Preplant

Planting

In-season

Harvest

Post-harvest

A3844

BioIPM

Pepper Workbook

Authors

Deana L. Knuteson, Nutrient and Pest Management Program

Walter R. Stevenson, Department of Plant Pathology

Jeffrey A. Wyman, Department of Entomology

Alvin J. Bussan, Department of Horticulture

Jed B. Colquhoun, Department of Horticulture

Carrie A.M. Laboski, Department of Soil Science

Erin M. Silva, Department of Agronomy

UW Extension Cooperative Extension

University of Wisconsin-Madison, College of Agricultural and Life Sciences, University of Wisconsin-Extension, Cooperative Extension

Introduction

This Pepper BioIPM Workbook is written for growers and the vegetable industry. It is organized seasonally to provide a comprehensive, year-round self-assessment tool and reference on pest management and cultural practices of pepper production systems. The workbook is organized into multiple chapters: preplant, planting, in-season, harvest and post-harvest management. 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 for farms to select current production practices. This self-evaluation section is formatted on a scale, from A to D. A is the minimal practice that can be used, increasing to Category D that describes advanced and 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. 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 for categories A to 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 consider the biologically based practices that may not currently be part of their pepper production system.

When the Wisconsin state symbol is noted, the information is specific to Wisconsin soils.

All photographs were contributed by the authors and editing staff, unless otherwise noted.

Please visit the Nutrient and Pest Management program's website at ipcm.wisc.edu for more IPM and nutrient management publications.

Funding for this workbook provided by USDA-FAS/OCBD.

An equal opportunity action employer, University of Wisconsin-Extension provides equal opportunities in employment and programming, including Title IX requirements.

Reproduction or use of this document in any form without the express written permission of the University of Wisconsin is prohibited. Please send request for permission to :

Deana Knuteson
University of Wisconsin, Nutrient and Pest Management Program (NPM)
445 Henry Mall, Madison, WI 53706
Fax: (608) 262-7743

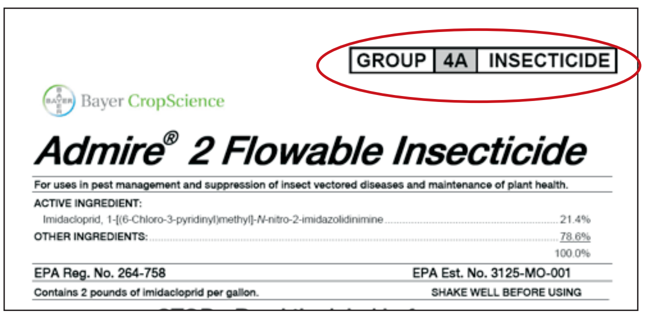
Editing and Layout:
UW NPM Program:
Mimi Broeske
Kit Schmidt
Julie Meyer
Molly Dobberke

Table of Contents

Pesticide Resistance Management in Rotational Years

Preplant

Resistance management is essential to maintain the efficacy of available pesticide groups in the pepper system. Growers need to consider resistance management strategies between rotational crops, both within and between fields. The goal is to avoid consecutive use of products from a single pesticide group, or two products with similar sites of action, against the same target pest.



Example of pesticide label with EPA Resistance Management Group information.

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 not considered when managing pests in rotational crops.***
- ☐ **B.** ***During rotational years, herbicides are chosen with a different chemical site of action than likely pepper herbicides.***
- ☐ **C.** ***Insecticide and fungicide chemistries are alternated on an area-wide basis according to the EPA resistance management designations.***
- ☐ **D.** ***BioIPM strategies are implemented including cultural control methods to manage pepper pests in rotational crops.***

A. Resistance Management 101

Growers are aware that they should implement resistance management strategies in the pepper cropping season. Growers must also use resistance management strategies from cropping season to cropping season so that insects, plant pathogens, and weeds are not exposed to the same groups of pesticides in consecutive applications, whether the exposure takes place within or between years (e.g. from the previous year to current year).

General resistance management strategies that 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 pesticide groups between applications.
- Controlling known pepper pests in rotational years by using different pesticide groups labeled for rotational crops that may not be registered in peppers.
- Utilizing BioIPM strategies that decrease reliance on pesticide use.

Pesticide Groups

Pesticide groups include products with similar chemical structures and have common target sites of action. The pesticide groups have been defined by fungicide, insecticide and herbicide resistance action commitees.

B. Rotational Crop Resistance Management

HERBICIDES

Rotational resistance management strategies can be very effective to control weeds during the non-pepper years, since there are few herbicides available for peppers and it is essential to maintain the registered herbicides on peppers. Certain problem weeds, such as nutsedge may be difficult to control in peppers due to limited activity with labeled herbicides. In addition, resistance to graminicides (grass herbicides) has been observed in several species worldwide. However, resistant grasses can be controlled in rotational crops with herbicides with different modes of action not labeled for pepper. Limiting the weeds that contribute to the seed bank will reduce populations in subsequent pepper crops. When using this strategy, chemical classes that are not available for the pepper crop should be used when possible, and chemical classes should be alternated between years.

Examples of rotational resistance management strategies for the pepper cropping system include:

- Use herbicide tank mixes of different pesticide groups during the non-pepper year.
- Rotate herbicides each year to prevent resistant weed selection to repeated exposure to the same chemical group. For example, if sethoxydim is applied during the pepper crop year, do not apply herbicides that are in the same group in rotational crops. The EPA resistance management designation codes for herbicides are found in the **In-Season Resistance Management** section.

Pests to watch for resistance development

Insects: aphids

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

Diseases: bacterial spot

C. Area Wide Resistance Management

INSECTICIDES

Insecticides with the same EPA resistance management designation code (see **In-Season Resistance Management** section for codes) should not be applied consecutively. Certain insect species have been shown to develop resistance quickly and maintaining insecticides in the toolbox is important for their management.

European corn borers overwinter as full grown larvae, usually living on old corn stalks and stubble, in the stems of weeds and hosts, or stems of host vegetables left in the field. In spring, the larvae pupate and new adult moths emerge to fly at night and lay eggs in susceptible crops. To limit the possibility of resistance developing, ECB insecticidal control methods should rotate from the previous season to the current cropping season. This limits the ECB exposure to insecticide from the same group. Use this general resistance management strategy for all pests that may migrate short distances between cropping seasons.

Resistance Concerns

If a grower has a concern that a population of weeds, insects, or plant pathogens is becoming resistant to a specific pesticide, an accurate sample and test should be done to confirm resistance. Many university laboratories and private companies have testing procedures for evaluating the pesticide resistance of weed populations. Consult the individual labs for specific sampling protocols. Laboratory documentation would confirm if resistance is present, and would therefore allow growers to alter their management strategies.

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.

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.

Notes:

Rotational Pest Management

Preplant

© M.E. Bartolo, Bugwood.org

© M.E. Bartolo, Bugwood.org

Cultural pest management strategies should be utilized in rotational crops to control pepper pest numbers during the pepper 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. Pepper pests were not culturally managed in rotational crops (in the field when peppers are not planted).***

☐ ***B. Cull peppers and/or other plant residues are eliminated. Weed escapes are controlled before they go to seed.***

☐ ***C. Weed, insect and disease problems are controlled using a variety of BioIPM techniques in rotational crops (e.g. European corn borer, hard to control weeds such as nightshades).***

☐ ***D. Field maps of insects, diseases, and weeds are maintained for long-term comparisons and evaluation of management strategies.***

A. Rotational Pest Management 101

Pest populations in the vegetable cropping season can be greatly limited if proper management strategies are utilized in the non-pepper years. Utilizing a variety of BioIPM strategies during the non-pepper crop will reduce in-season pest pressures. Proper planning and implementation of various strategies will greatly enhance pest management programs during the pepper season, and could decrease pest populations and limit pesticide usage. To effectively incorporate these various strategies, field maps showing pest numbers should be maintained from year to year. Areas with high pest pressures should be targeted when they are vulnerable in the non-pepper cropping years.

B. Destroy Cull Peppers and/or Plant Residues

To reduce inoculum sources for disease outbreaks, peppers should be completely plowed down within two weeks of harvest. Pathogen inoculum, such as the bacterial leaf spot pathogen, can overwinter in pepper residue, and eliminating these sources can greatly reduce pathogen populations in the subsequent growing season. Furthermore, European corn borer larvae will overwinter on plant debris. Shredding or plowing down plant residue will limit subsequent-year ECB populations.

C. BioIPM Techniques

INSECTS:

European Corn Borer There are many hosts of European Corn Borers (ECB), but plantings of field or sweet corn are the most common sources of overwintering populations. The European corn borer overwinters as mature fifth instar larvae in corn stalks and the stems of weedy vegetable hosts. Pupation occurs in spring with the first moths emerging shortly thereafter. 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. Corn stubble should be shredded or plowed under before adults emerge to destroy overwintering habitats. European corn borer adults begin to emerge in late May to June.

WEEDS:

Mechanical, physical, biological, or cultural practices should be utilized in the non-pepper years in and around the field to limit the number of seeds entering the seed bank. Tillage, burning, or other operations around field edges should occur before flowering to ensure that weeds do not contribute more seeds to the weed seed bank.

Spot spraying of weed patches around fields, and mowing or tilling operations on field edges during the non-pepper years are effective strategies if implemented prior to flowering.

Some herbicides can be biologically active at extremely low rates and residues are found in the soil for a long time (such as some sulfonylurea and imidazolinone products). There are various plant-back restrictions for these materials, so read the herbicide labels to ensure that they fit into the pepper system.

