processing Potatoes grown in Seed Production Areas:*

7.5 green peach aphids/25 leaves

50 aphids of any species/25 leaves

### *Seed Potatoes*

2.5 green peach aphids/25 leaves on virus susceptible varieties

5.0 potato aphids/25 leaves on virus-susceptible varieties

7.5 green peach aphids/25 leaves on virus resistant varieties

*Katahdin, Kennebec, Norgold, Norland, Red Pontiac, and Shepody have been identified as having potato leafroll virus tolerance.*

## Integrated Control

### Non-Chemical Control

**Natural Control:** Potato aphids are susceptible to both biotic and abiotic mortality factors which can drastically affect population levels. Abiotic factors such as heavy rain, can rapidly decrease populations or produce ideal conditions for the rapid spread of several fungal diseases which can reach epidemic proportions and decimate high populations very rapidly. Several predators including the ladybird beetle adult and larva, lacewing larvae, and syrphid fly larvae are active particularly in conjunction with high aphid populations. Parasitic wasps are also common, leaving characteristic, swollen, hard-shelled “aphid mummies” adhering to plant leaves. In general however, the enormous reproductive potential of the potato aphid is sufficient to override the effects of parasites and predators and economic levels of control cannot be expected.

**Cultural Control:** Due to the extremely large host range of this insect, cultural practices do not effectively reduce infestations. Geographic isolation in northern areas will delay the onset of the infestation.

**Biological Control:** Practices which conserve naturally-occurring natural enemies will help keep aphid populations

down. However, because of the high reproductive potential of the aphids, sufficient control may not be achieved.

### Chemical Control

**Commercial:** Systemic and foliar insecticides provide good control of the potato aphid. Insecticides registered for systemic control of aphids on potatoes include Thimet, Disyston and Admire. Systemics are prophylactic and use should be dictated by several considerations such as risk of groundwater contamination, efficacy against target pest, efficacy against other potato pests, and persistence of control. Systemic insecticides are recommended for potato aphid control in all seed potatoes. On table stock or processing potatoes, the use of systemic compounds is usually unnecessary and foliar sprays may be substituted. Systemic control of the potato aphid is not normally required on short season processing or table stock potatoes. Thimet and Disyston may be applied at plant emergence on irrigated crops, or in the furrow at planting time on dry land. Do not use phorate or disulfoton on muck soils. These materials should provide 70-80 days of protection, but scouting is recommended. Another option is to apply Admire in the furrow at planting time which will provide up to 100 days of protection.

Foliar insecticides can also provide good control of the potato aphid. Monitor provides the most effective followed by Thiodan, Provado, and Asana. Please refer to the product label for specific application information and precautions.

**Homeowner:** Insecticidal soaps are effective in controlling aphid populations in small garden situations.

**Insecticide Resistance:** Applications should only be made when thresholds are reached in order to minimize selection pressure. Chemical classes should be rotated when possible. Repeated use of Monitor should be avoided to preserve its effectiveness. Limit sprays of other classes of insecticides to two or less to avoid resistance build-up.

### References

- C. L. Metcalf and R. L. Metcalf (1993) Destructive and Useful Insects, Their Habits and Control 5th Ed. McGraw-Hill Book Co., New York.
- S. E. Rice Mahr, J. A. Wyman, E. B. Radcliffe, C. Hoy and D. W. Ragsdale. 1995. Potato: Chapter 5 in Midwest Vegetable Insect Management. R. Foster and B. Flood, Eds.

## Potato Fleabeetle

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**Scientific Name:** *Epitrix cucumeris*

**Order:** Coleoptera

**Family:** Chrysomelidae

### General Information

#### Biological Description

Adults are small, shiny, black beetles with enlarged hind legs which allow them to jump from foliage when disturbed. Eggs are tiny, white and cigar-shaped. Larvae are delicate, and thread-like in appearance with white bodies and brown head capsules. Pupae are white and enclosed in earthen cells. Several other species of fleabeetle such as the tuber fleabeetle, western potato fleabeetle and the tobacco fleabeetle may be found in Wisconsin however, these are usually present in lower numbers.

#### Economic Importance

The potato fleabeetle can normally be found in Wisconsin potatoes but is rarely a serious pest.

#### Life Cycle

Potato fleabeetles overwinter as adults in the soil in fields in which they have matured. Beetles become active when temperatures reach 50 degrees F. and emerge in late May and June. They begin feeding on weeds or volunteer potato plants until the crop emerges. Adult fleabeetles lay eggs in the soil at the base of host plants. The eggs hatch in 7-14 days and larvae feed on the roots of the host plant until fully grown. After feeding for approximately two weeks, the larvae pupate in earthen cells for 11-13 days before emerging as adults. A complete life cycle takes 30-50 days and the second generation adults emerge in July - August.

#### Host Range

The host range of the potato fleabeetle is extremely large and includes many other vegetables such as cabbage, carrots, eggplant, beans, tomatoes, and peppers. Flowering plants, trees, and weeds are also included in this insect's host range.

## Environmental Factors

Potato fleabeetle populations can occasionally be very high, however, it is not known what conditions lead to these outbreaks.

## Damage/Symptoms

Adult fleabeetles feed on both leaf surfaces but usually on the underside where they chew small, circular holes less than 1/8 inch, through the tissue to the upper cuticle. The circular holes give the plant a shotgun blast appearance which is characteristic of fleabeetle injury. Heavy feeding on young plants may reduce yields or even kill plants in severe cases. Larvae feed on the roots and tubers but do not cause economic injury.

## Scouting Procedure and ET

Scout for adult fleabeetles by taking 25 sweeps per sample site with an insect sweep net. Sample at least five sites per 30 acres and add one sample site for each additional 20 acres. Control measures are recommended when adult counts exceed two per sweep.

## Integrated Control

### Non-Chemical Control

**Natural Control:** Little or no significant natural control exist for this insect.

**Cultural Control:** Clean cultivation and the elimination of early-season hosts will reduce populations. There have been reports of more severe damage on heavy soils than on sandy soils. Crop rotation will also reduce populations.

**Biological Control:** There are no commercially-available biological control agents which are effective in reducing populations of the potato fleabeetle.

### Chemical Control

**Commercial:** Current pest management recommendations for potato fleabeetles on potatoes calls for insecticide treatment when populations exceed threshold levels. However, threshold levels are rarely exceeded in Wisconsin and foliar sprays should be coordinated with the need to control other, more damaging, pests. Guthion, Sevin, Furadan, Diazinon, Thiodan, Asana, Lannate, Monitor, Ambus, and Pounce are all registered for the control of the potato fleabeetle on potatoes. Refer to the product label for specific application instructions and precautions.

**Homeowner:** This insect is typically not a serious problem on small acreages of potatoes

**Insecticide Resistance:** None.

## References

C. L. Metcalf and R. L. Metcalf (1993) destructive and Useful Insects, their Habits and Control 5th Ed. McGraw-Hill Book Co., New York.

# Potato Leafhopper



**Scientific Name:** *Empoasca fabae*

**Order:** Homoptera

**Family:** Cicadellidae.

## General Information

### Biological Description:

Adults are small, wedge-shaped, pale green insects with whitish spots on the head and thorax. They have piercing/sucking mouthparts. Adults are extremely active; jumping, flying or crawling sideways or backwards when disturbed. Nymphs (immatures) are similar in appearance to the adults. They are yellow-green in color and do not have fully developed wings. Nymphs are less active but crawl rapidly, often seeking to regain the lower leaf surfaces when dislodged.

### Economic Importance:

The potato leafhopper is a serious pest of potatoes in most midwestern production areas.

### Life Cycle:

Potato leafhoppers do not survive northern states. Populations build up on legumes early in the year in isolated areas of the Gulf States and migrate northward in April and May on warm southerly winds. The first migrants, which are primarily females, reach midwestern states in early summer. Large influxes of migrants occur in June and early July causing populations to increase rapidly and seemingly 'explode' overnight. White eggs are laid on susceptible crops by insertion into stems or large leaf veins. Each female lays approximately 3 eggs/day and oviposition typically lasts about one month. Eggs hatch in 7-10 days. Nymphal development involves five successively larger instars and takes 12-15 days. Migrating adults die by July. First generation offspring mature in late July and the second generation matures in early September. There are normally only two generations per year in northern production areas with 3-4 in the south.

### Host Range:

Potato leafhoppers feed on and may damage a wide range of host plants including alfalfa, apples, all types of beans, clover,

dahlia, eggplant, potatoes, rhubarb, soybeans, strawberries, and other bedding plants and many weed species.

### Environmental Factors:

Leafhopper injury develops most rapidly during hot, dry weather.

### Damage/Symptoms:

Both nymphs and adults feed by inserting their piercing/sucking mouthparts into the vascular tissue of the plant and extracting sap. Damage is principally to the phloem cells which become blocked by salivary products during feeding, preventing translocation of photosynthetic products from the leaves. General symptoms include stunted plants, with chlorotic foliage which curls upward at the margins. Early symptoms include triangular, brownish spots at the leaflet tip or at the leaf margins near veinlets. Browning progresses inward from the margins and leaf margins become dry and brittle. Often, only a narrow strip of green tissue remains along the midveins. The burned appearance of the foliage is where the term "hopperburn" is derived. Symptoms of feeding injury begin on older foliage and move upward. Pre-mature death of untreated vines causes severe yield reduction. Damage may be more severe in hot, dry years. Nymphs are more injurious than adults. Yield loss may occur before obvious hopperburn symptoms develop and the level of yield loss is not directly related to hopperburn. Varieties Norland, Superior, Norgold, Norchip, and Atlantic are particularly susceptible to hopperburn.

### Scouting Procedure/ET:

Scouting at regular intervals for both adults and nymphs is critical for effective potato leafhopper control. Take 25 sweeps with an insect sweep net per sample site. Nymphs are less mobile and are best scouted by leaf samples. Carefully turn over 25 leaves per sample site. Select the leaves from the middle portion of the plant. Use at least 5 sample sites per 30 acres and add one sample site for each additional 20 acres. If fewer than 0.5 adult/sweep are caught, do not treat unless nymph populations exceed 2.5/25 leaves. If 0.5 to 1.0 adults /sweep are noted, treat if adults persist at this level for 10-14 days or nymphs are present. If there are 1.0-1.5 adults/sweep, treat within 5-7 days or immediately if nymphs are present. Finally, if there are more than 1.5 adults/sweep, treat as soon as possible.

### Integrated Control:

#### Non-Chemical Control:

**Natural Control:** No natural mortality factors of significance occur in potatoes although parasitic hymenopters (Mymaridae) are common when leafhopper populations are high. In humid conditions, entomopathogenic fungi may reduce populations. A rapid natural decline in population normally occurs in late summer.

**Cultural Control:** Healthy, vigorously growing vines will withstand damage more effectively than stressed plants.

Irrigation and cultural practices which favor the crop are recommended. Infestations are likely to be more severe in crops planted adjacent to alfalfa, particularly after alfalfa is cut in mid-summer. The following varieties are listed in the order of decreasing susceptibility to potato leafhopper injury: Norland, Norchip, Atlantic, Superior, Goldrush, Snowden, Norgold Russet, Kennebec, Red Pontiac, Ranger Russett, Russet Norkota, Russet Burbank, Ontario, Red LaSoda. Thresholds may need to be adjusted based on the cultivar's relative susceptibility to damage. Plants are also most susceptible to injury from emergence to completion of flowering.

**Biological Control:** None is available commercially.

### Chemical Control:

**Insecticide Resistance:** None.

### References:

- R.H. Davidson & W.F. Lyon (1979) *Insect Pests* 7th Ed. of Farm, Garden, and Home. John Wiley & Sons, New York. 596 pp.
- C.L. Metcalf & R.L. Metcalf (1993) *Destructive and Useful Insects, Their Habits and Control*. 4th Ed. McGraw-Hill Book Co., New York.
- S. E. Rice Mahr, J. A. Wyman, E. B. Radcliffe, C. Hoy and D. W. Ragsdale. 1995. Potato: Chapter 5 in *Midwest Vegetable Insect Management*. R. Foster and B. Flood, Eds.

## Tarnished Plant Bug



**Scientific Name:** *Lygus lineolaris*

**Order:** Hemiptera

**Family:** Miridae

### General Information

#### Biological Description

Adults 1/4 inch long and half as broad. They are dorsiventrally flattened with a small head. Coloration is variable, but generally brown with splotches of white, yellow, reddish-brown and black. There is a clear yellow triangle tipped with a smaller black triangle on the posterior end of the abdomen.



Nymphs range in size from 1/25 inches to 3/16 inches long. Coloration is variable, ranging from mottled black and white bands on a dull green base to light green with black flecks. Nymphs also lack the wings which are characteristic on the adults.

### **Economic Importance**

The tarnished plant bug is an occasional pest on potatoes.

### **Life Cycle**

Tarnished plant bugs overwinter as adults under leaf mold, stones, tree bark, and among the stubble of clover and alfalfa. Adults begin to emerge in late April to early May. After feeding for a few weeks, they migrate to various herbaceous weeds, vegetables, and flowers where eggs are inserted into the stems, petioles, or midribs of leaves. Eggs hatch in about 10 days. There are five nymphal instars which require 20-30 days to complete. New generation adults begin to emerge in late June-July. There may be 2-3 generations per year with adults entering hibernation in October or November. Appreciable numbers of plant bugs are not seen on potatoes until mid-July.

### **Host Range**

Tarnished plant bugs affect a wide host range including over 50 economic plants, as well as many weeds and grasses. They are often found on alfalfa, tobacco, beans, beet, cucumber, celery, chard, cabbage, cauliflower, turnip, potatoes, strawberries and other small fruits, tree fruit, and many flowering plants.

### **Environmental Conditions**

Weedy fields or fields with a high degree of plant residue may increase the numbers of tarnished plant bugs.