Crop rotation is an important part of any weed management program. Certain weeds naturally become associated with certain crops because of similar life cycles or similar growth requirements. If any one crop is grown continuously, weeds associated with that crop (such as wild proso millet in sweet corn) 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.

Quick note

Any corn stubble should be tilled under in areas that are known or expected to have high ECB populations. Cleaning up weedy, grassy areas around fields can reduce borer pressure as well.

D. Field Maps

Field maps designating areas where insect, disease and weed populations are found should be kept for long-term comparisons. Maps allow growers to become better managers by focusing on key concerns within fields, and by avoiding pests in the pepper cropping system when possible.

Field maps show an overview of a particular farm. Field maps can be created on a computer or drawn by hand and should include areas that were infested by insects, weeds, or disease the previous years and can track pesticide use, soil fertility, or yield and quality of previous crops.

Field maps should be used as a resource during field selection when planning crop rotations.

1) Draw an overview of the entire farm. This should include all of your fields.

2) Record what was planted in each field, including varieties.

3) Mark insect infestations from the previous year with X's or your choice of symbol. Be sure to differentiate between different pests.

4) Mark disease infestations from the previous year with stripes or your choice of 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).

Global Positioning Systems (GPS) and Geographic Information Systems (GIS)

Global Positioning Systems (GPS) and Geographic Information Systems (GIS) technologies can be used for a geo-referenced spatial interpretation of data. In agricultural systems, these data can be used to quantify sub-field similarities and/or differences in crop yield, quality, pest populations, soil fertility or pH. These data can be used to target agricultural inputs such as pesticides and fertilizer applications on a site specific basis.

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

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

Procedure:

1. Mark individual field boundaries using a GPS unit.
2. Mark all scouting sites 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 population distributions and dynamics.
7. Incorporate all crop year information into the database.

Pest Population Notes

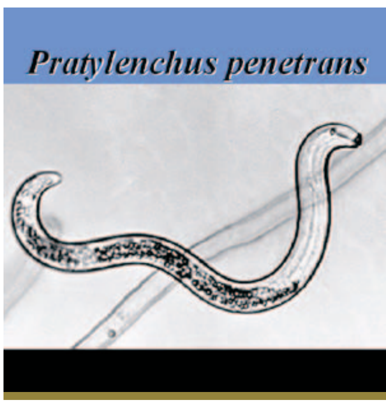
Complete field notes and histories of pest populations should be kept on pepper fields. Keep careful notes on long-term pest concerns such as fields with a history of root knot nematodes, aphids, pythium, cercospora, phytophthora blight, tomato spotted wilt, and bacterial spot. Knowing the exact locations of these pepper pest problems will allow growers to 1) determine if peppers should be planted in the field or not, and 2) avoid “hot spot” locations in those fields; resulting in better production and pest management.

Notes:

Soil Sampling

Preplant

Soil sampling is essential to ensure appropriate fertilizer recommendations. 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 and analysis 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.***

☐ ***B.*** ***Each field is sampled for root knot nematode levels before deciding to fumigate or plant peppers.***

☐ ***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 nutrient needs, pH, and organic matter levels. The following is detailed information on soil sampling.

NUMBER OF SAMPLES:

One composite sample should be taken for every 5 acres within the field. This will account for spatial variability across the field. Spatial variability across a field could have a great impact on liming practices, fertility programs, and pepper production potential.

FIELD AREA PER SAMPLE

Within each five acre area, collect a composite sample of 10 to 20 cores taken along a W-shaped pattern. Each sample area should have a similar crop and fertilizer history over the last two years as well as similar soil characteristics. Sample small areas within the field that differ topographically if they are large enough to warrant special treatment.

WHEN TO SAMPLE

Soil samples may be taken in the fall or the spring before the pepper crop is planted. Fall sampling ensures that the test results are ready prior to planting. Be aware of situations that may cause nutrients to leach beneath the root level between sampling and planting such as heavy rainfall or excessive pre-irrigation.

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. Sampling depth should be maintained 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, and available nutrients.

HANDLING AND MAILING

To obtain a composite soil sample, mix sub-samples thoroughly. From the mixed sample, put 1 to 2 cups into a clean paper bag. Take the sample to a local university extension office or fertilizer dealer for analysis.

Soil Test Results

Proper interpretation of the soil test results will allow growers to plan their fertility programs appropriately to ensure proper crop growth, production, and quality while limiting adverse environmental effects. Requirements for nitrogen, phosphorus, potassium, and liming needs can be derived directly from the soil test results. Results provide a current measurement of organic matter percentage and soil pH.

The soil analysis also provides secondary and micronutrient analysis (in ppm) including calcium, magnesium, boron, manganese, zinc, and sulfur if requested.

Using the test results from analysis and the corresponding fertility recommendations will provide adequate nutrition for the pepper crop.

Notes:

B. Sampling to Inform Fumigation Decisions

Root knot nematodes can cause a tremendous yield loss to susceptible peppers. Usually, fumigation for peppers is not economically viable and it is a better alternative to avoid fields with high nematode populations. Fumigation should only occur if high levels of nematodes are detected through soil sample results or if a strong field history of nematode populations is known to be present in the field (verified through cropping mappings and field histories). Only use a fumigant for peppers if it would also be needed for other crops in the rotational system.

Quick Note:

Fumigation should rarely occur specifically for pepper production.

Notes:

C. Organic Matter

Organic matter quality and quantity is directly related to many key soil quality indicators. Small increases in organic matter content can have many beneficial effects on soil health, including providing carbon and energy sources for soil microbes, stabilizing soil particles, increasing soil nutrient availability, resisting compaction, and filtering environmental pollutants. Practices that may increase soil organic matter (such as cover crops, green manures, residue management, tillage systems, organic amendments) should be implemented when possible, and the changes in organic matter content should be tracked from year to year for long-term comparisons.

Certain soil types may vary in organic matter content. Organic matter content affects availability of nitrogen in soils. Decomposition and mineralization of soil organic matter leads to increased plant available nitrogen. As a result, increasing soil organic matter content leads to a general decrease in the amount of nitrogen fertilizer required to optimize crop productivity.

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 have proven that the strategies are effective and economically feasible.

Quick Note:

Soil pH should range from 5.5-6.8 for pepper production. The pH should not exceed 7.0.

D. Advanced Screens of Soil Characteristics

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 enhance crop productivity, increase 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 by outside forces (usually associated with tillage, water or wind). 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 infiltration and improved root growth.
- Water holding capacity - water that can be retained by soil. Increasing water holding capacity increases plant available water, decreasing the need for irrigation.
- 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 includes fractions that are very easily degraded (mineralized within 1 to 5 years) to fractions that are extremely resistant to breakdown or recalcitrant (turnover times from 50 to 1000’s of years). Different soil carbon 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. Active soil carbon 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 incorporating organic materials like crop residues, green manures, and organic amendments (manure, compost, paper mill residuals, cannery wastes, etc.) can improve many soil properties including 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).

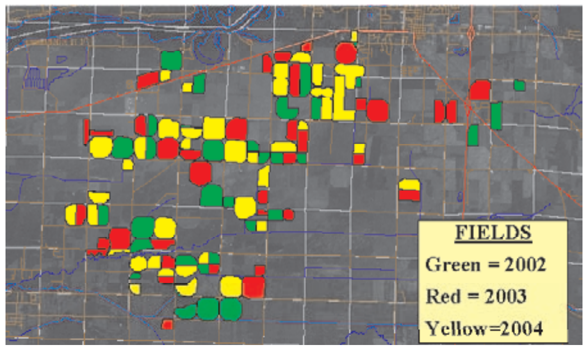
Quick Note:

Growers can manage pH levels by liming or adding organic amendments to the soil during the rotational cropping system. The time required before pH is adjusted will depend on lime particle size. The smaller the particle size the faster pH responds. Lime is usually applied 6 to 18 months before the target crop is planted (see **Plant Nutrition** section).

Field Selection

Preplant

Pepper health management begins with selecting the appropriate planting site. Field placement and selection should be based on several pest and crop management considerations.



Example of Spatial Field Locations

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

☐ A. *Peppers are rotated across fields on a three-year (or more) schedule.*

☐ B. *Crop rotations are planned by using crops that limit the buildup of disease, insect, weed, and nematode concerns.*

☐ C. *Spatial rotations are considered in field selection decisions.*

☐ D. *Fields are mapped to monitor pest populations over time.*

A. Temporal Rotation

Peppers should not be grown on fields where they were planted the previous year. Temporal (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 peppers were last planted. An example of a three year rotation is peppers-snap beans-peas-peppers.

Spatial rotation – refers to the distance from the current pepper fields to last year's pepper fields.

B. Rotational Crops

Viable rotation crops for pepper include oats, sweet corn, rye, wheat, field corn, vine crops, and onion. These crops should be grown in some rotation for at least two complete growing seasons prior to returning to peppers. Crops that should not be grown in rotation with peppers include snap beans, celery, potato, canola and crucifers. These crops should be avoided when possible due to nematode and other plant pathogen concerns. Rotations involving corn and sweet corn will build Eurpoean Corn Borer populations and require additional cultural management such as shredding or plowing of residue.

C. Spatial Rotations

The distance between the current and the previous season's pepper crop can have an effect on pest complexes. Considering the spatial dynamics and migration patterns of pests when determining crop locations can help limit pest infestations. In general, the longer the distance between the current and previous year's crop the better. For example, European Corn Borer (ECB) populations will overwinter in corn stubble in the previous year's corn field or in the stems of the previous year's pepper crop. Therefore, it is important to remove or shred corn residue and to not plant peppers adjacent to the previous year's corn or pepper field to limit ECB infestations once they emerge and begin flying to the next host crop.

D. Field Mapping

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 strategies. Field mapping systems should be used to designate possible field concerns. For example, if the field had soil-borne pest problems, rotate to a non-host crop to reduce the pest populations. Information on field mapping practices can be found in the **Rotational Pest Management** section.

Problem pests and concerns to consider may include:

- Insects — such as aphids, European Corn Borer.
- Disease — root knot nematodes, cercospora, phytophthora blight, bacterial spot, tomato spotted wilt virus, and non-persitent viruses such as cucumber mosaic virus and potato virus Y.
- Weeds such as pigweed, nightshades, foxtails, wild proso millet, marestail, smartweed, and common lambsquarters.
- Production information such as yields, quality, and marketability.

Seed Selection

Planting

© Howard F. Schwartz, Colorado State University, Bugwood.org

Seed selection and careful handling ensures vigorous seedling growth while limiting seed 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. Clean seed is used.***
- [ ] ***B. Certified pathogen free and tested seed is purchased.***
- [ ] ***C. Seeds are handled and treated appropriately prior to planting.***
- [ ] ***D. Varieties are selected for disease, nematode, and insect resistance.***

A. Clean Seed

To ensure a good start to the pepper production system, only pathogen free seed should be planted. It is critical to begin the season with pathogen free seed and/or transplants since pests of peppers can be transmitted via infected seed (bacterial spot) or by transplants (many insect pests).

B. Certified Seed

Planting only certified and tested seed is a crucial phase in the pepper BioIPM system, and is the foundation of any management program for a productive pepper crop. Non-certified seed may contain viruses or other pathogens that may cause problems during the season.

Certified seed must meet phytosanitary standards established by the international seed trade industry. These standards reduce the possibility of the introduction of disease-causing pathogens or micro-organisms on seeds. Clean seed means it has a phytosanitary certificate.

Be sure to plant only weed-free pepper seed. Historically, crop seed has been a major source of new weed introductions in agriculture. Moreover, the weed seed found in crop seed often includes species that are difficult to manage and thus escaped control in the seed crop.

Peppers are solely produced from transplants in Wisconsin. Make sure soil in transplants has been sterilized to prevent introduction of pathogens or weeds.

Notes:

C. Seed Handling and Treatment

Pepper plants are grown from transplants that can be bought directly from the seed dealer. However, if growing their own transplants, growers should use healthy seed. Pepper seeds should be started six to eight weeks prior to field transplanting.

Seeds used for pepper production may need to be treated with a fungicide to limit pythium damping-off concerns.

To limit bacterial spot concerns, a hot water dip or soak should be used to produce *Xanthomonas*-indexed seed. To apply this method, use a hot water dip or bath and soak the seeds in warm water (at least 126°F/52°C – precise temperatures are important) for 25 minutes. At the end of 25 minutes, remove the seed from the water bath and dip in cold clean water. Seed must be dried immediately to prevent sprouting. To achieve the same result and to limit bacterial spot concerns, seeds can also be soaked in a 1.08% sodium hydrochloride bleach solution for 40 minutes under constant agitation. One gallon of this solution will treat one pound of pepper seed.

D. Variety Selection

Pepper varieties are usually selected based on market analysis. However, resistance of the variety to pests should also be considered when determining your selection. Pepper varieties are now available that are resistant to nematodes, viruses, and bacterial spot. Short lists of these varieties are found below. More complete descriptions of the varietal resistance can be obtained from your seed dealer or in seed catalogs.

Nematode resistant varieties: Charleston Belle, Carolina Cayenne,Carolina Wonder.

Disease resistance (bacterial spot) varieties: Sentinel, Camelot X3R, Boynton Bell, Commandant.

Viral resistance: available for tobacco mosaic virus, potato virus Y, and cucumber mosaic virus.

Planting Process

Planting

both photos © Howard F. Schwartz, Colorado State University, Bugwood.org

A good stand of peppers is essential to maximize crop productivity and quality while minimizing the effect of plant pathogens and pests. Environmental conditions at planting, accurate equipment, careful planting processes, and healthy transplants all contribute to the quality and stand 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. Peppers start with transplant production in a greenhouse setting.***

☐ ***B. Planting occurs at proper row and plant spacing.***

☐ ***C. Planting occurs at proper soil and air temperatures.***

☐ ***D. Cultural pest management strategies are utilized during the planting process.***

A. Pepper Transplant Production

Commercial pepper growers usually buy transplants to plant into their fields, but growers can also produce their own transplants from seeds. This allows selection of specific varieties to meet customer or market needs as well as transplant quality.

Seed handling tips can be found in the **Seed Selection** section. An ounce of pepper seed produces just over 200 plants so determine seed and transplant needs based on desired plant population. Greenhouse production of transplants should start with seedlings six to eight weeks prior to field planting.

Make sure that transplant production is done in tobacco-free areas. Tobacco residues contain tobacco mosaic virus which is easily transmitted mechanically. The virus will severely limit pepper growth. Workers handling seed and transplants should periodically wash their hands in a phosphate-based soap to remove viruses and reduce the chance of virus transmission.

Compaction Management:

Soil compaction can minimize root development of transplants and increase transplant shock. To prevent surface soil compaction:

a. Do not till soils that are too wet.

b. Incorporate green manures, cover crops, or plant residues to improve soil organic matter and surface soil structure.

c. Minimize wheel traffic over the crop row and limit wheel traffic on wet soils.

d. Minimize the number of tillage passes (increased tillage degrades soil structure).

e. Plant deep-rooted crops to create macropores in compacted soil layers.

B. Proper Planting

Transplants should not be planted in the field until frost danger has passed, usually late May to early June in southern and northern Wisconsin, respectively. Transplants should be cold hardened for 5 to 7 days prior to field planting to minimize cold shock. Place transplants in cold frames to protect from winds and cool nighttime temperatures. Place shade cloth or other open cover over the plants to reduce direct light and prevent canopy damage from intense sunlight.

Peppers should be planted in rows spaced from 18 to 36 inches apart with transplants spaced 18 to 24 inches apart within the row. This results in a planting population of around 15,500 plants per acre. The planting configuration should encourage shading of the plants to decrease sun-scald concerns during the growing season.

Plastic mulch can improve soil temperatures and canopy microclimate under cool conditions and increase crop maturation, yield, and quality. Plastic mulch should not transmit light. Place the mulch in the field immediately after final tillage, 5 to 10 days prior to transplanting. This warms soils and prevents water loss due to evaporation prior to planting.

Pepper transplants should only be planted to the depth of the root ball. Do not bury pepper stems because planting pepper transplants too deep can limit growth. Deeper soils are colder and increases the potential for transplant shock.

Quick Note

Sun-scald can be a concern in peppers when the plant is stressed and already defoliated by diseases. Sun-scald forms bleached, sunken tissue on the fruit. These injured areas can be sites for secondary infections.

C. Planting Temperatures

Peppers are a warm season crop that grow sbest at temperatures of 70-80 degrees F during the day and 65-70 degrees F at night. Peppers will not grow when temperatures are below 50 degrees F, and poor fruit set can occur below 60 degrees F and above 75 degrees F. Night temperatures of less then 72 degrees will result in poor fruit set. Temperatures greater than 90 degrees F or below 55 degrees F can result in blossom drop.

Peppers should be planted when air temperatures range from 65 to 85 degrees F. Planting should not occur when temperatures are above 95 degrees F. Soil temperatures should be between 70-75 degrees F at planting. Planting should not occur when soils are below 68 degrees F.

Quick Note

These methods promote early transplant growth by trapping heat and increasing soil and air temperatures. To extend the season, growers can use:

- Plastic mulch
- Floating row covers
- Tunnels and cold frames
- Windbreaks
- Wavelength selective technologies or infrared transmitting (IRT) mulches

D. Cultural Pest Management Strategies

A range of biologically based pest management strategies can be used at planting to ensure limited pest populations later in the season. Some of these strategies include:

- Clean machinery from field to field to limit plant pathogen and weed spread. This usually occurs at the field entrance and tillage then spreads them though the field. To clean, remove all soil from the implement and tires (by pressure washing), and then spray all equipment parts coming in contact with the soil with a disinfectant. Disinfectant applications can be made with a simple hand sprayer before entering each field.
- Plant a perimeter trap crop for pepper maggot control. Planting 20-25 feet of hot cherry peppers as a trap area around the field greatly reduces maggot infestations into the main field.
- Use the stale seedbed method by preparing seedbeds about 2 weeks prior to transplanting. Control early-emerging weeds prior to planting with an appropriate non-residual herbicide, thus removing the first flush of weeds. The crop is then planted without additional tillage into a weed-free seedbed. Be sure to check the herbicide label for the required time between application and pepper planting.
- Keep a field fallow for at least one year or longer for nematode control.
- Use reflective mulches for insect control. This can be effective for aphid and thrip control but can also lead to sun-scald on fruit.
- Use living mulches to smother weeds in the crop row to reduce reliance on cultivation or weeding. Mulches minimize soil contact with vegetation and fruit, improving quality and storability.
- Plant early to avoid late season European Corn Borer (ECB) infestations.
- Stake plants to maintain upright growth and minimize lodging due to wind. This prevents fruit contact with soil. In addition, this maintains leaf cover over developing fruit thus decreasing sun-scald.