### **Damage/Symptoms**

The tarnished plant bug causes injury to potatoes by inserting their piercing-sucking mouthparts into the plant and removing sap. In addition, to the direct damage caused by feeding, the bug also injects a salivary secretion which is toxic to the plant. This toxin will produce small, circular, brown areas at the point of feeding. Feeding causes leaves to curl, new growth to wilt, and destruction of the flowers.

### **Scouting Procedure/ET**

Tarnished plant bugs are most accurately sampled with an insect sweep net: take 25 sweeps/sample site with at least 10 sites/100 acres scattered throughout the field. When counts exceed one tarnished plant bug per sweep as a field average, control measures are recommended.

### **Integrated Control**

#### **Non-Chemical Control**

**Natural Control:** A few insect predators do attack the tarnished plant bug, including a predaceous stink bug, an assassin bug, the big-eyed bug and a damsel bug. However, the amount of control provided by the predators is considered

minimal.

**Cultural Control:** Because the tarnished plant bug overwinters in weeds, often those standing semi-erect during the winter, removal of weeds and favorite hibernating places may help in reduce its numbers.

**Biological Control:** None.

#### **Chemical Control**

**Commercial:** Several foliar insecticides are registered for control of plant bugs with Asana, Monitor, Ambush, and Pounce providing effective control. Soil-applied, systemic insecticides also provide effective control and populations will rarely exceed threshold levels in systemic-treated fields until mid to late season. Refer to the product label for specific application recommendations and precautions.

**Homeowner:** Sevin applied when populations reach 5 adults or 2 nymphs/plant will provide adequate control. Aphid populations may be increased with repeated Sevin applications.

**Insecticide Resistance:** None.

### **References:**

- R.H. Davidson & W.F. Lyon (1979) *Insect Pests of Farm, Garden, and Home*. 7th Ed. John Wiley & Sons, New York 596 pp.
- C.L. Metcalf & R.L. Metcalf (1993) *Destructive and Useful Insects, Their Habits and Control* 5th Ed. McGraw-Hill Book Co., New York.



# Disease Profiles

## Bacterial Soft Rot

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**Common Name:** Bacterial Stem Rot

**Cause:** *Erwinia carotovora* var. *carotovora*

**Type:** Bacterium



### General Information

#### Biological Description

The bacteria which causes bacterial soft rot is a facultative anaerobe, gram-negative, motile rod.

#### Economic Importance

Bacterial soft rot is common wherever potatoes are grown. It is very widespread and often occurs in association with other stem and tuber diseases and injury. It may follow late blight, sunscald or freezing injury and may be serious in transit or storage if the temperature and humidity are not maintained properly. It is common whenever a film of moisture persists on stems and tubers for extended periods.

#### Disease Cycle

The bacteria are primarily transmitted through infected tubers. Contamination of seed lots is common. High soil temperatures favor disease development with the optimum temperature range between 77-86°F. In the field, the bacterium can spread by splashing rain and irrigation, gaining entrance to stems through wounds.

#### Host Range

*Erwinia carotovora* var. *carotovora* has a wide host range which includes most fleshy vegetables. Those vegetables susceptible to the bacterium include: asparagus, bean, beet, carrot, celery, crucifers, cucurbits, lettuce, onion, pepper, potato, spinach and tomato.

#### Environmental Factors

The bacteria live in the soil and enter the tubers through wounds and natural openings such as lenticels; and stems through wounds. Frost-injured tubers are commonly invaded by soft-rotting bacteria. Bacterial soft rot is favored by rainy weather when potato tissues are moist and covered by a film of moisture and the lenticels enlarge, providing an entrance for the bacteria. The disease often spreads from infected to healthy tubers in storage.

### Symptoms

When tubers are infected through the tuber lenticels, blisters formed on the affected tissues collapse to produce sunken areas 1/8 - 1/4 inch in diameter. If the tubers are infected through large bruises, the external lesions may appear light to dark brown and only slightly sunken. Affected tissues of tubers are typically white to cream-colored, soft, somewhat watery and slightly granular. A black margin separates diseased and healthy tissues. Later the infected tissue becomes gray-brown. A clear amber liquid often exudes from the decayed areas. Infected tubers break down partially or completely, and a watery rot develops. The decay may progress into either a wet-rot stage or it may dry up and leave chalky-white lesions. Soft rot affects tubers in storage, but seed pieces and newly-formed tubers can become infected. If secondary decay has begun, another bacterium, typically *Clostridium*, will be present. In such cases, the decay may become slimy and foul smelling. Stem infections appear as soft-rotted, often dark brown to black lesions several inches above the soil line. Infected tissues collapse and dry, leading to wilting of foliage or infected vines. Stem symptoms are differentiated from blackleg by observing the stem tissues at the soil line. In the case of blackleg, stem tissues at the soil line are black and decayed. This is generally not the case with bacterial stem rot.

### Scouting Procedure/ET

None.

## Integrated Control

### Non-Chemical Control

**Cultural:** Planting certified seed is a primary defense against the development of bacterial soft rot. To prevent bacterial soft rot, handle the potato crop carefully during harvest to decrease the number of wounds, cuts, cracks or bruises. Harvest potatoes in dry weather if possible, to promote rapid drying and healing of wounds. Closely monitor irrigation prior to harvest to lower soil moisture levels. Tubers left in the soil for 7-10 days after vine kill will develop a skin which is less susceptible to wounding. Also, harvest tubers when soil temperatures are between 50-65°F to prevent bacterial development, should wounding occur. Avoid sunscald of tubers. Exposure of tubers to direct sunlight for as short a period as one hour increases their susceptibility to soft rot. Use spray jets for washing potatoes; never soak tubers in water for long periods. Do not reuse wash or rinse water. Dry tubers immediately after they are washed. Hot air dryers hasten drying. Do not pack tubers in air-tight containers, such as unperforated plastic bags. During the first week or ten days, store tubers at 60°F with adequate ventilation to promote rapid healing of wounds. Afterward, tubers may be stored at cooler temperatures. Control of bacterial stem rot includes controlling insects such as the European corn borer, avoiding stem injury by equipment, and careful irrigation to avoid maintaining a film of moisture on the vines.

**Resistant Varieties:** Cultivars seem to differ in susceptibility to bruising and the incidence of infection by the soft rot bacterium. A study at the UW-Madison demonstrated that potato cultivars with the highest levels of tuber calcium (Butte, Norgold Russet, and Russet Burbank) were consistently most resistant to bacterial soft rot on silt loam and loamy sand soils. The cultivars Rhinered, Superior, and Red La Soda were intermediate. Norland, Norchip, and Belchip, which had lower levels of tuber calcium, were most susceptible.

### Chemical Control

The use of fixed copper sprays such as Kocide or Champion may help to reduce field spread and vine infection but are not a substitute for careful irrigation and irrigation scheduling. The application of calcium to field soil, and the accumulation of calcium by the tubers appears to reduce tuber susceptibility to bacterial soft rot.

### Fungicide Resistance

None.

## References

- Hodgson, W. A., D. D. Pond and J. Munro. 1974. Diseases and pests of potatoes. Canada Department of Agriculture Publication 1492. 69pp.
- O'Brien, M. J. and A. E. Rich. 1976. Potato diseases. USDA Agriculture Handbook No. 474. 79pp.
- Rowe, R.C. ed. 1993. Potato Health Management. American Phytopathological Society, Inc. 178pp.

## Black Dot

Black dot is usually of minor importance but can be severe on early varieties such as Superior. Black dot overwinters as sclerotia on plant debris or tubers. Infection occurs when plants are subject to stress from high temperatures and low nitrogen fertility. Root infection can occur at soil temperatures of 60- 85 degrees F in moist soil. The amount of infection is directly proportional to the amount of microsclerotia present in the soil. Symptom expression is most severe when plants are subjected to environmental stress.

The black fungal bodies on the stem, roots and tubers are responsible for the name of this disease. Symptoms first appear after flowering with a slight yellowing and rolling of the lower leaves. Later symptoms include reduced vine growth, wilting and chlorosis of the affected plants. These symptoms may mimic the symptoms of verticillium and fusarium. Lower stems of dead plants are often covered with sclerotia, especially at nodal regions. Roots and stolons of affected plants are often girdled by numerous small brown lesions. Root and stolon lesions may resemble those of rhizoctonia. Remnants of the stolons up to one inch in length are commonly attached to small tubers produced on infected plants. Microsclerotia or other evidence of infection by this pathogen are usually not found on tuber surfaces or internal tuber tissues, but sclerotia frequently occur on stolon remnants.





# Common Scab

**Cause:** *Streptomyces scabies*

**Type:** Bacterium

## Biological Description

*Streptomyces scabies* is an aerobic organism which is classified as a bacterium but resembles a fungus. When grown in culture on potato dextrose agar, *S. scabies* produces colorless filaments. Conidia are barrel-shaped and borne on branched, filamentous conidiophores.

**Economic Importance:** Common scab is a serious soil-borne disease of potato tubers and is found throughout the world. Although the disease does not affect eating quality, surface lesions blemish tubers and reduce their commercial grade and market price. Scabbed tubers tend to shrink excessively during storage and are often invaded by secondary soft rotting organisms. Scab does not develop on tubers in storage.

**Disease Cycle:** The organism responsible for common scab overwinters in the soil. Infection occurs through natural openings in the plant such as the lenticels and stomata. Once the periderm develops on the tubers, this method of disease transmission no longer presents a problem, but rather, wounds serve as the site of infection.

**Host Range:** The organism that causes potato scab has a limited host range. Besides potatoes, it can infect turnips, sugar beets, garden beets, parsnips, rutabagas and radishes.

**Environmental Factors:** The scab-causing organism can live indefinitely in the soil. It is distributed on infected tubers by wind- and water-blown soil. It can survive passage through the digestive tract of animals and is distributed in manure. For this reason, manure applied to soil may favor scab infection. The organism persists for many years in fields that receive heavy applications of manure or in old barnyard sites. Scab is most common on potatoes grown in soils with a pH between 5.5 - 7.5 which have been in continuous potato production for several years. Scab rarely occurs in soils with a pH below 5.3 or above 8.0. Warm, dry soils and early season stress favor the development of the disease.

**Symptoms:** Common scab attacks tubers causing brownish spots that are small at first but later enlarge. The resulting lesions may be large, raised and corky or more frequently, they appear as small, russetted areas that occur only on the tuber surface. Both types of lesions may vary in size, shape and color. Lesions are usually grayish-white to dark tan, and are a little darker than normal healthy tissue. Thin-skinned potato varieties are more severely affected than varieties with a russetted surface, but surface scab affects russetted varieties as well. Scab should not be confused with enlarged lenticels that are found on tubers grown in excessively wet soils.

**Scouting Procedure/ET** None.

## Integrated Control: Non-Chemical Control

**Cultural Control:** The best control of common scab is through prevention. Always plant scab-free seed pieces on land that is free from scab. Practice long rotation of 3-5 years, preferably with legumes. Rotations should avoid potatoes, sugar beets, garden beets, radishes, and turnips in the rotational sequence. Soil pH should be tested before planting potatoes and adjusted to a pH of 5.2 to 5.8. Even tolerant varieties of potatoes may be attacked by scab when grown in slightly acid or alkaline soils. Choose proper fertilizers which help reduce the soil pH. Avoid the excessive use of lime, manure, and wood ashes. Maintain adequate soil moisture, especially during tuber initiation and early growth.

**Resistant Varieties:** The most effective way to control scab is to plant resistant varieties. Although no variety in commercial production is immune to common scab, several varieties are available with a relatively high tolerance to this disease. Some of the resistant varieties include: Butte, Caribe, Frontier Russet, Norland, Norchip, Onaway, Red Dale, Russian Banana, and Superior. Of the varieties commonly grown in Wisconsin, Superior and Russett Burbank have very good resistance; Norland and Norchip have good resistance; Kennebec and Katahdin have fair resistance.

**Integrated Control: Chemical Control:** None.

**Fungicide Resistance:** None

## References

Compendium of Potato Diseases. 1981. American Phytopathological Society Press. St. Paul, MN. 125 pp.



# Early Blight

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**Cause:** *Alternaria solani*

**Type:** Fungus

## General Information

### Biological Description

Early blight is caused by *Alternaria*, a fungus which belongs to the group of fungi referred to as imperfect fungi. The fungus reproduces solely by asexual conidia.

### Economic Importance

Early blight is a common foliage disease of potatoes. When leaf spots are numerous, foliage is prematurely killed and yield may be reduced. In years when the environmental conditions favor disease development, disease management costs may exceed 10% of the total cost of production.

### Disease Cycle

*Alternaria solani* overwinters as spores and mycelium in plant refuse in the soil. In the spring, spores are released and spread to other plants by wind, rain and insects. The fungus penetrates the leaves through natural openings. As the infected plant grows, the infection spreads. Inoculum levels become high at the time of blossoming. Plants that lack vigor are predisposed to attack by this fungus. Plants with nutrient imbalances, virus infections, and insect damage have an increased risk of infection. Many cycles of early blight may occur within one season. Secondary infection occurs when foliar lesions begin to sporulate and spores are carried to nearby non-infected plants. Early blight may appear slightly earlier in the season than late blight, and is usually first observed in mid-summer but often causes its greatest damage late in the season if the weather is favorable.

### Host Range

The early blight fungus causes serious diseases of tomato and eggplant as well as potato and can attack weeds such as hairy nightshade.

### Environmental Factors

Moderate temperatures, high humidity, and prolonged leaf wetness from dews, rain, or irrigation, favor the development of early blight, but rain is not necessary for the development of the disease. Alternating periods of wet and dry weather tend to increase progression of the disease. The Potato Crop Management computer program uses environmental data to predict the occurrence of early blight and assists growers in the scheduling of fungicide applications.