High Tunnels

High tunnels provide the opportunity to modulate temperature and maintain optimal conditions. High tunnels have a greenhouse frame covered with a single or double layer of plastic inflated with forced air using fans. High tunnels can have supplemental heat, but seldom have supplemental light. Crops are typically planted into soil in high tunnels.

High tunnels can extend the Wisconsin growing season by 60 to 120 days depending on supplemental heat. Peppers and other summer annual crops can be planted in late February or early March in Wisconsin with supplemental heat. Crops can be maintained in the fall until late November or early December.

Proper temperature monitoring, heating, and ventilation will maximize pepper production within high tunnels. During early spring, the tunnel captures sun energy in the form of heat which maintains warmer temperatures around the clock. During summer, the tunnel intercepts light, reducing incoming light energy. Proper ventilation can then dissipate the heat from the tunnel. Not only does the tunnel allow for season extension, but tunnels optimize conditions for maximum productivity. Per plant yield potential within the tunnel can be 50 to 200% higher than in the field.

Temperatures in high tunnels can be increased. For example, maximum air temperatures inside the tunnel were 20 to 40 degress F higher during the day than outside in the spring.

In addition, high tunnels can be used to decrease temperatures during summer months with proper ventilation. Air temperatures in mid to late June exceeded 90 degrees F outside the tunnel, but inside air temperature ranged from 78 to 85 degrees, which is optimal for pepper growth. This also minimized the potential for flower and fruit abortion due to high temperatures.

Notes:

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 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 that maintain efficacy of chemical groups are an important component of IPM programs. The principal components of IPM programs are:

- Decision making tools, scouting and economic thresholds.
- Utilization of multiple 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 general IPM principles. Specific IPM strategies are also described in other sections for use throughout the production year.

B. Chemical Management Decisions

Chemical control measures are often 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. IPM programs use tools to provide adequate information on when to initiate fungicide spray programs.

Crop Health

Crop health should be maximized to optimize nutrient use, growth, and productivity while minimizing pest effects. To do this, growers must have a knowledge about resource requirements of the crop to maximize yield and quality, and must understand life history of pests and the vulnerable pest stages for optimal management.

On-line resources for Resistance Management Classifications:

Fungicide Resistance Action Committee
http://www.frac.info/frac/index.htm

Insecticide Resistance Action Committee
http://www.irac-online.org/

Herbicide Resistance Action Committee
http://www.plantprotection.org/HRAC/

When selecting chemical control measures, proper resistance management strategies are also needed. For more information, read the handbook's **Resistance Management** sections and look at the resistance management groups for insecticides, fungicides, and herbicides.

C. Pest Life Cycles and Ecology

Implementation of IPM programs require growers' knowledge of pest life cycles, 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 pests' 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 peppers are described below.

DISEASES:

Bacterial spot is a bacterial disease that produces small brown lesions on all above ground plant parts. It is caused by *Xanthamonas campestris*, a bacterium that overwinters in infected plant debris. This infected debris is the primary source of infection in new pepper plantings. This pathogen can be seed borne.

Cercospora leaf spot is a fungal disease that is spread by water and wind. Wet conditions are needed to initiate the disease. The fungus overwinters on plant debris or weed hosts.

Phytophthora blight is a fungal disease of peppers, cucurbits, and other crops. Phytophthora causes water-soaked lesions to appear on the plant. This pathogen can lead to high plant mortality, severe fruit rotting, and yield loss. *Phytophthora capsici* overwinters on infected plant leaf material.

CMV virus on pepper

Several viruses (**cucumber mosaic virus (CMV), tobacco mosaic virus (TMV), tobacco etch virus, pepper mottle virus, and others)** can infect peppers. The viruses are spread primarily by aphids (CMV) or contact (TMV). Viruses are commonly found in weed reservoirs where insects can acquire the viruses for subsequent transmission.

Non-persistent Viruses

Many viruses of peppers, such as the cucumber mosaic virus (CMV), are transmitted by aphids in a non-persistent manner. This means that aphids can pick up the virus very quickly, and then transmit it to other plants in a short amount of time. In this system, a few aphids can infect a large section of the field. For these types of viruses, insecticides are not an effective control method since the virus can already be spread prior to the insect's death.

Prevention methods, such as reflective mulches that prevent aphids entering the field, or aphoil sprays that prevent transmission should be used. Avoiding dark brown field perimeters by planting wheat, grass, etc. helps to avoid edge effects. This allows aphids to "clean" their stylets on non-host plants before moving into the crop field.

INSECTS:

European Corn Borer is difficult to control because of the short time interval between egg hatch and fruit tunneling. The female moths lay eggs in masses on the underside of leaves, and eggs hatch in 4-7 days. Weather conditions during egg laying affect the severity of infestations. There are normally 1-2 generations in temperate regions with up to 5 generations possible in warmer climates. Damage is caused primarily by generations where peak adult flights coincide with the presence of pepper fruit.

Aphids are small, soft bodied insects that feed on the underside of leaves and can build to large numbers rapidly. The primary damage results from the transmission of viruses (e.g. CMV) by winged aphids entering the crop from outside sources. Green peach aphids are the most common species. Green peach aphids overwinter as eggs on bark of peach, plum, apricot, or cherry trees. In mild climates, wingless females reproduce continually without mating, depositing live nymphs that feed and mature in 2-3 weeks before depositing new nymphs. In this way, populations can increase rapidly. When overcrowding occurs, winged females are produced that disperse to new food resources and deposit wingless females. In temperate climates, winged aphids are produced that undergo a sexual cycle and lay overwintering eggs on prunus trees and shrubs. These eggs give rise to nymphs that develop into winged females in spring and migrate to susceptible crops. Over three hundred plants can serve as hosts for green peach aphid.

Flea beetles are small, dark beetles that overwinter as adults in leaf litter, in hedgerows, in windbreaks, or in wooded areas. The beetles emerge in spring (after temperatures reach 50 degrees F) and begin infesting plants. Adults lay eggs in the soil that hatch 10-14 days later, and larval stages infest plant roots, but rarely cause economic damage. Feeding looks like tiny shot holes in leaves and is most serious on small plants.

Corn earworms do not overwinter in Wisconsin, but migrate from southern states. Adult moths fly at night, and typically arrive in Wisconsin in late July. Eggs are laid on the plant; larvae hatch and begin feeding for about a 2 week period. There is only one generation of corn earworms per year.

WEEDS:

The term ***broadleaf weed*** usually describes 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 arrangement of the leaves which will vary for different species. Some broadleaf weeds have leaves arranged alternately on the stem, some have leaves arranged opposite each other, and some have leaves arranged in a rosette about the stem.

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

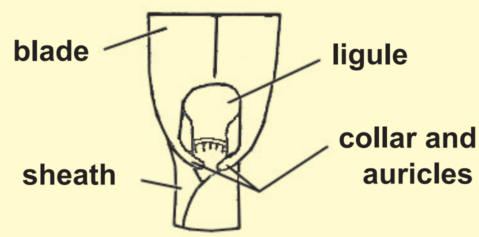
Problem Weeds in Peppers

Weeds of concern in pepper production include nightshades, pigweed, common lambsquarters, nutsedge, foxtails, and wild proso millet.

Grass weeds are typically monocots, and most **annual grasses** have narrow leaves with parallel veins. To ensure proper control measures, correctly identifying grasses found in the field is important. Seedling grasses are more difficult to identify than seedling broadleaf weeds. As grasses grow, distinguishing features develop that aid in proper identification. The five basic parts of the grass plant leaf that are commonly used for identification include.

- The **blade** is the flattened portion of the leaf.
- The **collar** 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.
- The **auricles** may or may not be present at the collar and clasp around the stem.

Monocot Anatomy



D. BioIPM Systems

Biologically based IPM (bioIPM) systems include numerous components based on the pepper system's ecology and incorporate 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, the use of scouting data with knowledge of the pest life cycle, economic damage, other pest complexes, and beneficial species is critical to make informed decisions and properly design the pest management strategy. In general, as IPM systems become more complex and prevention-oriented, pest managers will need routine access to data with greater resolution in time and space. Several tactics that 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 efficacy of reduced-risk, low toxicity compounds in the production system.
- Area-wide pest and crop 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.

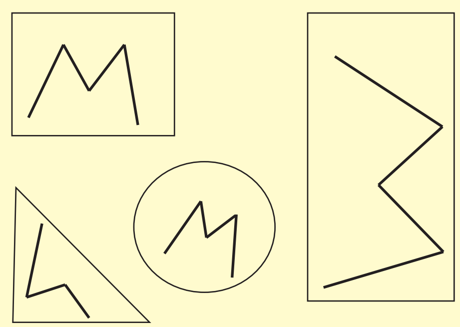
Notes:

Scouting

In-season

Effective scouting during the growing season will ensure that pests are controlled 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.

Suggested W Patterns for Scouting



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.*

☐ *C.* *Written records are kept for long-term comparisons of pest pressures.*

☐ *D.* *Field maps of pest "hot spots" are created to observe general patterns of changes in pest populations over time within a field.*

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.

In large fields, the number of scouting locations should be determined by field size. One scouting site per 10 acres is recommended. In smaller fields (under 10 acres) or field portions, use at least 4 scouting locations to obtain an average. 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 make sure that a reasonable amount of the field is scouted, including the edges and areas of the field with a history of pest problems. 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 concerns. Scouts and growers should completely inspect areas prone to disease development. 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.

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 pepper pests are provided below.