## Symptoms

Symptoms appear on the older foliage initially and progress upward in the plant. Leafspots are round, oval, or angular and are dark brown to black in color. These necrotic spots usually have concentric rings that produce a bull's-eye or target board effect. There is usually a narrow chlorotic zone around the lesion which fades to the normal green coloration further from the central lesion. As lesions enlarge and coalesce they are often delimited by the large leaf veins. Sometimes the spots coalesce, killing large areas and causing a leafroll that resembles tip burn. On stems, the fungus causes an elongated brown-black necrosis. Stem infection is less destructive than leaf infection. Early blight sometimes attacks the tuber. On tubers, the lesions are small, sunken, round or irregular in shape with slightly raised margins. The skin around the margin is slightly puckered. Affected tissue also develops a corky, brown dry rot. Tissue near the margin of the tuber lesion is yellow to green in color and water-soaked. Wounds are often necessary for tuber infection to occur.

## Scouting Procedure/ET

Monitor fields weekly to determine the level of infection. Sample 5-10 sites per field following a 'W' pattern across the field.

## Integrated Control

### Non-Chemical Control

**Cultural:** Crop rotation is an important control measure. Fields infested with early blight the previous year are likely to have large overwintering populations of inoculum. Because the spores are wind-blown, however, crop rotation only delays the initial



onset of the disease. Practices which reduce plant stress and which maintain healthy, vigorous plants reduces the severity of infection. Proper moisture and nutrition are also important. Avoid excessive irrigation and frequent irrigation that keeps foliage wet for prolonged periods. Provide adequate control of other diseases and insects to avoid predisposing the plants to infection. A 7-14 day delay between vine killing and digging reduces the risk of tuber infection. In small plots and gardens where the disease is serious, destroy the dead vines after harvest.

**Resistant Varieties:** Cultivars differ greatly in their susceptibility to early blight, but all cultivars currently grown in Wisconsin exhibit symptoms of early blight at some point during each growing season. Short season cultivars tend to be more susceptible than longer season cultivars. Within the following list of early and mid-season cultivars, susceptibility decreases further through the list with Norland being most susceptible and Castile least susceptible: Norland, Redsen, Belrus, Norchip, Norgold Russet, Early Gem, Superior, Monona, LaChipper, Atlantic and Castile. Late season cultivars include Russet Burbank, Kennebec, Katahdin and Rosa with Rosa being the least susceptible. Very late cultivars such as Butte, Ontario and Nooksack have exhibited some tolerance to the early blight disease.

### Chemical Control

Chemical protectant fungicide applications of maneb, mancozeb and chlorothalonil retard disease spread. Protectant materials must be applied to asymptomatic foliage before infection begins. Complete coverage and repeated applications, as new foliage emerges, are important. Use of disease management software helps growers analyze weather and crop information and determine when sprays are needed and the rates of application.

**Fungicide Resistance.** None.

### References

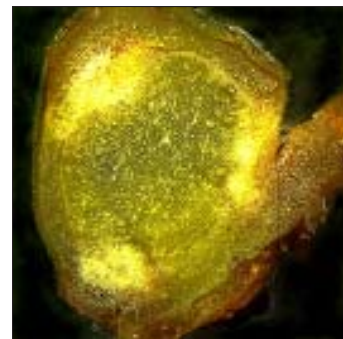
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- Rowe, R.C. ed. 1993. Potato Health Management. American Phytopathological Society, Inc. 178pp.

## Early Dying

**Common Name:** Verticillium Wilt

**Cause:** *Verticillium albo-atrum*, *Verticillium dahliae*

**Type:** Fungus



### General Information

#### Biological Description

There are two species of fungi responsible for early dying of potatoes. Both species are soil-borne but differ in the means in which they overwinter. *Verticillium albo-atrum* forms thickened mycelia within the infected plant tissue while *V. dahliae* produces small, hard, round black microsclerotia.

#### Economic Importance

Early dying is a disease that can cause serious losses in potatoes. Severe infections may reduce yield by 20% or more. Wilt severity and yield losses depend on the level of inoculum in the soil, prevailing weather conditions, and cultivar susceptibility.

#### Disease Cycle

*Verticillium albo-atrum* overwinters as mycelium in plant debris while *V. dahliae* survives as microsclerotia. Infection occurs through natural openings and wounds. Initial outbreaks are typically localized. Severity of each infection increases with each subsequent year potatoes are planted in the infested field. Dissemination occurs via infected seed and tubers.

## Host Range

The *Verticillium* fungus that causes early dying disease can infect over 200 species of plants. Some of the vegetable crops affected include tomato, eggplant and okra as well as potato. Non-susceptible plants include corn and small grains.

## Environmental Factors

The pathogen responsible for early dying can persist in the soil for two to seven years. Under conditions of low temperatures accompanied by sufficient soil moisture, typical wilt symptoms do not develop. Wet soils during the period of emergence to tuberization favor infection by the *Verticillium* fungus and dry, hot soils during tuber bulking favor symptom expression.

## Symptoms

Symptoms can appear as early as flowering. The leaves of the infected plant wilt from the bottom of the plant upward. The wilted foliage becomes pale yellow and then brown. Sometimes only one stem is affected or possibly all but one stem may escape infection. Plants may either die very quickly or may succumb gradually. Often, on hot, sunny days, plants may wilt but regain turgor after sundown. Some curling and rolling of the leaflets and a tipburn may occur. Often, only the uppermost leaves remain green. The interior vascular tissue of the stems becomes yellow, and later, reddish brown. All of the fine feeder roots as well as the bark of the main taproot decay entirely. Tubers may exhibit a brown or black discoloration of the veins at the stem end.

## Scouting Procedure/ET

None. Refer to the section on Integrated Control for soil sampling recommendations.

## Integrated Control

### Non-Chemical

**Cultural:** Soil sampling the fall before anticipated planting is useful in determining the level of inoculum present. Samples should be obtained in the standard soil-sampling method which collects multiple samples along a W pattern across the field. If inoculum is >10 microsclerotia per cubic centimeter of soil, either the field should be bypassed for planting or the field should be fumigated to kill the *Verticillium* fungus.

Avoid planting infected seed pieces or planting clean seed pieces into infested soil. If the soil is infested, practice a three to four year rotation including a cereal crop or hay, but not strawberries, raspberries, tomatoes, peppers, eggplants or members of the cabbage family. Control weeds such as velvetleaf which may serve as a host to the fungus.

### Resistant Cultivars

Cultivars differ widely in resistance to *Verticillium* wilt. Ontario is resistant. Sebago and Katahdin are slightly to moderately resistant. Most other cultivars are susceptible to the disease.

### Chemical Control

Soil fumigation with metham-sodium to reduce nematode and *verticillium* populations is beneficial in reducing the spread of disease.

**Fungicide Resistance:** None.

## References

- Hodgson, W. A., D. D. Pond and J. Munro. 1974. Diseases and pests of potatoes. Canada Department of Agriculture Publication 1492. 69pp.
- O'Brien, M. J. and A. E. Rich. 1976. Potato diseases. USDA Agriculture Handbook No. 474. 79pp.
- Rowe, R.C. ed. 1993. Potato Health Management. American Phytopathological Society, Inc. 178pp.

# Fusarium Wilt

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**Cause:** *Fusarium* spp.

**Type:** Fungus

## General Information

### Biological Description

There are at least four species of *Fusarium* which may cause Fusarium wilt. Spores produced by each of the species may be variable in morphology depending on the environment in which they are grown. All four species are readily isolated from



infected tissue.

### **Economic Importance**

Fungi in the genus *Fusarium* cause a variety of potato problems. *Fusarium* causes wilt, tuber rots, dry rot of tubers in storage, jelly end rot or soft rot of tubers, and seed piece decay.

### **Disease Cycle**

*Fusarium* is a soilborne pathogen which enters the plant through the roots. The disease progresses through the root tissue until the xylem vessels become invaded, causing vascular plugging. Nearby phloem tissues may also be affected. Seed pieces which are infected with *Fusarium* may transmit the disease to the developing plant. Inoculum dissemination may occur via any means which transports soil.

### **Host Range**

*Fusarium* species cause diseases of many vegetable crops in addition to potato. Asparagus, Jerusalem artichoke, carrot, cucumber, lettuce, onion, pepper, sweet potato, and tomato are among those vegetables which commonly are infected by *Fusarium*.

### **Environmental Factors**

Early in the season, wet, cool soil favors infection by the *Fusarium* fungus which may cause the underground stems to rot and the plants to wilt and die. During wet weather, the wilt progresses more slowly and there is greater discoloration of the vascular system. In general, hot weather, wet soil, and rain or irrigation favor further development of the disease once infection has occurred. Cool, dry weather suppresses disease development.

### **Symptoms**

The rate or type of symptom expression on potato is controlled by weather conditions and the species of *Fusarium*. Usually there is a yellowing of the lower leaves followed by rapid wilting, but sometimes plants show the effect of infection slowly and succumb gradually. The underground stems may decay and brown flecks appear in the stem pith. The woody stem tissues are yellow to brown from the base well into the top. A dry shredding of the tissue may be apparent. Discoloration is more marked at the nodes where the veins may turn dark brown. If soil moisture is high, the foliage may not wilt, but will show yellowing, rolling, and rosetting, sometimes accompanied by the development of aerial tubers. Affected leaves sometimes dry, droop, and often hang from the stem by the shriveled petioles. Vascular ring discoloration of roots and tubers may develop. Stem ends of infected tubers darken to a brown color.

### **Scouting Procedure/ET**

Monitor potato fields weekly from mid season until vine kill following a "W" shaped pattern across the field.

### **Integrated Control**

#### **Non-Chemical Control**

**Cultural Control:** *Fusarium* wilt is difficult to control and is often confused with another disease, Verticillium wilt. Plant disease-free seed pieces and handle cut seed pieces carefully to avoid bruising and allow cut tubers to suberize before planting if possible. To reduce losses from seed piece decay, plant small, whole seed potatoes. If soil is infested, practice a 3-4 year rotation including a cereal crop and hay, but not strawberries, raspberries, tomatoes, peppers, eggplant, or members of the cabbage family. Follow good soil management, including the use of proper irrigation practices.

**Resistant Varieties:** Susceptibility varies between cultivars but differences are not well documented. The variety Shurchip is reported to be tolerant to *Fusarium* wilt while Superior is only slightly susceptible to the disease.

**Chemical Control:** None.

**Fungicide Resistance:** None.

### **References**

Compendium of Potato Diseases. 1981. American Phytopathological Society Press. St. Paul, MN. 125 pp.

# Late Blight

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**Cause:** *Phytophthora infestans*

**Type:** Fungus



## General Information

### Biological Description

The late blight fungus is found throughout the world and has been responsible for periodic epidemics of late blight when weather conditions favor infection and spread. There are two mating types of the late blight fungus, A1 and A2. Both of these mating types are present in Mexico and until recently, only the A1 mating type was distributed worldwide. All this changed beginning in 1984 when the A2 mating type was reported in Europe. Since 1984, strains of the A2 mating type have become widely distributed and it wasn't long before the A2 mating type was observed in the U.S. and Canada. The presence of both mating types in a specific area has important implications in control. When only one mating type is present in an area, the fungus reproduces asexually (sporangia) and survives only in association with living host tissue (living foliage, stems, tubers, fruit (tomatoes)). When both mating types are present, however, sexual reproduction is possible leading to the development of oospores with thick walls and the capability of surviving overwinter in the soil in the absence of living host tissue. Oospores are produced in large numbers in culture, but may be less common in nature. Oospores germinate by producing a sporangium, but can also germinate by producing a germ tube that grows directly into mycelium. Progeny of the A1 + A2 mating are either A1 or A2 mating types. Recently, oospores were observed on potato tissues in Europe. We have much to learn about oospores in nature. Data are lacking on the length of time oospores can survive in our harsh environment and what role oospores play in initiating plant infections in subsequent cropping years.

In addition to the A1 and A2 mating types, there are several genotypes of each mating type. Dr. Bill Fry (Cornell University) has tracked both the mating types and genotypes as the populations of the late blight fungus become increasingly complex. The current clonal structure of the pathogen populations in the U.S. allows researchers to identify specific genotypes and to track their spread. There are currently only four genotypes that are widely distributed in the U.S. and parts of Canada until recently. This genotype was the predominant form in Wisconsin during 1993 and appeared in some Wisconsin fields in 1994. US-1 is still susceptible to Ridomil application and in fact, still responds to Ridomil treatment in grower fields. The US-6 genotype appeared in the U.S. in the late 1970's/early 1980's. This genotype belongs to the A1 mating type and is resistant to Ridomil fungicide. We have not observed US-6 in Wisconsin. The US-7 and US-8 genotypes appeared in the U.S. in the early 1990's. Both belong to the A2 mating type and both are resistant to Ridomil fungicide. Two fields in northwest Wisconsin were infected with the US-7 genotype in 1993, but this genotype did not reappear during 1994. The US-8 genotype caused damage in Florida and eastern U.S. and Canada during 1993. During 1994, this genotype was identified as far west as Wisconsin, North Dakota and Manitoba. The US-8 genotype is very aggressive and appears capable of long distance transport via storms. This genotype is very difficult to control with protectant fungicides and it is resistant to Ridomil fungicide.

### Economic Importance

Late blight can be a very serious disease on potatoes particularly where the weather is consistently cool and rainy in late summer and fall. In Wisconsin, late blight occurs about once in six years, but when it does occur, losses can be significant. The disease has been widespread and serious in 1978, 79, 80, 93 and in 1994, late blight caused losses to the Wisconsin potato industry exceeding \$9 million.