Pepper Disease Scouting: Scout at least weekly throughout the growing season until pepper harvest. Properly identify the disease found at each location in the field and note disease incidence (number of plants affected and severity). Scouting should occur just after transplanting in sites where overwintering inoculum may be present. Scout additional sites that could be prone to pathogen infections weekly. These include areas near windbreaks, woodlots, near the irrigation pivot, or near power or utility lines. Assess pathogen incidence based on the Horsfall-Barrett disease rating system.

HORSFALL-BARRETT

Disease Rating System

Foliar disease severity can be monitored using the Horsfall-Barrett disease rating scale. This scale runs from 0 to 11 and accounts for proportion of the field that exhibits disease symptoms. The scale should be recorded on the scouting form.

0= no infection

1=1-3% infection

2=3-6% infection

3=6-12% infection

4=12-25% infection

5=25-50% infection

6=50-75% infection

7=75-88% infection

8=88-94% infection

9=94-97% infection

10=97-100% infection

11=all foliage infected

INSECTS

Aphids should be scouted by removing leaves from the middle to lower half of 25 plants at each sample site. Count the number of adult and nymph aphids found on the leaves.

Flea beetles are scouted by counting the number of adults per plant at each sample location.

European corn borer (ECB) cannot be monitored on plants and must be monitored in the adult stage using blacklight traps. Place one blacklight trap per field and record the number of adult ECB per night. An estimate of adult numbers may be obtained by walking grassy areas in the vicinity of pepper field and counting the number of adult moths.

Corn earworms need to be monitored using black light traps or pheromone traps. Treatment should occur when adult populations are increasing.

WEEDS

Begin scouting after pepper transplanting and continue until harvest.

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

C. Information Gathering and Management

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, physical, 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. The information can 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 that are prone to pest infestations. 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 **Rotational Pest Management** section.

Notes:

Disease Management

In-season

Utilize an integrated disease management program that incorporates cultural, physical, mechanical, biological, and chemical control strategies.

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.***
- [ ] **B.** ***Disease management strategies are employed pre-planting and at planting to eliminate in-season disease concerns.***
- [ ] **C.** ***Crop is irrigated in a timely manner to meet crop needs- never in excess to prevent conditions that favor disease development.***
- [ ] **D.** ***Cultural control strategies are added to the pepper disease management system.***

A. Calendar Applied Fungicides

Traditionally fungicide applications for pepper disease control begin early in the growing season and continue 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.

Fungicide Toxicity Values

Toxicity values measure both human and environmental effects a pesticide would have in the system.

Fungicide	Relative Toxicity Level
Copper ammonium	Mid
Copper hydroxide	Mid
Copper sulfate	Mid
Streptomycin sulfate	Low*
Cymoxanil	Low
Famoxadone	Low
Dimethomorph	Mid
Mefenoxam	Mid
Maneb	High

*There is a concern about antibiotic resistance in humans.

B. Pre-plant Avoidance Techniques

Basic disease management strategies start prior to planting and at planting in pepper. Using bioIPM techniques and proper preventative management strategies will adequately limit disease development during the growing season. Basic pre-plant and planting strategies include:

- Using certified and clean seed sources.
- Planting in well drained soils.
- Using fungicide seed treatment and/or indexed seeds.

C. Crop Irrigation

The crop needs to be watered to ensure proper growth, but irrigation should not be in excess – see the **Irrigation** section for specifics. Well water is the preferred source of irrigation water. The source of water is important since using surface drainage water or water from contaminated sources increases risk of diseases on pepper and food-borne illnesses for consumers.

Diseases of Concern in Peppers

Diseases of concern in pepper production include cercospora leaf spot, phytophthora blight, bacterial spot, verticillium wilt, and virus (cucumber mosaic, PVY, pepper mottle virus PeMV).

D. BioIPM Techniques for Disease Management

General bioIPM disease management strategies during the growing season include:

- Foliage should be kept dry as much as possible to limit the spread of disease. Work to maintain healthy plants with minimal stress and with careful irrigation to minimize the duration of wet foliage and high relative humidity within the canopy.
- Alternate hosts species provide reproductive and overwintering sites that act as sources of plant pathogens. 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.

Resistance Management Concerns and Options for Pepper Diseases

- Repeated use of copper-based materials can select strains of the bacterial spot pathogen with high levels of copper resistance.
- Repeated use of streptomycin sulfate in the seed bed for transplant production can select strains of the bacterial spot pathogen with high levels of streptomycin resistance.
- Streptomycin sulfate should never be used in the field after transplanting because of risk of exposing humans to low levels of this antibiotic that is still being used in human medicine.

Notes:

Insect Management

In-season

An integrated insect management program that incorporates cultural, physical, mechanical biological, and chemical control strategies should be utilized during the pepper growing season. Insect management should be focused on the most damaging species, European corn borer and aphids.

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 and coincide with vunerable crop stages.***
- ☐ ***C. Cultural control strategies such as crop location, crop residue destruction, or spot treatments are also used for insect management.***
- ☐ ***D. Management decisions consider beneficial insects as 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 thresholds. Threshold levels are set to limit yield loss from insect damage to the peppers. The control strategy employed does not necessarily have to be a chemical application. Cultural, biological, physical, and chemical options are available to combat insect pests.

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

Aphids need to be treated when more than 50 aphids are found per 25 leaves early in the season, or when more then 100 aphids are found per 25 leaves later in the season. Do not treat if less than 2-3 aphids per leaf are present. If parasitized aphid mummies are present, delay treatment to allow natural control to occur.

Flea beetles need to be treated when they are found to be at levels of:

• 1 per sweep when plants are less than 3-6 inches

• 2 per sweep when plants are above 6 inches

Corn earworms are monitored by checking the nightly flights of adult moths using blacklight traps or pheromone traps. Twenty-five moths caught over a 5 day period will trigger field scouting. If eggs and/or small larvae are found on the plant, a treatment should be made if pepper fruit are

Insecticide Toxicity Values

Insecticide	Relative Toxicity Level
Acephate	Mid
Bacillus thuringensis subsp. Kristaki	Low
Bifenthrin	Mid
Carbaryl	Mid
Cyfluthrin	Mid
Deltamethrin	Mid
Esfenvalerate	High
Gamma cyhalothrin	Mid
Lamda cyhalothrin	Mid
Methoxyfenozide	Low
Permethrin	Mid
Spinosad	Low
Tebufenozide	Low
Zeta-cypermethrin	Mid
Acetamiprid	Low
Dimethoate	High
Endosulfan	High
Imidacloprid	Low
Malathion	High
Methomyl	High
Oxamyl	High
Oxydemeton-methyl	Mid
Pymetrozine	Low
Thiamethoxam	Low

present in the crop. Treatment is ineffective if the larvae have entered the pepper fruit.

European Corn Borers should be sprayed if more than 5 to 10 adults per trap per night are present and pepper fruit have formed. If more than 2 moths per 10 paces are present in adjacent grassy areas, a treatment should be considered.

Traps

Blacklight traps use ultraviolet lights to attract flying insect pests at night. Moths are commonly attracted to this type of trap. Scouts need to count and monitor the number and variety of species that are collected in the traps. European corn borers, corn earworms, and other night flying moth populations can be determined using this method.

Pheromone traps use an insect sex attractant to collect male moths of specific species. They also need to be monitored and the number collected to determine the insect pest presence in the areas of the traps. Pheromone traps are insect species specific and can be used to monitor key insect pests (such as Corn Earworms) in peppers.

Blacklight traps and pheromone traps attract adult moths in the general vicinity of the trap. A single trap in a representative location can be used to direct control decisions on up to 10 acres.

C. Cultural Management Strategies

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

Spot treatments (chemically treating only the part of the field where pests are threatening) can be effective for insect control. Spot treatments greatly reduce the amount of pesticide used and the potential adverse affects of pesticides on beneficial insects. Spot treatments can prevent or delay full field infestations. Spot treatments are most effective for insects with little mobility. Unlike highly mobile or flying pests, insects that walk or are in larval stages are more likely to remain in the area where they originated. Field edge sprays are a spot treatment that is effective by limiting full-field infestations of insect pests. When pests are found in field edges, just spraying those areas can prevent further field infestation. In peppers, initial infestation of plants by green peach aphids often occurs close to field edges that can be spot treated to prevent further spread. Frequent and accurate scouting is needed to pinpoint spray locations.

Perimeter trap crops can be implemented for control of certain pests, such as pepper maggot. To use a trap crop, plant the outer region of the crop early or to a preferred variety. For example, pepper maggots prefer to infest hot cherry peppers. If hot cherry peppers are planted on the outer regions of a bell or sweet pepper crop, pepper maggots are first attracted to these “trap” regions and, little infestation is found in the field. This will limit the need for an insecticide spray, and maintain the beneficial species found within the main pepper crop. Other plant species can be used as trap attractants as well, as long as the insect is more attracted to it than the main cropping area.

Field edges and weedy hosts of pests should be mowed to limit insect pests. For peppers, field edges should be mowed to limit leafminer concerns.

Notes:

Aphids and Virus Transmission

Aphids need to be controlled in peppers to limit transmission of non-persistent viruses. A strategy that is effective for aphid control is using aphoil sprays weekly during the growing season when aphid flights are occurring. These sprays limit aphid feeding and therefore limit virus transmission. At the same time, these are extremely low-toxicity products, do not have adverse affects on beneficial species, and work well within the system.

Since many aphid species can transmit non-persistent viruses, oil sprays should be applied when any winged aphids are moving into the crop. Monitor aphid movement with yellow sticky traps.

For aphid and virus transmission control, avoid bare soil at field margins by planting green crops such as oats, rye, and wheat. In these areas, aphids can feed and probe non-host crops to cleanse the stylet, limiting viral transmission in the full field areas.