### Disease Cycle

The pathogen survives during winter months in association with potato tubers. Tubers that overwinter in the soil, tubers dumped in cull piles from warehouses in the spring and infected seed slivers serve as sources of inoculum for neighboring fields. The late blight fungus grows in and on plants which develop from infected tubers. After crop emergence, the fungus infects developing sprouts. Primary inoculum is produced under moist conditions and the disease is disseminated further by wind or water or human activity. Sporangia of the fungus are formed at a relative humidity of 91-100% and a temperature of 37-79 degreesF with an optimum temperature of 64-72 degrees F. Zoospores germinate most rapidly at 54-59 degreesF and rapid germ tube formation occurs at 70-75 degreesF. Temperatures above 86 degrees F are unfavorable to late blight development.

### Host Range

The late blight fungus primarily attacks only tomato and potato but eggplant and other solanaceous plants such as hairy and black nightshade are occasionally infected.

## Environmental Factors

The pathogen is most active during periods of cool moist weather. Cool nights with temperatures of 50-60 degreesF, and warm daytime temperatures of 60-70 degrees F are ideal for late blight development. Fog, rain or heavy dew for four to five consecutive days will also favor disease development.

## Symptoms

Symptoms of late blight appears on leaves, stems and tubers. Leaf symptoms appear as pale green, water-soaked spots that often begin at the edges of leaves or leaf tips where water from rain and dew accumulates. The circular or irregularly shaped lesions are often surrounded by a pale yellow to yellow green border that blends into healthy green tissue. The lesions enlarge rapidly and killed tissues turn brown to black. It is not uncommon for leaf lesions to expand in diameter by 1/4" to 1/2" per day until the whole leaflet is killed. Often during periods of ideal temperature 64-72 degrees F and abundant moisture, there may be multiple lesions per leaflet. When relative humidity is above 90% and leaves are wet from rain or dew, leaf lesions are bordered by a cottonlike white mold on the lower leaf surface. The mold consists of masses of sporangia (spores) and the structures that bear the sporangia. Wind, rain, machinery, workers, wildlife, etc. can dislodge the sporangia and carry them to other plant parts and neighboring plants. There was evidence in 1994 that sporangia were being transported via storms as far as 25 or more miles, making late blight a community as well as a regional problem. During high temperatures and low humidity, leaf lesions dry and infected leaves die and fall from the plants. Stems and petioles may also be infected by the late blight fungus. Infected stems and petioles turn brown to black and entire vines may be killed, depending on the location of the lesions. Stem and petiole infections may be covered with white masses of sporangia during wet weather. Stem and petiole infections may be more prevalent in some fields than leaf lesions and in fact, leaf lesions were rare in some fields while tubers harvested in these fields had a high incidence of tuber blight. Because of a similarity in appearance to bacterial stem rot, Botrytis vine rot and even blackleg diseases, the stem and petiole lesions may be overlooked or misidentified in the field. It should also be noted that in addition to symptoms appearing on potato, tomato and a weed, hairy nightshade, are also susceptible to the late blight fungus. Tomato foliage, stems and fruit are susceptible to the late blight fungus, while symptoms on hairy nightshade seem to be confined to the leaves.

Tuber infection occurs when sporangia, washed into the soil via cracks or crevices in the hill, come in contact with tubers. Moisture in the hill provides an ideal environment for tuber infection. Varieties with shallow-set tubers and plantings where there is significant hill erosion or cracking experience the greatest risk of tuber infection. Tubers may also come in contact with sporangia when green infected vines are present at harvest. Tuber infection results in a coppery brown dry rot that spreads irregularly from the tuber surface through the outer 1/8" to 1/2" of the tuber tissues. The boundary between healthy and infected tissue is not well defined and the depth of infection may vary from one variety to another. Later in storage, tuber lesions become sunken as water is lost from infected areas. Tubers infected with the late blight fungus are often infected with soft rotting bacteria and fungi, often leading to a slimy and smelly breakdown of stored tubers. Infected tubers surviving in the field as volunteers or in cull piles serve as overwintering sites for the late blight fungus. Potato cultivars differ in susceptibility to late blight infection. The Ranger Russet variety is especially susceptible to tuber infection and during 1994, up to 40% tuber infection at harvest was observed in some fields.

## Scouting Procedure/ET

Monitor potato fields weekly for early symptoms of disease. Examine 5-10 sites per field following a 'W' pattern across the field. As favorable conditions develop, scouting frequency should be increased. The use of disease prediction programs will benefit commercial growers in their monitoring and management practices.

## Integrated Control

### Non-Chemical Control

**Cultural:** Cultural control measures include the following: 1) eliminate all potato cull piles, 2) destroy volunteer potato plants that grow from overwintered tubers, 3) plant only disease-free seed that has passed a seed certification program. Certified tubers are identified by appropriate labels that indicate they were grown under supervision and inspected for various disease. Several late blight forecasting systems have been developed. These include the Hyre system (temperature and rainfall), the Wallin system (temperature and humidity), and the Blitecast system that integrates both systems into a computer program. The Potato Crop Management Program (PCM) uses the Blitecast system to forecast disease development on the basis of temperature, relative humidity and rainfall. Forecasting systems are crucial in determining whether fungicide applications may be necessary to reduce crop loss to late blight. In addition, maintain adequate tuber coverage with soil to prevent tuber infection.

Allow two weeks between vine kill and harvest. This will reduce the amount of inoculum present on the foliage as well as improve identification of infected tubers before storage.

**Resistant Varieties:** No cultivars are immune to late blight, but several cultivars possess some resistance to the common Race O as well as some of the other races of the fungus. Moderately resistant varieties include Rosa, Kennebec, Sebago, and Nooksack. Moderately susceptible varieties are Russett Burbank, Atlantic, and Katahdin. Susceptible varieties include Norchip, Monona, Belrus, Belchip, Superior, Norland, and Norgold Russet.

### Chemical Control

Protectant materials including maneb, mancozeb, chlorothalonil, triphenyltin hydroxide and fixed coppers must be applied to asymptomatic foliage before infection begins. Complete coverage and repeat applications of protectants as new foliage emerges is important. Metalaxyl with mancozeb, chlorothalonil or fixed copper may provide systemic and curative control of susceptible strains of the late blight fungus. Historically, the fungicide metalaxyl (Ridomil MZ58/Bravo 81W and Ridomil/Copper 70W) has been highly effective for late blight control in Wisconsin. During 1994, some potato fields were observed that were attacked by a metalaxyl sensitive genotype of the A1 mating type (20% of potato isolates) and many fields attacked by the aggressive US-8 genotype (80% of potato isolates). All potato isolates of the US-8 mating type were insensitive to metalaxyl fungicide while all of the US-1 isolates were still sensitive to metalaxyl. Many growers who relied on treatment with metalaxyl fungicide combinations experienced a lack of late blight control, often with serious consequences to yield and tuber quality.

### Fungicide Resistance

Strains of the late blight fungus which are insensitive to metalaxyl fungicide were observed in Wisconsin in 1993 and 1994. For an assay of metalaxyl sensitivity, send samples of late blight-infected leaves and tubers to Walt Stevenson, UW-Madison Department of Plant Pathology. There is a charge to cover the cost of this service.

### References

- Hodgson, W. A., D. D. Pond and J. Munro. 1974. Diseases and pests of potatoes. Canada Department of Agriculture Publication 1492. 69pp.
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- Rowe, R.C. ed. 1993. Potato Health Management. American Phytopathological Society, Inc. 178pp.

## Leaf Roll

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**Common Name:** Net Necrosis

**Cause:** Potato Leaf Roll Virus

**Type:** Virus

### General Information

#### Biological Description

Potato Leafroll Virus (PLVR) is one of many viruses which attack potatoes. At the present time, there are several strains of the virus which may occur naturally. All strains are transmitted by aphids.

#### Economic Importance

Leaf roll is one of the most serious virus diseases of potato. It is a disease of great economic impact since virus infection can cause a 30-50% reduction in yield. The severity of symptoms produced in potatoes depends on which virus strain infects the plant. The virus affects both the foliage and the tubers.

#### Disease Cycle

Transmission of the virus occurs primarily by the green peach aphid (*Myzus persicae*) and through infected seed pieces. Once an aphid has fed on an infected plant, it remains capable of transmitting the virus to healthy plants for the remainder of its life. At the time of symptom expression, necrosis of phloem tissue begins.

#### Host Range

The host range of potato leaf roll virus is restricted to members of the potato family: potato, tomato, jimsonweed, groundcherry and a few other weeds.



## Environmental Factors

The severity of the leaf roll symptom varies with the virus strain as well as with the temperature. Plants growing under very high temperatures (95 degrees F) will not show symptoms, but those grown under moderate temperatures at or below 77 degrees F show the characteristic leaf roll symptoms. Tubers produced from plants infected during the current growing season do not always show the net necrosis at harvest. Storage conditions may favor development of tuber symptoms. Maximum development of the net necrosis occurs when tubers are stored at temperatures near 50 degrees F for 2-3 months. Net necrosis may also increase during transit and marketing if tubers are maintained near 50 degrees F and are shipped early after harvest.

## Symptoms

Initial symptoms become noticeable about one month after plants emerge if seed pieces are infected. Leaflets of the lower leaves roll up at the edges and become papery, brittle, and leathery to the touch. Affected leaves will “rattle” when shaken. The rolled leaves are lighter in color than normal. As the plant grows, the rolling appears on the upper leaves and eventually affects the whole plant. In some varieties, the lower leaf surfaces may take on a purple cast. Plants are often stunted. If late season infection occurs, plants may show no symptoms. Plants infected by aphids show their initial symptoms on the young leaves. Symptoms are similar to those expressed on plants resulting from infected tubers. As the disease progresses, symptoms begin to appear on the lower plant parts.

Net necrosis occurs on tubers. A network of brown strands appear throughout the tuber flesh, especially near the stem end. The appearance of the strands varies with the angle that the tuber is cut. In cross sections, they show up as dots or streaks; length-wise cuts show the network of brown strands. Plants infected during the season produce tubers with net necrosis; plants produced from seed pieces with net necrosis produce infected, but symptomless tubers.

## Scouting Procedure/ET

Please refer to the plant pest profile on the green peach aphid for scouting procedures and economic thresholds.

## Integrated Control

### Non-Chemical Control

**Cultural Control:** Good cultural practices and the use of resistant varieties aid in the control of potato leaf roll. Plant only seed potatoes which have been certified as disease free since the virus is transmitted in tubers with or without the net necrosis symptom. Grow potatoes in isolated fields - away from prevailing winds coming from other potato fields. Winds may blow aphids that may vector the virus. Control aphid populations. Rogue all plants showing symptoms of virus infection throughout the season. The virus is not easily transferred by sap, but aphids can transmit the virus from one infected plant to non-infected plants in a field.

**Resistant Varieties:** Several potato varieties are resistant to the potato leaf roll virus. These include Abnaki, Alamo, Cherokee, Chieftan, Houma, Katahdin, Kennebec, Merrimack, Pungo, Redskin, Reliance, Saco, Sebago, Wauseon, and Yukon Gold. Varieties that are susceptible and should be avoided include Green Mountain, Irish Cobbler, Norland and Russet Burbank. Penobscot and Sequoia are resistant to leaf roll, but are susceptible to net necrosis. Atlantic, Chippewa and sometimes Wauseon are susceptible to leaf roll but are resistant to net necrosis.

### Chemical Control

There is no chemical control for the virus itself, however, insecticide applications to reduce aphid populations can effectively limit the spread of the potato leafroll virus. Please refer to the plant pest profile on the green peach aphid for chemical pesticide recommendations.

### Fungicide Resistance

None.

## References

Compendium of Potato Diseases. 1981. American Phytopathological Society Press. St. Paul, MN. 125pp.

# Root Lesion Nematode

---

**Cause:** *Pratylenchus penetrans*

**Type:** Nematode

## General Information

### Biological Description

Nematodes are microscopic, unsegmented roundworms. The lesion nematode is a damaging parasite of potatoes.

### Economic Importance

Lesion nematodes damage both the roots and tubers of potatoes. Nematode infestations can reduce plant growth by almost 60% and can cause losses in tuber yields of 20-50%. The feeding of these nematodes may predispose potatoes to other diseases, or the nematodes may act with other pathogens in the development of potato disease complexes.

### Disease Cycle

The lesion nematodes are endomigratory parasites and move freely into and out of roots. Eggs are laid in the soil or within the root. Nematodes undergo the first of their molts while still in the egg. Upon emerging from the egg, second instar larvae penetrate unsterilized areas of the root. All developmental stages can enter the root. Penetration is achieved by cutting the tissue with their stylet. Typically, the larvae feed and develop into adults within 40-45 days depending on temperatures and other environmental conditions. It takes between 4-8 weeks to complete one generation.

### Host Range

The host range of the lesion nematode is very wide. In this case, a host is defined as a plant on which the nematode can reproduce. Over 500 species of plants including ornamentals, field and vegetable crops, and weeds are attacked by this nematode. Crops commonly infected include apple, beet, cabbage, carrot, corn, forages, grape, grasses, mint, onion, pea, potato, soybean, strawberry, and tomato.

### Environmental Factors

Lesion nematodes are inhabitants of the soil and occur throughout Wisconsin. They are more common and cause more damage in sandy soils, but they may also be abundant in heavier soils with more clay. Optimum temperatures for reproduction are between 70-85 degrees F. Alternate freezing and thawing of the soil tends to kill the nematodes quicker than continuously low temperatures. Lesion nematodes require moderate soil moisture for migration from plant to plant. Some species however, are relatively resistant to drought.

## Symptoms

Above-ground symptoms of severely affected potato plants are manifested in poor growth. In the field, affected plants often appear in patches with stunted growth and chlorosis. Sometimes, affected plants may show no obvious above-ground symptoms. Underground symptoms are more obvious. Roots may be girdled at the infection site so that the outer tissue layers will readily slip off from the central cylinder. The nematodes cause root necrosis, often visible externally as darkened lesions. Small feeder roots are often completely destroyed, resulting in a reduced root system. Internally, nematodes tunnel through root tissue as they feed, damaging root cells. This damage causes plants to grow poorly with reduced yields. Where nematodes feed on tubers, pimples appear that later change to black depressions. When infection is severe and pimples and depressions are numerous, tubers are marred and become unmarketable. The nematode may act with other diseases such as fusarium or verticillium wilts in the development of potato disease complexes.

## Scouting Procedure/ET

Monitor potato fields weekly and note any symptoms of stunting or chlorosis. Soil samples can determine the presence and relative abundance of nematodes in fields expressing symptoms.

## Integrated Control

### Non-Chemical Control

**Cultural Control:** Lesion nematodes can be controlled by sound cultural practices, tolerant varieties, and nematicides.

Always plant nematode-free seed pieces. Plant as early as possible. Practice crop rotation. Non-host crops grown for 1-2 years

will generally reduce the nematode population so that potatoes may be grown for at least one year. Good weed control is necessary as the nematodes can reproduce on many weeds. Plowing, disking, harrowing, and cultivation after harvest helps to reduce nematode populations by exposing them to sun, wind, and mechanical injury as well as depriving them of a living host.

**Resistant Varieties:** None.

### Chemical Control

Soil fumigation with metam sodium can successfully reduce nematode populations in infested fields, however, the cost may be prohibitive. In addition, soil fumigation is of limited effectiveness on heavier soils. A minimum of three weeks is necessary between fumigation and planting to prevent phytotoxicity.

### Fungicide Resistance

None.

## References

Compendium of Potato Diseases. 1981. American Phytopathological Society Press. St. Paul, MN. 125 pp.

# Rhizoctonia Canker

**Common Names:** Black Scurf, Stem Canker

**Cause:** *Rhizoctonia solani*

**Type:** Fungus

## General Information

### Biological Description

Mycelium of rhizoctonia is tan to brown in color. Characteristic right-angle branching with a constriction and septum near the junction easily identifies the fungus.

### Economic Importance

Rhizoctonia canker is a very common and serious disease of potato. An expression often applied to this disease is “the dirt that won’t wash off” referring to the dark resting structures (sclerotia) on the mature tubers. The presence of sclerotia on the tuber surface may adversely affect the tuber grade. Yield losses are mainly due to uneven stands that produce small, irregular-shaped potatoes.

### Disease Cycle

Rhizoctonia overwinters in the soil as sclerotia. These resting spores germinate in the spring under favorable conditions and attack developing plants through wounds. Disease development is rapid in cool, wet weather.

### Host Range

Rhizoctonia has a wide host range. In addition to potatoes, the fungus also affects beet, cabbage, carrot, celery, cucumber, eggplant, lettuce, melon, onion, pepper, rhubarb, soybean, snap bean, spinach, squash, and tomato.

### Environmental Factors

The fungus lives indefinitely in the soil on plant debris. The conditions that favor disease are high moisture, cool soil temperatures, high soil fertility, and soil with a neutral or acidic pH.



## Symptoms

The fungus causes dark-brown lesions on roots, stolons, and sprouts. Infection may be so severe that it may kill the infected plant part or the tips of sprouts before or after they emerge. If the infection is mild, plants only show a lack of vigor. The leaves of infected plants become thick and sparse, roll upward, and turn pinkish to purple in color. The stalks may also thicken and bear green or reddish aerial tubers. The underground tubers develop in a tight cluster with small, numerous, and irregularly shaped tubers. Affected tubers may be cracked or pitted. The most common symptom of *Rhizoctonia* canker is the presence of numerous, hard, dark-brown resting bodies called sclerotia on the surface of mature tubers. These sclerotia may vary from the size of the head of a pin to 1/4 inch in diameter. Sclerotia are often mistaken for adhering soil until it is found that they do not wash off.

## Scouting Procedure/ET

Monitor fields weekly throughout the growing season for symptoms of the disease on aerial portions of the plant. During harvest and grading, inspect tubers for discoloration.

## Integrated Control

### Non-Chemical Control

**Cultural Control:** *Rhizoctonia* canker is very difficult to control. Always plant disease-free, certified seed. Avoid planting in cold, wet soil. Shallowly planted seed will emerge more quickly and may suffer less infection when conditions are favorable for the disease. Rotate potatoes with cereals, grasses, or some other type of green cover crop that is plowed under before potatoes are planted. Crop rotation is also useful in preventing other potato diseases. Harvest tubers as soon as they are mature to reduce the number of sclerotia that develop on the tubers.

**Resistant Varieties:** None.

**Chemical Control:** None.

**Fungicide Resistance:**None.

## References

Compendium of Potato Diseases. 1981. American Phytopathological Society Press. St. Paul, MN. 125 pp.

# Silver Scurf

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**Cause:** *Helminthosporium solani*

**Type:** Fungus

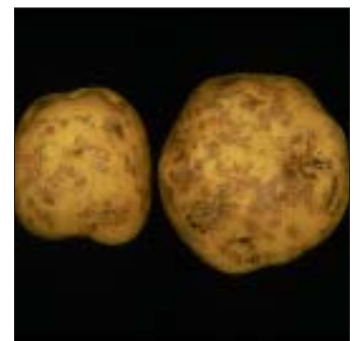
## General Information

### Biological Description

*Helminthosporium* is characterized by its hyaline or translucent mycelium that darkens with age. Conidia are produced in whorls on conidiophores. Individual conidia are large, thick-walled, and septate.

### Economic Importance

Silver scurf is a common and widespread potato disease. It has previously been considered of little economic importance. However, the increasing demand for "clean" potatoes has recently made it a major problem. This is particularly true where potatoes are washed before being offered for sale in plastic bags. When potatoes are grown on muck soil, the blemishes produced by this fungus may cause reduction in grade or prevent seed certification. Periderm infection may result in increased fresh weight loss through alteration of the periderm.





## Disease Cycle

The fungus overwinters in infected tubers in storage and those left in the soil after harvest. Tubers become susceptible at the time of maturity while they are still in the soil and remain susceptible throughout storage. Healthy tubers are infected through wounds or lenticels.

## Host Range

All potato varieties are susceptible to some degree.

## Environmental Factors

High soil moisture and humidity favor disease development.

## Symptoms

The symptoms of silver scurf seem to be confined to the tubers. Light to dark brown round or irregular spots develop on the tuber surface. On wet tubers, the spots are silvery and glassy and easily observed. After prolonged storage under warm moist conditions, spores may form in the diseased spots which makes them look sooty or smudgy. The affected areas become black and may develop small black lumps. The affected skin sloughs off and tubers shrivel and shrink. The color of red-skinned potatoes may be completely destroyed by the disease.

## Scouting Procedure/ET

None.

## Integrated Control

### Non-Chemical Control

**Cultural Control:** Plant disease-free seed pieces and practice crop rotation to reduce the incidence and severity of the disease. Harvest tubers as soon as they are mature, cull out noticeably infected tubers at digging and grading, and store healthy tubers in a cool, dry place.

**Resistant Varieties:** None.

**Chemical Control:** None.

### Fungicide Resistance

Strains of this pathogen are resistant to thiabendazole fungicide while other strains are still susceptible to normal use patterns of this material.

## References

Compendium of Potato Diseases. 1981. American Phytopathological Society Press. St. Paul, MN. 125 pp.

# Physiological Disorder Profiles

## Hollow Heart

---

**Cause:** Unfavorable growing conditions

**Type:** Environmental

### General Information

#### Biological Description

Hollow heart is the name given to a conspicuous cavity at the center of a potato tuber.

#### Economic Importance

This disorder is prevalent in large, oversized tubers, and it can occur in potatoes during the growing season, in storage, or in transit. Normally, no external symptoms are noticeable, but the disorder can affect the marketability of the tubers.

**Disease Cycle:** None.

#### Host Range

All varieties of potato are susceptible to hollow heart.

#### Environmental Factors

Extremes in temperature and moisture can induce hollow heart. Growing conditions which favor rapid tuber enlargement increase the incidence of this disorder; particularly if they follow a period of moisture stress.

### Symptoms

There are no external symptoms of hollow heart. Initial symptoms appear as small, brown spots near the tuber centers. With time, these spots enlarge and become hollow. Internally, cavities form in the center of very large tubers. These cavities may vary greatly in size and usually have cracks extending in many directions from the central cavity. The cavities are lined with pinkish tissue at first but this later turns brown. This disorder is thought to be due to conditions that cause very rapid growth. Some tubers that contain from one to many small cavities distributed throughout the flesh often with jet black tissue, have been exposed to extremes in temperature. Very high temperatures during growth, storage or transit, or chilling injury may cause this type of hollow heart.

**Scouting Procedure/ET:** None.

### Integrated Control

#### Non-Chemical Control

**Cultural Control:** To control hollow heart, space seed pieces closely within the row and space rows close together. Close spacing prevents rapid and uneven growth of the tubers and tends to prevent internal splitting. Practice timely top vine killing to prevent excessive tuber growth. Harvest tubers as soon as vines are completely dead to reduce the time of exposure to high soil temperatures which may be present after vines are killed. Apply adequate amounts of fertilizer and irrigation water to the crop. During storage and transit, proper air circulation will prevent the buildup of excessively high temperatures. Storage of tubers at 40 degrees F and above will prevent chilling injury.

Resistant Varieties:

Avoid the use of varieties which are susceptible to hollow heart.

**Chemical Control:** None.

**Fungicide Resistance:** None.

### References:

Compendium of Potato Diseases. 1981. American Phytopathological Society Press. St. Paul, MN. 125 pp.



# Black Heart

---

**Cause:** Oxygen Stress

**Type:** Physiological

## General Information

### Biological Description

Black heart develops in tubers while they are growing, in transit, or in storage. It is a condition that results from lack of oxygen in the tissues of the tuber.

### Economic Importance

This condition occurs when tubers are subjected to very high storage temperatures, poor storage ventilation or both.

**Disease Cycle:** None.

### Host Range

This disease is only a problem on potatoes.

### Environmental Factors

Black heart occurs at any temperature when the supply of oxygen available to internal tissues is used up faster than it can be supplied. The affected tissue is damaged and turns black. Conditions causing black heart can occur in the field when the soil is flooded or soil temperatures are extremely high; in storage when aeration is poor; in transit when tubers are overheated; or in prolonged storage near 32 degrees F. Black heart can be induced experimentally in nearly 100 percent of the tubers when they are held at 105-110 degrees for 24 hours.

## Symptoms

Tubers affected with black heart generally show no external symptoms. In rare instances, moist areas that may be purple to black may appear on the surface. The common internal symptom is a dark discoloration: grey-purple or inky black. This discoloration is usually restricted to the heart of the tuber but may occasionally radiate to the skin. The discolored tissues generally are sharply set off from the healthy tissues, being firm and leathery if they have dried out. Affected tissues in advanced stages dry out, shrink and form cavities. If tubers are cut soon after injury, the exposed tissues are normal in color. Shortly after exposure to air, they turn pink, then grey, purplish, or brown and finally jet black.

**Scouting Procedure/ET:** None.

## Integrated Control

### Non-Chemical Control

**Cultural Control:** Avoid high temperature storage and provide good ventilation in storage areas. When potatoes are in transit, do not allow temperatures to go above 60-70 degrees F. To prevent oxygen shortages, do not store tubers in solid piles higher than 6 feet, unless aeration is provided. During harvest, remove tubers promptly from hot, light soils after the vines die. Remove tubers from the soil surface when dug during hot weather.

**Resistant Varieties:** Russet Burbank is reported to have some resistance to black heart, but most potato varieties from all growing areas are susceptible to this disorder.

**Chemical Control:** None.

**Fungicide Resistance:** None.

## References

Compendium of Potato Diseases. 1981. American Phytopathological Society Press. St. Paul, MN. 125 pp.







# Identification of Common Wisconsin Weeds

## Annual Broadleaves

### Buckwheat Family

#### Wild buckwheat (51)\*

cotyledon:	oblong-oval with granular-waxy surface
ocrea:	at leaf axils; small
stems:	trailing vines
leaves:	heart-shaped with pointed tips
flowers:	greenish-white, small and inconspicuous
seeds:	3-sided



### Buckwheat Family

#### Pennsylvania smartweed (52)

cotyledon:	lanceolate to oblong, rounded tips
ocrea:	at leaf axils; smooth top
stems:	reddish, branched swollen nodes
leaves:	rounded at base; pointed at tip
flowers:	pink, terminal flower clusters
other:	seed black, shiny, flattened, circular with pointed tip



### Buckwheat Family

#### Ladysthumb smartweed (52)

cotyledon:	lanceolate to oblong, rounded tips
ocrea:	at leaf axils; hairy top
stem:	reddish with swollen nodes; branched
leaves:	pointed at both ends, often have "thumb print"
flowers:	pink, terminal flower clusters
other:	seeds black, most triangular



\* Numbers indicate the page in *Weeds of the North Central States* that describes the plant.