IMPORTANT FACT BOX

Preserve predators by using a pest specific insecticide that won't kill the beneficial insects. Using 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 pest species and reduce the populations. Biological control will not entirely suppress these populations, but they 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 easily 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 note the number of aphid mummies found in the field. If high numbers of aphid mummies are seen, insecticide applications may not be necessary, as wasps are controlling the aphid population.

To maintain both predatory and parasitic beneficial insect populations, use low toxicity insecticides that do not damage the beneficial species. Certain materials, such as systemic neo-nicotinyls, spinosad, pymetrozine, and Bt compounds are not detrimental to beneficial species and will allow beneficial populations to reproduce, increasing the overall number of beneficials in the field. Traditional chemistries, such as organophosphate's, carbamates, and pyrethroids usually are detrimental to beneficial species. When these compounds are applied, growers may want to re-invigorate the beneficial populations by releasing beneficial species. General predators that feed on pepper pests include big-eyed bugs, damsel bugs, spiders, and other general predators. Maintaining habitats 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.

Weed Management

In-season

An integrated weed management program that incorporates cultural, mechanical, biological, and chemical control strategies should be utilized during the pepper 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.** *Weeds are controlled prior to planting peppers with stale seedbed techniques and tillage.*

☐ **C.** *Weeds are controlled in other crops in the rotation that have a greater number of viable weed control options.*

☐ **D.** *Advanced cultural management strategies are utilized when possible. These include the use of plasticulture, cultivation, and sanitation.*

A. Chemical Weed Control

Traditionally, weeds were controlled solely through the use of herbicides and no other cultural or mechanical control methods. BioIPM strategies recommend growers manage weeds in a more comprehensive, year-round program.

Both annual and perennial broadleaf weeds affect pepper production. Annual species live only a single year and reproduce by seed. They die at the end of the season after producing seed. Perennial species live several years and reproduce by various types of reproductive structures. Perennials regenerate shoots each year using food reserves stored in vegetative structures in the soil and are not dependent on seed germination for survival. 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 perennial broadleaves.

Weed management in pepper production relies heavily on herbicides that are applied preemergence to weed-free soil surfaces. Postemergent herbicide options are limited and primarily for grass control. Previous weed history in the field can be used to predict weed pests in the pepper crop and select appropriate preemergent herbicides.

Weed Control for Insect Management

Nightshade should be controlled in pepper production because it is an alternative host for pepper weevils and for Colorado potato beetles.

Weed species should also be controlled in and around fields as they can lead to leafminer insect problems.

Herbicide Toxicity Values

Herbicide	Relative Toxicity Level
Clomazone	Mid
Trifluralin	High
DCPA	High
Napropamide	Mid
Bensulide	High
Halosulfuron	Low
Glyphosate (non-selective)	Low
Paraquat (non-selective)	High
Clethodim	Low
Sethoxydim	Low

B. Weed Control Prior to Planting Peppers

Given that herbicide options are limited in pepper production, starting the season free of weeds is critical. Use tillage or appropriate non-residual herbicides to eliminate weeds prior to planting. If planting time can be delayed, consider using the stale seedbed technique for weed control. In the stale seedbed method, seedbeds are prepared about two weeks prior to planting. Early-emerging weeds can then be controlled prior to planting with an appropriate non-residual herbicide, thus removing the first flush of weeds. The crop is then planted without additional tillage into a weed-free seedbed. Be sure to check the herbicide label for the required time between application and pepper planting.

C. Weed Control in Rotational Crops

Weed control options are extremely limited in peppers and therefore it is essential that weeds be controlled in other crops in the rotation that have a greater number of viable weed control options. In these crops, prevent weed seed production and limit establishment of perennial weeds. Weed seeds can remain viable in soil for many years. Also, rotational crops that are competitive with weeds can reduce weed growth and seed production. Examples of crops more competitive with weeds than peppers and that have more weed control options include potatoes, soybeans, snap beans, and corn. Consider mowing or tilling weeds that escape control after the crop season to ensure that they don't produce seed.

Herbicide Resistance in Weeds

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 that grow normally following 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.
- Effectiveness 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 groups.

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.
- Plan 4 - 5 year crop rotation that addresses herbicide rotation.
- Avoid sequential applications of high risk herbicides (such as some ALS and ACCase herbicides).
- Use multiple modes of action.
- Choose herbicide groups that pose a low risk of developing resistance.
- Follow label instructions.
- Use mechanical weed control in rotational crops to reduce the reliance on herbicides.
- Eliminate weed escapes to prevent seed production.
- Tank mix herbicides with different modes of action.

Early detection of weed resistance and control of localized resistant populations can reduce the spread of herbicide resistance.

D. Advanced Cultural Management Strategies

Use advanced cultural methods when possible and when the situation dictates. In general, these techniques are implemented to minimize weed seed production for long-term weed control. Some techniques that can be implemented are described below.

- In-season cultivation in peppers grown on bare soil can control small weeds. Weed control within the transplanted pepper rows can be difficult and may require hand-weeding or multiple cultivations. Be sure to cultivate when weeds are very small for optimum efficacy.
- Growing peppers on plastic can significantly reduce herbicide inputs, but non-degradable plastics will require disposal at season end. Weeds growing through the pepper transplant hole can cause problems and will likely need to be removed by hand-weeding. In addition to the benefits of weed control, peppers grown on plastic also may mature earlier and produce a greater amount of fruit than peppers grown on bare soil.
- Use additional measures to control weeds adjacent to but not in the pepper crop. This prevents the spread of weed seeds 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.
- Clean equipment when traveling from one field to another to prevent weed seed and vegetative tissue movement to new sites. The perennial weed quackgrass, for example, is easily transported as vegetative tissue on tillage or cultivation equipment.
- After pepper harvest, be sure to control surviving weeds with tillage, mowing, or appropriate herbicides prior to seed production.

Notes:

Plant Growth, Nutrition and Fertility

In-season

© David Riley, University of Georgia

© John Stommel, Bugwood.org

Fertility programs should follow research-based, University of Wisconsin recommendations. Inadequate nutrient applications can limit crop productivity and quality and compromise crop health. Excessive nutrient applications are 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. Fertilizers are applied for plant nutrition.***
- [ ] ***B. Fertilizer programs follow the University of Wisconsin recommendations.***
- [ ] ***C. Plant tissue samples are taken to monitor crop fertility and to justify in-season adjustments.***
- [ ] ***D. Soil management practices (such as green manures and soil amendments) are used to supply some crop nutrient needs.***

A. Plant Nutrition 101

University of Wisconsin recommendations and yield goals should be used in determining nutrient application rates. Applying nutrients without regard to soil conditions or cultivar and in season growing conditions may lead to excessive applications which are both uneconomical and may contribute to environmental contamination through nutrient leaching and/or runoff. Application timing should be based on interactions of nutrients with the soil and the influence on nutrient availability and time of crop need. The growing season for peppers can vary widely with 100 day seasons in Northern US and up to 250 day seasons in southern US. Peppers produced under longer growing seasons will have higher nutrient demands.

Nitrogen is important in the promotion of crop growth as it influences protein synthesis and influences photosynthesis. Early season nitrogen is required to support development of crop canopy. However, excessive nitrogen applications can lead to excessive vegetative growth at the expense of reproductive development which will decrease yields or delay maturity. Crop demand for nitrogen increases during flower bud development and fruit formation. Therefore, nitrogen must be available to crops early during vegetative growth as well as during flowering and fruiting. Nitrogen is available for plant uptake in the nitrate form (NO_3) which is water soluble, making it highly vulnerable to movement by water. On fine textured soils (high silt and clay content), nitrogen can be applied at transplanting as the threat for leaching is relatively low. On coarse soils (sands), nitrogen should be applied in split applications (at planting and flower formation) to meet crop demands during vegetative and reproductive growth. Spoon feeding nitrogen once the crop begins to produce fruit is a common practice used by many pepper growers.

Crop demand for P and K is similar to crop demand for nitrogen. P and K are relatively immobile in the soil in plant available form. Therefore, P and K are primarily applied prior to transplanting. Fertilizer applications made prior to transplanting are generally applied broadcast and tilled into the surface of the soil. Fertilizer applications made at transplanting are typically applied adjacent to the crop row so that they are available to the crop. This is common practice for P applications due to its limited mobility in soil and the importance of P for newly planted peppers. Be cautious to not apply P directly in the root zone as it can cause crop damage. Applications at transplanting are typically applied 1 to 1 ½” to the side of the row.

Fertilization is also important during transplant production. Fertilizers are necessary to promote healthy transplant growth. However, excessive fertilizer applications can lead to “leggy” plants that are too tall and suffer from shock after transplanting. Transplant production can be successful using good transplant media that includes organic substrates such as peat or compost. Weekly applications of soluble fertilizers can promote healthy transplant growth.

Calcium Use in Peppers

Peppers need adequate calcium for growth and development. Calcium deficiency will result in blossom end rot, a disorder that causes small water soaked spots at the distal end of the developing fruit, and this is most frequently seen in soils with low pH levels. Blossom end rot will also occur if nitrogen and/or water are over-applied. Areas affected by blossom end rot can be attacked by fungi, leading to a black coloration of colonized tissues. Frequent, adequate irrigation levels will prevent this disorder. Calcium fertilizers broadcast applied prior to planting can minimize the potential for blossom end rot.