# Annual Broadleaves

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## Goosefoot Family

### Common lambsquarters (57)

- cotyledon: linear, small
- leaves: often have whitish, 'mealy' covering; shape is triangular or "goosefoot" shaped
- stems: have reddish streaks, branched
- seed: shiny, black, disk-shaped, 1/16 inch in diameter
- other: many biotypes, some resistant to herbicides



## Pigweed Family

### Redroot pigweed (65)

- cotyledon: linear, smooth
- root: often reddish-pink taproot
- leaves & stems: notch in tip of first leaves; finely pubescent; reddish-purple color on underside of leaves
- seed head: somewhat spiny, small, black, shiny seeds
- other: also called rough pigweed



## Pigweed Family

### Smooth pigweed (64)

- cotyledon shape: linear, smooth
- root: often reddish pink taproot
- leaves & stems: generally smooth
- seed heads: longer than redroot pigweed ; rarely branched
- other: resistant biotypes





# Annual Broadleaves

## Pigweed Family

### Waterhemp

- cotyledon shape: linear; egg-shaped
- leaves: nick in tip of first leaves; long-petioled; 3 to 6 in. long; somewhat shiny
- stems: smooth, often with colored stripes
- inflorescence: small greenish flowers, male and female flowers on separate plants
- other: several species of waterhemp in the region; resistant biotypes



## Purslane Family

### Purslane (71)

- cotyledon: linear or oblong, smooth
- leaves: fleshy, rounded, opposite
- stems: fleshy, prostrate, reddish, branched
- flowers: 5 yellow petals; small; numerous
- seeds: small, flattened, oval, glossy black
- other: plants can establish from stem pieces



## Mustard Family

### Wild mustard (89)

- cotyledon: heart or kidney-shaped; smooth
- leaves and stems: few bristly hairs
- lower leaves: large, triangular and lobed (not to midrib)
- upper leaves: reduced in size; no petioles
- flowers: 4 bright yellow petals
- seed pods: "beak" of seed capsule 1/3 length of whole capsule; open to release round seeds



# Annual Broadleaves

## Mustard Family

### Wild radish (100)

- cotyledon: heart or kidney-shaped, smooth
- lower leaves: rounded lobes often reach to midrib
- stems & leaves: stiff, scattered hairs
- flowers: 4 yellowish-white petals; sometimes with purplish veins
- seed pods: form constrictions and break into small segments with seed inside
- other: fruits contaminate oats and barley grain



## Mustard Family

### Shepherd's purse (91)

- cotyledon shape: ovate to rounded
- rosette leaves: starlike branched hairs on upper surface; leaf lobes point to leaf tip
- stalk/stems: elongated stalk; leaves clasp stem
- flowers: small with 4 white petals
- seed pod: small, triangular-shaped



## Mustard Family

### Field pennycress (104)

- cotyledon: round, bluish-green
- leaves: rosette and stem leaves; ear-like lobes that clasp stems on upper leaves
- flowers: flowers with 4 white petals; in clusters
- seed pod: notch in top of pod and flat wing around edge
- other: garlic-like odor in crushed leaves and stems





# Annual Broadleaves

## Mallow Family

### Velvetleaf (122)

- cotyledon: round or heart-shaped
- leaves: very large, heart-shaped, softly hairy
- stem: pubescent
- flowers: yellow with 5 petals
- seed capsules: 13-15 segments; resembles "butterprint"



## Nightshade Family

### Jimson weed (157)

- cotyledon: lanceolate, smooth
- leaves: ovate (egg-shaped) with pointed tip lobes; wavy margins
- stems: hollow, purplish, and smooth
- flower: white tubular flowers
- seed capsules: spiny, golf ball sized with many seeds
- other: strong, foul odor in leaves and stems; poisonous



## Nightshade Family

### Eastern black nightshade (162)

- cotyledon: ovate, smooth, small
- leaves: purplish color on underside; often with "shot holes"
- stems: erect or spreading; widely branched
- flowers: 5 white reflexed petals
- fruits: green, turning black at maturity; contaminate harvested products





# Annual Broadleaves

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## Nightshade Family

### Hairy nightshade

cotyledon:	ovate, hairy
leaves:	ovate to nearly triangular; finely hairy, especially veins & margins
stems:	finely hairy
flowers:	3-9 flowers on short stalk; 5-petaled; white or tinged with purple
fruit:	turns yellowish brown when ripe



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## Gourd Family

### Bur Cucumber (178)

cotyledon:	large; spoon-shaped, thick with dense short hairs
stem:	long, ridged vines; sticky-hairy; branched tendrils allow plants to climb over crops
leaves:	3 to 5 shallow lobes (pentagon- shaped), alternate, petioled
flowers:	male and female flowers arise at separate axils; 5 greenish-white fused sepals and petals
fruits:	in clusters of 3 to 20 egg-shaped, barbed, prickly pods; each pod with one seed



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## Composite Family

### Common ragweed (181)

cotyledon:	oval to spatulate, thick
leaves:	lacy, finely divided, opposite initially, then alternate; first leaves with 5 lobes
stems:	rough, hairy and branched
flowers:	male flowers in terminal clusters; female flowers in leaf axils



# Annual Broadleaves

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## Composite Family

### Giant ragweed (183)

- cotyledon: oval to spatulate
- leaves: opposite, large and 3-5 lobed; upper leaves often simple; roughly hairy
- stems: woody and 1-2 inches thick; tough, hairy; 6-14 feet tall
- flowers: male flowers in terminal clusters; female flowers in leaf axils



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## Composite Family

### Horseweed (204)

- cotyledon: round to ovate
- leaves: many leaves, no petioles; hairy; entire or toothed
- stems: covered with bristly hairs; branched at top
- flowers: many small flowers on axillary branches
- other: also called marestail; common in no-till sites



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## Composite Family

### Gallinsoga (210)

- cotyledon: oval to squarish, hairy; abruptly tapered at base
- leaves: opposite, toothed
- stems: branched, hairy
- flowers: 4-5 white ray flowers surrounding yellow disk flowers



# Annual Broadleaves

## Zomponte Family

### Prickly Lettuce (224)

cotyledon:	ovate to spoon-shaped
first leaves:	rosette of pale green leaves; no spines
later leaves:	lobed with spiny edges and spines on midrib of underside of leaves; leaf bases clasp the stem
stem:	hollow; top very branched when mature
flowers:	pale yellow flower heads that release seeds attached to a pappus
other:	leaves and stems with milky sap



## Composite Family

### Cocklebur (240)

cotyledon:	lanceolate, thick
leaves:	large, triangular and lobed; 3 prominent veins
stems:	rough texture, dark purple spots
stem & leaves:	sandpaper-like textured surface
flowers:	small, male and female separate but borne together in clusters in axils of upper leaves



# Biennial Broadleaves

## Composite Family

### Burdock (187)

taproot:	large, thick, and fleshy
rosette leaves:	huge with heart-shaped base; white-woolly below
stem leaves:	alternate, prominent veins
stem:	tough; much branched
flowers:	red-violet color; 3/4 - 1 inch across
fruit:	a bur with hooked spines





# Biennial Broadleaves

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## Composite Family

### Musk thistle (199)

- leaves: smooth, waxy; grey-green margin with a white, hairless midrib; spiny edges that extend down stem
- stems: spiny from leaf bases except right below flower head
- flowers: 1 ½ to 2 inches in diameter; rich pink color; head often tips downward



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## Composite Family

### Plumeless thistle (198)

- leaves: leaves deeply divided; hairy esp. lower surface midrib; decurrent
- stems: spiny from base to flower head due to decurrent leaves
- flowers: ¾ to 1 ½ inches in diameter; pinkish



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## Composite Family

### Bull thistle (202)

- leaves: deeply cut, spiny margins with a wrinkled surface; hairy
- spines: prominent; needle-like
- stems: spiny with decurrent leaves (extend down the stem)
- flowers: 1 – 2 inches in diameter; are flask-shaped; pink to pink-lavender





# Perennial Broadleaves

## Horsetail Family

### Horsetail (11)

- spreads: by spores and rhizomes
- fertile stems: stems hollow, not branched; easily separated joints
- vegetative stems: "leaves" in whorls at joints; looks like small pine trees
- other: most common in wet areas



## Buckwheat Family

### Curly dock (55)

- taproot: fleshy, branched, and yellow
- ocrea: long; prominent
- basal leaves: 6-12 inches with wavy edges
- stems: smooth, erect, reddish
- flowers: small greenish becoming reddish brown at maturity, found in dense clusters on branches at tip of stem



## Pink Family

### White cockle (74)

- leaves: hairy and opposite, with no petiole; softly hairy
- stems: softly hairy
- flowers: white; male & female parts on separate plants (dioecious)
- fruit: seed pods with 10 short teeth



# Perennial Broadleaves

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## Mustard Family

### Yellow rocket (86)

- rosette leaves: pinnate with large terminal lobe  
stem leaves: smooth with waxy surface  
upper leaves: clasp stem  
flowers: 4 yellow petals, similar to wild mustard but smaller



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## Mustard Family

### Hoary alyssum (87)

- stem/leaves: grey-green in color; rough hairs on whole plant  
flowers: white with 4 deeply-divided petals  
fruit: seed pods small with short "beak"



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## Spurge Family

### Leafy Spurge (118)

- roots: deep and spreading  
stems: smooth  
leaves: alternate, strap-shaped, 1/4 inch wide, usually drooping  
flowers: small and borne above greenish-yellow bracts  
fruit: explode when ripe, shooting 3 seeds, from parent plant  
other: all plant parts have milky sap





# Perennial Broadleaves

## Dogbane Family

### Hemp dogbane (134)

- roots: deep and branched
- leaves: opposite, narrow and pointed tips
- stems: smooth, reddish
- flowers: 5 greenish white petals that are slightly longer than green sepals
- fruits: long, slender pods; occur in pairs
- other: all plant parts have milky ap



## Milkweed Family

### Common Milkweed (137)

- roots: deep and branched
- leaves: opposite, thick, oblong, rounded tips, prominent veins
- flowers: pink to white in large many-flowered ball-like clusters at tip of stem and in axils of upper stems
- other: all plant parts have milky sap



## Morningglory Family

### Field bindweed (139)

- roots: deep and spreading
- stems: trailing or climbing
- leaves: "arrowhead"-shaped leaves with 3 "points"
- flowers: white or pink, funnel-shaped, 1 inch or less in diameter, found in axils of leaves
- other: flower stalks have 2 stipules below flowers



# Perennial Broadleaves

## Morningglory Family

### Hedge bindweed (140)

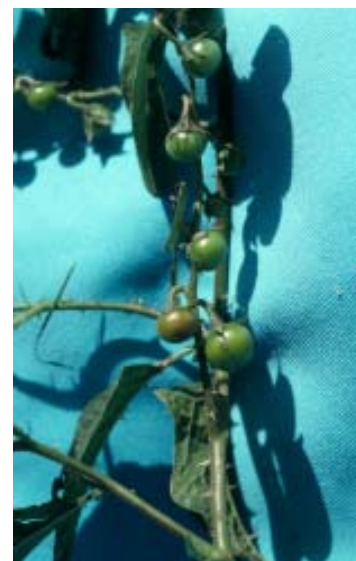
- roots: deep and spreading
- stems: trailing or climbing (similar to field bindweed)
- leaves: "arrowhead"-shaped leaves with 5 "points"
- flower stalks: no stipules below flowers
- flowers: large, 1 ½ to 2 inches, white or pinkish



## Nightshade Family

### Horsenettle (160)

- root: spreading, deep with adventitious buds
- leaves: with yellow prickles on the petioles, veins and midribs; hairy; oblong with wavy edges (like oak leaf)
- stems: with sharp, stout spines; simple or branched
- flowers: potato-like with 5 fused white to purple petals; prominent anthers
- fruits: smooth green berries to 0.5" diameter, becoming yellow; become wrinkled and hang on plants most of winter
- other: plants poisonous



## Plantain Family

### Blackseed Plantain (171)

- root: fibrous, tough
- leaves: in rosette, broad, ovate with 3 to 5 prominent veins; smooth; petioles purplish; egg-shaped, wavy margins
- flowering stems: leafless with many small inconspicuous flowers
- other: broadleaf plantain similar but lacks purple petioles and has smaller leaves



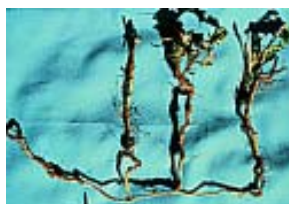


# Perennial Broadleaves

## Composite Family

### Canada thistle (200)

- roots: deep and branched
- stems: smooth
- leaves: crinkled edges and spiny margins; smooth
- flowers: pink to purple, flash-shaped rarely white,  $\frac{3}{4}$  inches wide; male and female flowers on separate plants



## Composite Family

### Perennial SowThistle (234)

- roots: spreading; shoots arise from buds
- leaves: prickly toothed, lobed; milky sap
- stems: milky juice; hollow; branch near top
- flower heads: branched with yellow ray flowers
- seeds: ribbed; with feathery pappus



## Composite Family

### Dandelion (237)

- roots: deep taproot with many buds
- leaves: lobes point to base of plant; watery, milky juice
- flowers: bright yellow with many seeds
- seeds: ribbed with barbs to aid in soil penetration; pappus aids in seed