Soil pH

Soil pH influences the availability of most nutrients to the crop. Acid soils (less than 6.0 to 6.5) can be amended with lime to increase pH. Basic soils (pH > than 7) are difficult to amend. Some fertilizer applications, such as P, may have to be adjusted to deal with high pH soils.

B. University Recommendations

Nutrients should be applied to ensure plant available forms are available during highest periods of crop demand. Potassium and phosphorous should be broadcast applied prior to transplanting and rates adjusted based on soil test results. Starter solutions of nitrogen should applied as a side dress at planting. Supplemental nitrogen should be applied in split applications and rates adjusted according to soil type, crop condition, and precipitation (leaching potential). Specific varietal recommendations can be found in varietal profiles available through your seed dealer. In general, a third to a half of the necessary nitrogen is applied at planting, followed by split applications later in the season. It is important to maintain adequate nitrogen levels in the plant in the last two-thirds of the growing season. On heavier soils, split applications may not be needed. In situations where drip irrigation is used, nitrogen can be spoon fed via the irrigation throughout the growing season.

Recommendations for Peppers

Nitrogen — Soil organic matter (%)

Yield Goal	<2	2-9.9	10-20	>20
	lb N per acre to apply			
8-10 tons	100	80	60	30

P_2O_5 — Soil Test Level

Yield Goal	Very Low	Low	Optimum	High	Excessively High
	lb P_2O_5 per acre to apply				
8-10 tons	85	60	10	5	0

K_2O — Soil Test Level

Yield Goal	Very Low *	Low*	Optimum	High	Very High	Excessively High
	lb K_2O per acre to apply					
8-10 tons	150,175	110,135	50	25	15	0

* Where there are two application rates in a category, the lower rate is for soils in groups E and O, and the higher rate is for soils in groups A-D. Soil groups A – D are medium- and fine-textured. Soil group E is coarse-textured. Soil group O is organic. To determine the exact soil group for your soil series see Table 4.1 in UWEX publication **A2809 Nutrient Application Guidelines for Field, Vegetable, and Fruit Crops in Wisconsin.**

C. Petiole & Foliar Nitrate Sampling

Use plant tissue testing to determine the current nutrient status of the crop and if additional nitrogen needs to be applied later in the season. Visual estimates of crop health can be deceiving as "hidden hunger" can limit crop productivity even though vegetation appears to be healthy.

Take samples before noon because plant tissue concentrations can fluctuate greatly as plants grow throughout the day and moisture levels change in the plant. Sample the newest fully mature leaf only. Older or younger leaves will not give accurate representation of the nutritional status of the plant.

Nitrogen content of plant tissue can change quickly due to metabolism occurring even after harvest. Samples should be stored short term in a cooler or refrigerator in plastic bags. Cooled samples should be delivered to the lab for tissue analysis within 12 to 24 hours.

D. Soil Management Practices

Crop nutrients can be supplied through a number of mechanisms other than commercial fertilizers. Using these sources can increase management requirements as nutrient content is not always consistent and commonly the nutrients are available in organic form and must be converted to plant available form. In addition, many of these practices are more complex and require much higher application rates, increased tillage, or additional seeding operations (i.e. green manures). However, these inputs are often cheaper than commercial fertilizers and provide benefits other than crop nutrients including improved soil quality and pest management benefits.

Specific examples include:

Animal manures: Application of animal manures can provide N, P, K, and other nutrients to the crop. Source of animal manure influences nutrient content and quantity. Soil and plant analysis labs will commonly test manures for nutrient content, so manure and other fertilizer rates can be adjusted to meet crop demand. Manure must be applied to fields six months prior to harvesting peppers to minimize contact between manure and fruit and potential contamination of fruit with bacteria or other human pathogens.

Compost: Application of compost also provides N, P, K and other nutrients to the crop. Compost can be derived from a number of organic materials including animal manures or plant residues. The benefit of compost is that the material is partially decomposed, increasing the availability of plant nutrients. In addition, compost poses less human health risks as temperatures achieved during the composting process kills pathogens dangerous to human health as well as plant pathogens. Compost can also be tested for nutrient content to allow for optimization of rates in meeting pepper fertility needs.

Green manures: Green manures or cover crops can also provide crop nutrients. Green manures can capture plant available nutrients that remain in the soil after harvest of the previous crop. These nutrients are then released upon incorporation into the soil. Planting legume green manures can provide nitrogen from crop fixation. A key for success is that rhizobium bacteria are present for nodulation and subsequent N fixation by the legume green manure. Rhizobium bacteria are typically present if the legume crop was successfully grown previously, or can be improved by inoculating seed.

Other soil amendments: A number of alternative soil amendments exist. For example, by-products from paper production contain nutrients that improve plant growth. Use of amendments should be approached cautiously as some may contain elements that hinder crop growth. Make sure amendments are safe for the crop and analyzed for nutrient content to optimize use on pepper.

Maintaining Crop Health for Pest Control

Conditions optimizing crop health can improve crop tolerance to pest infestations. Optimizing soil quality (i.e. improving soil organic matter content, minimizing compaction, optimizing soil fertility) will promote optimal crop health. In general, crops that have experienced climatic or nutrient stresses will be less productive and tend to be more vulnerable to pests.

Irrigation

In-season

© Howard F. Schwartz, Colorado State University

© G.E. Cardon, Bugwood.org

Irrigation management strategies should provide adequate water to ensure proper growth and development of the pepper crop without over watering to prevent nutrient losses due to leaching.

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 according to crop knowledge and past experience.*
- [ ] ***B.*** *Irrigation scheduling tools are used to determine irrigation timing and amounts.*
- [ ] ***C.*** *Water is used efficiently and when most needed by pepper crop.*
- [ ] ***D.*** *Drip or another micro-irrigation system is utilized when possible.*

A. Irrigation

The goal of water management is to maintain adequate soil moisture throughout crop growth, while avoiding extremes and excessive fluctuations. A general rule is that peppers require 1 to 2 inches of water per week depending on precipitation and weather. Irrigation frequency will depend on the water holding capacity of the soil. Coarse textured soils will require irrigation every 1 to 3 days whereas irrigation on fine textured soils will only be necessary every 3 to 5 days. Irrigation is critical for peppers during flower and fruit development and when air temperatures exceed 85 degrees F. Inadequate soil moisture during flower and fruit development can lead to crop loss. Similarly, peppers become stressed when air temperatures exceed 85 degrees F, and hot weather combined with drought stress can lead to severe crop losses.

Transplant production requires adequate and uniform watering of bedding plants prior to transplanting. Frequent watering will be important during warm sunny days, as temperatures can rapidly increase to 20 to 40 degrees F warmer than outside air temperatures. Venting should be available to prevent heat stress, and watering used as a means to minimize negative effects of hot conditions during transplant production. Make sure transplants are well watered in pots prior to field planting.

Irrigation of the crop is critical after transplanting. Irrigate soils to field capacity if precipitation has been limited. Make sure transplants are well watered immediately after field planting. Peppers should be transplanted in the morning or evening to avoid the heat of the day. Transplant during overcast and cool conditions if possible.

B. Irrigation Scheduling Tools

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

High Tunnel Variations

Pepper production under different plasticulture techniques such as high tunnels may change ET estimates compared to those occurring under field conditions. First of all, plastic reflects a fraction of the incoming sunlight. Light intensity is reduced 20 to 30 % by each layer of plastic depending on thickness and transparency. Temperatures are also influenced by high tunnels. Temperatures within a high tunnel are 20 to 40 degrees F warmer than outside air temperature when the vents are closed. Temperatures are 10 to 15 degrees F cooler within a high tunnel when the vents are open due to decreased light intensity. Finally, when vents on high tunnels are closed, the humidity is commonly higher within the tunnel due to transpiration.

Quick Notes

- Uneven watering may result in blossom end rot concerns.
- To ensure quality, healthy transplants, make sure to adequately and uniformly water bedding plants prior to transplanting.
- Use a clean water source whenever possible.
- Beware of food safety issues with water. Use of surface water contaminated with manure may cause food safety problems.

Available Soil Water and the Wisdom module

The **plant available water (PAW)** of soil 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 die). Yield and quality losses can occur in peppers before plants show symptoms of drought stress such as leaf wilting. The critical point is the water content that leads to closure of stomata and reductions in photosynthesis and plant growth. That difference between field capacity and the critical point is called the **allowable depletion**. The maximum allowable depletion for the pepper crop is 50 to 55% of available soil water. If the field is allowed to go below the allowable depletion, significant stress will occur, and yield and quality will suffer.

Allowable depletion levels for pepper on different soil types

		Pepper rooting depth (in)		
Soil type	AD/foot	12"	18"	24"
Sand, loamy sand	0.5	0.5	0.75	1
Sandy loam	1	1	1.5	2
Clay, Silty Clay, Sandy Clay Loam	1.5	1.5	2.3	3
Silt Loam, Loam, Silty Clay Loam, Clay Loam	2	2	3	4

Although the allowable depletion is 50-55% of the plant available water, peppers require at least 70-75% PAW for optimal growth during flowering and hot conditions.

Whatever the type of irrigation system, use irrigation scheduling to balance crop water use (evapotranspiration) with irrigation and rainfall. The simplest tool to use is a checkbook 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. An irrigation scheduling spreadsheet which uses the checkbook method can be accessed at: http://www.soils.wisc.edu/wimnext/water.html.

In Season: 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 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 www.soils.wisc.edu/wimnext/et/wimnext.html

C. Efficient Water Use

Young pepper transplants can remain healthy when irrigated at 20% ET. Lower watering promotes root development. From canopy cover to fruit formation, plants should receive enough water to recover 100% ET. During the final growth stages of peppers, plants need to recover 85% ET.