# WWF/WPVGA/UW Collaboration - Toxicity Chart

## Toxicity Factor<sup>1</sup> Chart

Name	Active ingredient (ai)	Trade Name	Toxicity Factor <sup>1</sup> 1 lb. ai	Average Toxicity Units per Application <sup>2</sup>	EPA Resistance Mgmt Group Designation
<b>Herbicides</b>					
	Diquat	Reglone®	73	18	22
	Endothall	Desiccate®	56	56	NA
	ETCP	Eptam	69	210	8
	Glyphosate	Roundup®	40	19	9
	Linuron	Lorox®	62	31	7
	Metolachlor	Dual/Dual II®	22	42	15
	Metribuzin	Sencor®, Lexone®	115	58	5
	Paraquat	Gramoxone Extra®	81	37	22
	Pendimethalin	Prowl®, Pentagon®	102	85	3
	Rimsulfuron	Matrix®	116	2	2
	Sethoxydim	Poast®	48	9	1
	Sulfentrazone	Spartan®			14
	Sulfuric Acid		21	21	NA
	Trifluralin	Treflan®	208	208	3
<b>Insecticides</b>					
	Aldicarb	Temik®			1A
	Azinphos-methy	Guthion®	326	245	1B
	Btt	Novodor®	10	10	11A
	Cyfluthrin	Baythroid®	489	15	3
	Cyfluthrin + Imidacloprid	Leverage®	489+159	23	3+4A
	Carbaryl	Sevin®			1A
	Carbofuran	Furadan®	401	200	1A
	Diazinon	Diazanone®	360	107	1B
	Dimethoate	Dimethoate/Cygon®	360	180	1B
	Disulfoton	Disyston®	249	275	1B
	Endosulfan	Thiodan®, Phaser®	266	200	2A
	Esfenvalerate	Asana®	509	26	3
	Ethoprop	Mocap®	309	924	1B
	Imidacloprid	Admire®/Provado®	159	32	4A
	Indoxicarb	Avaunt®	118	13	22
	Malathion	Cythion®	145	182	1B
	Methamidophos	Monitor®	330	250	1B
	Methoxomyl	Lannate®			1A
	Novaluron	Rimon®	109	9	15
	Oxamyl	Vydate®	343	171	1A
	Permethrin	Ambush/Pounce®	324	43	3
	Phorate	Thimet/Phorate®	621	1560	1B
	Phosmet	Imidan®	105	105	1B
	Piperonyl butoxide	Incite®	55	28	NA
	Pymetrozine	Fulfill®	118	21	9B
	Thiomethoxam	Platinum®/Actara®	159	20	4A
	Spinosad	Spinosad®	129	8	5

# WWF/WPVGA/UW Collaboration - Toxicity Chart

Name	Active ingredient (ai)	Trade Name	Toxicity Factor <sup>1</sup> 1 lb. ai	AvAverage Toxicity Units per Application <sup>2</sup>	EPA Resistance Mgmt Group Designation
<b>Fungicides</b>					
	Azoxystrobin	Quadris®/Amistar®	47	5	11
	Basic copper sulfate		22	25	M
	Boscalid	Endura®	15	3	7
	Chlorothalonil	Bravo®/Echo®	82	82	M
	Copper hydroxide	Kocide®	36	54	M
	Copper sulfate	Bordeaux/Tribasic	21	42	M
	Cymoxanil	Curzate®	46	6	27
	Dimethomorph	Acrobat®	40	20	15
	Famoxadone+Cymoxanil	Tanos®	201	50	11+27
	Fluazinam	Omega®			29
	Mancozeb	Dithane®/Penncozeb®	185	209	M
	Maneb	Maneb®/Manex®	151	227	M
	Metalaxyl	Ridomil®	120	135	4
	Metiram	Polyram®	250	300	M
	PCNB/Quintozene	Blocker®	84	210	14
	Propamocarb hydrochloride	Previcur®	48	42	28
	Pyralclostrobin	Headline®	47	5	11
	Thiabendazole	Mertect®			1
	Triphenyltin hydroxide (TPTH)	SuperTin®/AgriTin®	385	70	30
	Zoxamide+Mancozeb	Gavel®	232	190	11+M
<b>Others</b>					
	Maleic Hydrazide	MH30 or Royal®	37	110	NA
	Harpin Protein	Messenger®	11	3	NA

<sup>1</sup> Toxicity Factors are a multiattribute system derived from four components including: (1) acute mammalian toxicity; (2) chronic mammalian toxicity; (3) ecotoxicity (4) impacts biointensive IPM (effects on beneficial organisms, bees, and resistance management) . Note: values are re-evaluated and updated annually

<sup>2</sup> Based on average applications rate. For total calculations, one must multiply toxicity factor by pounds of active ingredient of compound applied.

**Appendix C1: EPA Resistance Management Groups for potato pesticide active ingredients. (updated November 2004)**

## Insecticides

EPA Group	Chemical Group	Product(s)	Active Ingredient	Target Site of Action
<b>1A</b>	Carbamates	Sevin	carbaryl	Acetylcholine esterase inhibitors
		Furadan	carbofuran	
		Lannate	methomyl	
		Vydate	oxamyl	
<b>1B</b>	Organophosphates	Guthion	azinphos-methyl	
		Diazinon	diazinon	
		Dimethoate	dimethoate	
		Disyston	disulfoton	
		Mocap	ethoprop	
		Malathion	malathion	
		Monitor	methamidophos	
		Thimet, Phorate	phorate	
		Imidan	phosmet	
<b>2A</b>	Chlorinated cyclodienes	Thiodan	endosulfan	GABA-gated chloride channel antagonists
<b>3</b>	Synthetic pyrethroids	Baythroid, Leverage	cyfluthrin	Sodium channel modulators
		Asana	esfenvalerate	
		Ambush, Pounce	permethrin	
<b>4A</b>	Chloronicotines	Admire, Provado, Gaucho, Genesis, Leverage	imidacloprid	Acetylcholine receptor agonists/antagonists
		Platinum, Actara	thiamethoxam	
<b>5</b>	Spinosyns	Spintor	spinosad	Acetylcholine receptor modulators
<b>6</b>	Avermectin	Agrimek	abamectin	Chloride channel activators
<b>9A</b>	Feeding Disruptors	Cryocide	cryolite	Compounds of unknown or non-specific target site of action (feeding disruptors)
<b>9B</b>		Fulfill	pymetrozine	
<b>11B1</b>	Bt Microbials		<i>Bacillus thuringiensis</i> aizawai strain	Microbial disruptors of insect midgut membranes
<b>11B2</b>			<i>Bacillus thuringiensis</i> kurstaki strain	
<b>11C</b>		Novador	<i>Bacillus thuringiensis</i> tenebrionis strain	
<b>15</b>	Benzoylureas	Rimon	Novaluron	Inhibition of chitin biosynthesis
<b>22</b>	Oxadiazine	Avaunt	indoxacarb	Voltage dependent sodium channel blocker

Insecticide classes can be found at [www.irac-online.org](http://www.irac-online.org)



**Appendix C3: EPA Resistance Management Groups for potato pesticide active ingredients. (updated November 2004)**

## Herbicides

EPA Group	Chemical Group	Product	Active Ingredient	Target Site of Action
1	Cyclohexanediones	Select	clethodim	Inhibitors of acetyl CoA carboxyl (ACCase)
		Poast	sethoxydim	
2	Sulfonylureas	Matrix	rimsulfuron	Inhibition of acetolactate synthase (ALS)
3	Dinitroanilines	Prowl	pendimethalin	Seedling root inhibition
4	Phenoxy carboxylic acids	2,4-D	2,4-D	Growth regulators (synthetic auxin)
5	Triazinones	Sencor, Lexone	metribuzin	Photosynthesis inhibitors PS II Site A
7	Ureas	Lorox	linuron	Photosynthesis inhibitors PS II Site B
8	Thiocarbamates	Eptam	EPTC	Inhibition of lipid synthesis - not ACCase inhibition
9	Glycines	Roundup	glyphosate sulfosate	Amino acid inhibitors
10	Phosphinic Acid	Rely	glufosinate ammonium	Inhibitor of glutamine synthetase
14	Triazolinone	Spartan	sulfentrazone	Inhibition of protoporphyrinogen oxidase (PPO)
15	Chloroacetamides	Dual	metolachlor	Seedling shoot growth inhibitors - Inhibition of cell division
22	Bipyridyliums	Diquat Paraquat	diquat paraquat	Photosystem I electron diverters

Herbicide classes can be found at [www.plantprotection.org/HRAC](http://www.plantprotection.org/HRAC)

## Fungicides

EPA Group	Chemical Group	Product Name	Active Ingredient	Activity Group/target site of action	Risk of Resistance Development
1	Thiophanates Benzimidazoles	Tops Mertect	thiophanate-methyl thiabendazole	Inhibition of tubulin formation	high
4	Acylamines	Ridomil  Ridomil Gold	metalaxyl  metalaxyl/mefenoxam	Phenylamides affecting RNA synthesis	high
7	Carboxamides	Monocoat, Moncut Endura	flutolanil boscalid	Complex II in fungal respiration	medium
11	Stobilurin Strobilurin: methoxyacrylate Strobilurin	Quadris/Amistar Gem Headline	azoxystrobin trifloxystrobin pyraclostrobin	Quinone Outside Inhibitors	high
12	Phenylpyrroles	Maxim	fludioxonil	MAP protein kinase in osmotic signal transduction	low/medium
14	Aromatic Hydrocarbons	Blocker	PCNB/quintozene	Lipid peroxidation	low/medium
15	Cinnamic acid	Acrobat	dimethomorph	Cell wall synthesis	low/medium
27	Cyano-acetamide oxime	Curzate	cymoxanil		low/medium
28	Carbamate	Previcur Flex	propamocarb	Cell membrane permeability	low/medium
29	2,6-dinitro-anilines	Omega	fluazinam	Uncoupler of oxidative phosphorylation	low
30	Organotins	Super Tin	tri-phenyl tins	Inhibitors of oxidative phosphorylation	low/medium
M	Chloronitrile Dithiocarbamates and relatives Inorganics	Bravo, Echo, Equus Dithane, Manex, Manzate Kocide, Champ	chlorothalonil mancozeb Copper hydroxide	Multi-site activity	low
<b>Fungicides that contain more than one mode of action</b>					
1 and M		Tops MZ	thiophanate methyl plus mancozeb		high
4 and M		Ridomil Gold Bravo	mefenoxam plus chlorothalonil		high
4 and M		Ridomil Gold MZ	mefenoxam plus mancozeb		high
12 and M		Maxim MZ	fludioxonil plus mancozeb		low/medium
7 and M		Moncoat MZ	flutolanil plus mancozeb		medium
11 and 27		Tanos	famoxadone and cymoxanil		high
11 and M		Gavel	zoxamide plus mancozeb		high

Fungicide classes can be found at [www.frac.info/publications](http://www.frac.info/publications)

Appendix C4 - EPA Resistance management groups for potato herbicides AND selected rotational crop herbicides. (updated November 2004)

## Herbicides

EPA Group	Chemical Group	Potato Herbicide Product	Rotational crop herbicide choices	active ingredient
1	Cyclohexanediones	Select	Select	clethodim
	Aryloxyphenoxy propionates	Poast	Poast Assure II Fusilade Fusion	sethoxydim quizalofop fluaizifop-butyl fluaizifop + fenoxaprop
2	Sulfonylureas	Matrix		rimisulfuron rimisulfuron + nicosulfuron nicosulfuron cloransulam thifensulfuron foramsulfuron
	Imidazolinones		Steadfast Accent FirstRate Harmony GT Option Pursuit Raptor Python	imazethapyr imazamox flumetsulam
	Triazolopyrimidine			
	Dinitroanilines		Prowl Balan Treflan	pendimethalin benefin trifluralin
4	Phenoxy carboxylic acids	2,4-D	2,4D	2,4D
	Benzoic acid		Banvel, Clarity Distinct MCPA Stinger	dicamba dicamba + diflufenzopyr MCPA clopyralid
5	Pyridine carboxylic acids	Sencor, Lexone		
	Triazinones		Sencor Velpar Atrazine Princep	metribuzin hexazinone atrazine simazine
7	Triazines	Lorox		
	Ureas		Lorox Karmex	linuron diuron
8	Thiocarbamates	Eptam	Eradicane Sutan Ro-neet Prefar	EPTC, EPTC+ butylate cycloate bensulide
	Benzofuran			
9	Glycines	Roundup	Roundup, Clearout, Glypomax, Touchdown	glyphosate
14	Sulfentrazone	Spartan		Trizloinones
15	Chloroacetamides	Dual		metolachlor acetochlor alachlor s-metolachlor demethenamid flufenacet
	Oxyacetamides		Harness, Surpass Lasso Dual II Magnum Outlook Define	
22	Bipyridyliums	Diquat		diquat
		Paraquat	Paraquat	paraquat

## Fixed Cost Analysis

	Total Cost	Per Acre Cost	Example Per Acre Cost
<b>Insurance</b>			
Workmen's Comp Insurance			\$7.00
Insurance - Liability			\$1.00
Insurance On Property			\$4.00
Insurance - Irrigators			\$0.00
Insurance - Auto & Truck Liability			\$1.00
<b>Total</b>	<b>\$ -</b>		<b>\$13.00</b>
<b>Depreciation<sup>(1)</sup></b>			
Total Depreciation from Calculation <sup>(2)</sup>			\$35.00
Depreciation - Irrigators			\$0.00
Depreciation - Farm Equipment			\$0.00
Depreciation - Truck & Pickup			\$0.00
Depreciation - Warehouse			\$0.00
Depreciation - Warehouse Equip.			\$0.00
Depreciation - Houses For Farm			\$0.00
Depreciation - Office Equip.			\$0.00
Depreciation - Automobiles			\$0.00
<b>Total</b>	<b>\$ -</b>		<b>\$35.00</b>
<b>Land &amp; buildings</b>			
Lease & Rent On Land			\$175.00
Lease & Rent On Warehouse			\$0.00
Lease & Rent On Warehouse Equip.			\$25.00
Property Taxes - Land And Irrigator			\$0.00
Property Taxes - Buildings			\$0.00
Interest - Land Contr. & Working Capital			\$0.00
<b>Total</b>	<b>\$ -</b>		<b>\$200.00</b>
<b>Equipment</b>			
Lease & Rent On Farm Equipment			\$53.00
License - Pickup Trucks			\$1.00
Repairs & Maintenance. - Irrigator			\$0.00
Repairs & Maintenance. - Farm Equipment			\$0.00
Repairs & Maintenance. - Trucks & Pickup			\$0.00
Repairs & Maintenance. - Warehouse			\$15.00
Repairs & Maintenance. - Whse Equip.			\$0.00
Repairs & Maintenance. - Office Equip.			\$1.00
Estimate on Repair and Maint. <sup>(3)</sup>			\$15.00
Automobiles - Fuel & Repairs			\$1.00
<b>Total</b>	<b>\$ -</b>		<b>\$86.00</b>

continued on next page



## Fixed Cost Analysis (cont'd)

### Admin and Sales Costs

Hired Wages - Crop Production		\$0.00
Salaries & Wages - Farm Manager		\$50.00
Payroll Taxes		\$20.00
Group Health And Life Insurance		\$0.00
Employee Health & Education		\$3.00
Accounting & Admin		\$3.00
Advertising - Help Wanted		\$0.50
Office Supplies		\$3.00
Telephone		\$2.00

<b>Total</b>	<b>\$ -</b>	<b>\$81.50</b>
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### Others

Uniforms		\$1.00
Utilities - Buildings		\$5.00
Contributions		\$1.00
Dues & Subscriptions		\$0.50
Financing & bank Service Charges		\$0.30
Interest		\$0.32
Legal & Accounting Fees		\$3.00
Licenses & permitting		\$1.00
Meetings & Convention		\$0.35
Travel Expenses		\$1.00
Meals		\$0.25
Employee Training - Spray Safety		\$0.20
Other		\$5.00

<b>Total</b>	<b>\$ -</b>	<b>\$18.92</b>
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<b>Total Fixed Costs per Acre</b>	<b>\$ -</b>	<b>\$434.42</b>
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# Potato Production Enterprise Budget

## Variable Cost Analysis

<u>Expenses</u>	<u>Units</u>	<u>Cost per acre</u>	<i>Example Cost per acre</i>
Transportation (all trucking)	acre		\$81.00
Preplant Tillage <sup>(2)</sup>	acre		\$9.00
In-Season Tillage <sup>(2)</sup>	acre		\$6.00
Post-Harvest Tillage <sup>(2)</sup>	acre		\$10.00
Planting Equipment <sup>(2)</sup>	acre		\$21.00
Crop Maintenance Equipment <sup>(2)</sup>	acre		\$37.00
Harvesting Equipment <sup>(2)</sup>	acre		\$56.00
Cover Crop Costs	acre		\$5.00
Pest Scouting Services	acre		\$10.00
Consultant Services - Soil Analysis	acre		\$6.00
Federal Crop Insurance	acre		\$40.00
Hail Insurance	acre		\$15.00
Custom Field Work	acre		\$0.00
Supplies	acre		\$15.00
Utilities - Irrigator	acre		\$28.00
Seed Potatoes	acre		\$250.00
Seed Cutting/Dust	acre		\$50.00
Fertility Program	acre		\$200.00
Chemicals			
Insecticides	acre		\$100.00
Fungicides	acre		\$200.00
herbicides	acre		\$30.00
Fumigation	acre		\$150.00
Other:			
Seasonal Workers			\$15.00
Salaries			\$150.00
<b>Production Expenses per Acre</b>			<b>\$1,484.00</b>
Pest Control - Storage			
Chemical Treatment	acre		\$12.00
Sprout Inhibitor	acre		\$30.00
Wages - Storage	acre		\$28.00
Loading and Unloading Costs	acre		\$30.00
Utility Costs	acre		\$40.00
Supplies - Storage And Shop	acre		\$0.00
Other	acre		\$5.00
<b>Total Storage Expenses per Acre</b>			<b>\$145.00</b>
<b>Total Variable Expenses per Acre</b>			<b>\$1,629.00</b>

<sup>(2)</sup> If you don't know your costs for these operations, please refer to the Worksheet titled "Machine OP. Costs."

The Tillage, Planting, Crop Maintenance and Harvesting Equipment Totals include labor costs, power costs, repairs and overhead costs.

Net Return

Net return is the difference between *total gross return* and *operating costs* . The following is a comparison of different net returns with varying price/Cwt and Yields

ASSUMPTIONS		
	Total Receipts	Per Acre Receipts
Price per Cwt.	<input type="text"/>	\$ <input type="text"/> -
Marketable Yield (Cwt.)	<input type="text"/>	<input type="text"/>
Acres	<input type="text"/>	-
Gross Output (\$)		
Net Return Above Operating Costs (\$/acre)		
Operating Costs (\$/acre)		
Total Cost (\$/acre)		

Net Returns Above Operating Costs

	Yield Cwt/Acre						
	160.00	220.00	290.00	350.00	410.00	470.00	550.00
4.09	654.40	899.80	1,186.10	1,431.50	1,676.90	1,922.30	2,249.50
4.56	729.60	1,003.20	1,322.40	1,596.00	1,869.60	2,143.20	2,508.00
5.03	804.80	1,106.60	1,458.70	1,760.50	2,062.30	2,364.10	2,766.50
5.50	880.00	1,210.00	1,595.00	1,925.00	2,255.00	2,585.00	3,025.00
5.97	955.20	1,313.40	1,731.30	2,089.50	2,447.70	2,805.90	3,283.50
6.44	1,030.40	1,416.80	1,867.60	2,254.00	2,640.40	3,026.80	3,542.00
6.91	1,105.60	1,520.20	2,003.90	2,418.50	2,833.10	3,247.70	3,800.50

## Seasonal Expense Analysis

ASSUMPTIONS	Sept	Oct	Nov	Dec	Jan	Feb	March	April	May	June	July	Aug	Sept	Total
<b>Pre-Harvest</b>														
Transportation (all trucking)														
Preplant Tillage <sup>(2)</sup>														
In-Season Tillage <sup>(2)</sup>														
Post-Harvest Tillage <sup>(2)</sup>														
Planting Equipment <sup>(2)</sup>														
Crop Maintenance Equipment <sup>(2)</sup>														
Cover Crop Costs														
Pest Scouting Services														
Consultant Services - Soil Analysis														
Federal Crop Insurance														
Hail Insurance														
Custom Field Work														
Supplies														
Utilities - Irrigator														
Seed Potatoes														
Seed Cutting/Dust														
Fertility Program														
Chemicals														
Insecticides														
Fungicides														
herbicides														
Fumigation														
Other:														
<b>Pre-Harvest Cost</b>														
<b>Harvest</b>														
Vine Kill														
Harvesting Equipment <sup>(2)</sup>														
Crop Hauling														
Assessments														
Other														
<b>Harvest Cost</b>														
<b>Storage</b>														
Chemical Treatment														
Sprout Inhibitor														
Wages - Storage														
Loading and Unloading Costs														
Utility Costs														
Supplies - Storage And Shop														
Other														
<b>Storage Cost</b>														
<b>Interest on Operating Capital</b>														
<b>Other</b>														
Other														
Other														
<b>Total</b>														
<b>Total Operating Cost per Acre</b>														

<sup>(2)</sup> If you don't know your costs for these operations, please refer to the Worksheet titled "Machine OP. Costs."

The Tillage, Planting, Crop Maintenance and Harvesting Equipment Totals include labor costs, power costs, repairs and overhead costs.

\*Accounting & Admin, Advertising - Help Wanted, Office Supplies, Telephone



## Machine Operation Cost

### ASSUMPTIONS:

1. The costs associated with each type of machinery are **averages** based on **estimates**.
2. The labor rate associated with each type of machinery is based on an hourly rate of \$9.50 for unskilled labor and \$12.00 for skilled labor.
3. The rates listed are for planting, harvesting and sprayer equipment.
4. Operating costs are based on on-farm diesel, lubrication as well as repair and maintenance estimates
5. Rates are on a **per acre** basis.

### Potato Machinery Operating Costs - Estimates<sup>(1)</sup>

Type	Labor Cost		Power Cost		Repairs		Overhead		Total Cost	
Tillage Equipment										
Chisel Plow	\$	3.48	\$	1.01	\$	0.40	\$	1.19	\$	6.08
Moldboard Plow	\$	5.37	\$	2.34	\$	1.82	\$	1.54	\$	11.07
Field Cultivator	\$	1.21	\$	0.53	\$	0.27	\$	0.35	\$	2.36
Tandem Disk										
Planting Equipment										
Potato Row Marker	\$	3.80	\$	2.12	\$	0.21	\$	3.00	\$	9.13
Potato Planter	\$	4.70	\$	4.94	\$	2.07	\$	8.14	\$	19.85
Crop Maintenance Equipment										
Potato Cultivator	\$	2.36	\$	1.54	\$	0.31	\$	0.31	\$	4.52
Harvesting Equipment										
Potato Windrower	\$	7.39	\$	5.15	\$	5.13	\$	10.50	\$	28.17
Potato Harvester	\$	13.31	\$	21.08	\$	11.84	\$	9.39	\$	55.62

<sup>(1)</sup> Listed costs are based on **MINNESOTA FARM MACHINERY ECONOMIC COST ESTIMATES FOR 2000**  
by William Lazarus, Extension Economist - Farm Management, Department of Applied Economics, University of Minnesota

# Chemical Application Record

Grower: \_\_\_\_\_

Farm: \_\_\_\_\_

Field:

Crop: \_\_\_\_\_

Crop Maturity:

## DATE AND TIME

Date: \_\_\_\_\_

Start Time:

Duration (hours) :

## PRODUCT INFORMATION

Product:

Amount (units):

Target pest(s):

Product:

Amount (units):

Target pest(s):

Product:

Amount (units):

Target pest(s):

## EQUIPMENT

Wind Direction:

Wind Speed (mph)

Gallons/Acre:

Personnel :

## NOTES

# Fertility Record

Grower:	DATE AND TIME
Farm:	Date:
Field:	Start Time:
Crop:	Duration (hours) :

## FERTILIZER / MICRONUTRIENT INFORMATION

Fertilizer / Micronutrient:
Amount:
Application Method:
Fertilizer / Micronutrient:
Amount:
Application Method:
Fertilizer / Micronutrient:
Amount:
Application Method:

## EQUIPMENT

Personnel :

NOTES

## Tillage Record

Grower: \_\_\_\_\_

Farm:

Field:

Crop:

## DATE AND TIME

Date: \_\_\_\_\_

Start Time:

Duration (hours) :

## TILLAGE PRACTICES

Soil Moisture (%):

Number of Passes thru Field:

Tillage depth (in.):

If deep tillage or otherwise, describe:

## EQUIPMENT

Personnel :

## RESIDUE

Before tillage (%):

After Tillage (%):

Type of Residue:

## NOTES



# Irrigation Record

Grower:

Farm:

Field:

Crop:

Amount (in.):

DATE AND TIME

Date:

Start Time:

Duration (hours) :

Personnel :

EQUIPMENT

NOTES

# Growth & Development Record

Grower:

Farm:

Field:

Crop:

GrowthStage:

## DATE AND TIME

Date:

Start Time:

Duration (hours) :

## EMERGENCE

Emergence observed (at least 50% of plants)? Y or N

Soil Temp (F):

Air Temp (F):

Soil Moisture (%):

## TUBER INITIATION

Tuber initiation observed? Y or N

Soil Temp (F):

Air Temp (F):

Soil Moisture (%):

## PRE-HARVEST YIELD TEST STRIPS

### Number per 10 foot row

Total (lbs):

A's (%) :

B's (%) :

Culls (%) :

>10 oz.(%) :

6-9 Oz.(%) :

2-5 oz.(%) :

<2 oz.(%) :

>3.5 in.(%) :

3.0-3.5 in.(%) :

:2.5-2.9 in.(%) :

2.0-2.4in.(%) :

1.5-1.9in.(%) :

<1.5in.(%) :

## VINE KILL

Vine kill initiated? Y or N

### Green stems after vine kill

1 day (%)::

7 days (%):

10 days (%):

Harvest:

## MISCELLANEOUS

Stem Count (average of 10 plants):

### Petiole nitrate samples

Sample 1 (ppm) :

Sample 2 (ppm) :

Sample 3 (ppm) :

Sample 4 (ppm) :

# Planting Record

Grower: \_\_\_\_\_

Farm: \_\_\_\_\_

Field: \_\_\_\_\_

Crop: \_\_\_\_\_

Amount (in.): \_\_\_\_\_

## DATE AND TIME

Date: \_\_\_\_\_

Start Time: \_\_\_\_\_

Duration (hours) : \_\_\_\_\_

## SEED TEMPERATURE

7 AM (F): \_\_\_\_\_

Noon (F): \_\_\_\_\_

5 PM (F): \_\_\_\_\_

## AIR TEMPERATURE

7 AM (F): \_\_\_\_\_

Noon (F): \_\_\_\_\_

5 PM (F): \_\_\_\_\_

## PLANTING DETAILS:

Acres planted (in.): \_\_\_\_\_

Row spacing (in.): \_\_\_\_\_

Seed spacing (in.): \_\_\_\_\_

Seed depth (in.): \_\_\_\_\_

Seeding rate (cwt/acre): \_\_\_\_\_

Seed batch: \_\_\_\_\_

Wound heal (if applicable): \_\_\_\_\_

## SOIL INFORMATION

Soil Moisture (%): \_\_\_\_\_

Soil Temp(F):	7 AM	noon	5 PM	
2 in.				
4 in.				
6 in.				
seed depth				

## EQUIPMENT

Personnel: \_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

## DESCRIPTION OF PLANTED AREAS

## NOTES

# Daily Harvest Record

Grower:

Farm:

Field:

Crop:

GrowthStage:

## DATE AND TIME

Date:

Start Time:

Duration (hours) :

## PULP TEMPERATURE

7 AM (F):

Noon (F):

5 PM (F):

## AIR TEMPERATURE

7 AM (F):

Noon (F):

5 PM (F):

## HARVEST DETAILS

Acres Harvested:

Average Yield (cwt/A)

Amount per Day placed in storage (cwt)

Maximum Pulp Temperature (F):

## STORAGE BINS

Bin 1 (cwt):

Bin 2 (cwt):

Bin 3 (cwt):

Bin 4 (cwt):

Bin 5 (cwt):

Bin 6 (cwt):

## SOIL MOISTURE

7 AM (%):

Noon (%):

5 PM (%):

Variety:

Personnel :

## EQUIPMENT

Adjusted Harvester to limit bruising ? Y or N





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