Irrigation management within high tunnels is typically done with drip or micro irrigation systems. Yields and quality of pepper in high tunnels are high enough to justify investments in soil moisture monitoring equipment to be used in tandem with the drip system to optimize soil moisture management and crop growth.

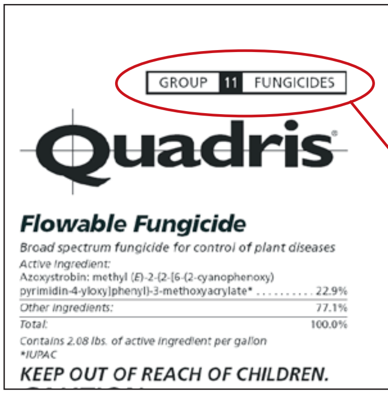
D. Drip or Micro-irrigation Methods Used

Drip irrigation systems effectively limit over watering while providing adequate moisture to plants in the root zone. Improved quality and water use in high value crops such as peppers can often justify investment in 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.

Drip irrigation minimizes water contact with leaf surfaces and decreases in-canopy humidity. Compared to sprinkler or furrow irrigation, drip irrigation provides more even watering, improves nutrient use efficiency, and greater water use efficiency. As a result, disease and weed management are improved with drip irrigation and so are crop yield and quality, resulting in increased return per acre.

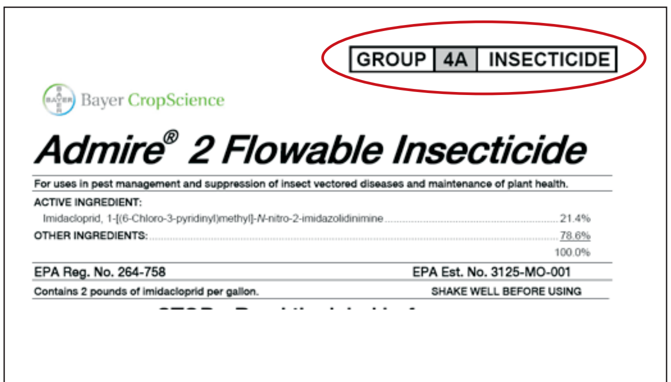
Notes:

Resistance Management



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

Examples of pesticide labels with EPA Resistance Management Group information.



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 groups.*
- ☐ **B.** *Pesticides from the same group are not used consecutively within the growing season.*
- ☐ **C.** *Fungicides with single-site of action are not used in consecutive applications.*
- ☐ **D.** *Disease, insects, and weed populations are monitored for resistance development.*

A. Pesticide Modes of Action

Pesticides all have a specific way in which they control pests. This is known as the pesticide's mode of action. The site of action is the specific enzyme affected by the pesticide. Growers need to know the pesticide's mode of action to implement proper resistance management strategies. Ultimately, applying these strategies will minimize the likelihood that resistance will develop and thus growers will maintain more options for pepper pest management.

The Environmental Protection Agency (EPA) and the Fungicide, Insecticide, and Herbicide Resistance Action Committees (FRAC, IRAC, HRAC) have developed a voluntary pesticide labeling method that groups pesticides with similar modes of action and designates them with a number. Look at the tables in this section for the EPA resistance management groups for insecticides, fungicides, and herbicides.

Pesticide resistance develops in a variety of ways. In general, the pest species become resistant through selection of biotypes of disease, insects, and weeds exposed to a particular group of pesticides over a period of years. These pests have the genetic potential to pass along the resistance trait during reproduction. Many times the resistance 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 same fungicide group in the following years.

B. Resistance Management Recommendations

Resistance management programs should incorporate bioIPM approaches that limit pest infestations, limit the number of applications needed, time the products appropriately, and target the vulnerable life stages.

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 (Group 11) of fungicides 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.
- Use disease forecasting programs and IPM approaches to target fungicides when control is most needed.
- Integrate lower risk fungicides into a season-long, seed to market disease management program. Use bioIPM strategies that limit inoculum sources and disease potential whenever possible.

Fungicide Resistance Codes and Resistance Risk Levels

Fungicide	Resistance Code	Risk Level
Copper ammonium	M1	High
Copper hydroxide	M1	High
Copper sulfate	M1	High
Streptomycin sulfate	25	High
Cymoxanil	27	Mid
Famoxadone	11	High
Dimethomorph	15	Mid
Mefenoxam	4	High
Maneb	M3	Low

INSECTICIDES:

- Rotate crops and select field locations to avoid high, early season pest pressure.
- Scout pests using the correct method.
- Treat only at economic thresholds.
- Time application to target the most vulnerable life stage.
- 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) or rates and timings with minimal non-target effects.
- Use cultural control to reduce populations.
- Rotate peppers 400 meters from previous crop.
- Treat edges as a trap crop in spring and fall.

Resistance Concerns

In peppers, there is a concern of resistance development against copper-based fungicides used for bacterial spot control. Growers should closely monitor efficacy of copper fungicides used against bacterial spot. If resistance is a concern, use alternative products and test the population in the lab to confirm tolerance or resistance levels.

Insecticide Codes

Insecticide	Resistance Code
Acephate	1B
Bacillus thuringensis subsp. Kristaki	11B
Bifenthrin	3
Carbaryl	1A
Cyfluthrin	3
Deltamethrin	3
Esfenvalerate	3
Gamma cyhalothrin	3
Lamda cyhalothrin	3
Methoxyfenozide	18
Permethrin	3
Spinosad	5
Tebufenozide	18
Zeta-cypermethrin	3
Acetamiprid	4A
Dimethoate	1B
Endosulfan	2A
Imidacloprid	4A
Malathion	1B
Methomyl	1A
Oxamyl	1A
Oxydemeton-methyl	1B
Pymetrozine	9B
Thiamethoxam	4A

HERBICIDES

- Rotate crops.
- Rotate herbicide families and use herbicides with different modes of action.
- 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.

Herbicide Resistance Codes

Herbicide	Resistance Codes
Clomazone	13
Trifluralin	3
DCPA	3
Napropamide	15
Bensulide	8
Halosulfuron	2
Glyphosate	9
Paraquat	22
Clethodim	1
Sethoxydim	1

Quick note

If resistance concerns exist, monitor the pesticide efficacy and the populations. Closely monitor resistance levels of aphid species to insecticides and blight pathogens to fungicides.

C. Single-site Fungicides

Single-site fungicides, including the new, reduced-risk Group 11 strobilurin fungicides, may be prone to the selection of resistant plant pathogens. Recommendations for Group 11 fungicides are to avoid consecutive sprays of any Group 11 fungicide. This includes pre-mix products that include a Group 11 material, or if the applications are tank-mixed with other, non Group 11 materials.

D. Monitoring for Resistance

If a population is suspect of becoming resistant, an accurate sample and test should be done to confirm resistance. Many university laboratories and private companies have testing procedures for resistant populations. Consult the individual labs for specific sampling protocols. Laboratory documentation would confirm if resistance is found, and would therefore allow the growers to alter their pest management strategies.

Notes:

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 pepper 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) 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. However, maintenance of beneficial populations in or around the field may increase beneficial species and may aid in biological control. Maintained areas may include non-agriculture areas in and around fields that are ecologically diverse and planted with multiple species with a variety of colors. These areas attract beneficial species and also serve as areas 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 make targeted pesticide applications possible and usually do not adversely affect beneficial populations. Review the in-season disease, insect, and weed sections to determine the reduced-risk options that do not adversely affect beneficial species.

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

C. Beneficial Insect Habitat

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 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, that can be put directly in the field. These agents may be effective if they are released in large quantities in the life stage where they do the majority of the feeding, normally in the larval stages.

Quick Note

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. To verify, see the label listing.

Common Beneficial Species

Common natural enemies of pepper insect pests include:

Predaceous stink bugs

- Shield-shape and distinctive odor.
- Preys on larvae.

Tachnid flies

- Adult species are robust, dark and look like houseflies, except tachnids, which have stout bristles at the tip of their abdomens.
- Internal parasites of larvae - lay eggs on larvae.

Ten-spotted ladybird beetle

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

Parasitic wasps

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

D. Biocontrol Potential

When insecticides are used that do not adversely affect 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.

Notes:

Harvest and Post-harvest Handling


© M.E. Bartolo, Bugwood.org

Proper harvest and post-harvest handling techniques are essential in the maintenance of a high-quality product. Peppers sold fresh are only stored for short time periods after harvest, but several pepper types can be dried and stored for extended time after harvest.


© Gerald Holmes, Valent USA Corporation, Bugwood.org

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 principles of harvest and post-harvest management are understood.*
- [ ] *B. Harvest is optimized to maximize product quality.*
- [ ] *C. Correct storage temperatures and relative humidity are maintained to maximize shelf life.*
- [ ] *D. Storage facilities are managed to prevent ethylene contamination.*

A. Post-harvest Storage 101

Proper harvest and post-harvest handling of peppers are keys to maintaining a good quality product. The best possible quality of a crop exists at harvest. Quality cannot be improved, only maintained after harvest, as is the case with most vegetables. Growers need to consider crop maturity at harvest, harvest methods, and cooling and storage temperatures and other conditions. Through proper harvest and post-harvest handling, growers will minimize disease, water loss, injury, and other issues that will diminish product quality.

In order to maintain pepper quality for the maximum length of time, several factors need to be considered. Fresh produce maintains living tissue after harvest and thus continues to respire during the post-harvest period. This process of "breathing" releases heat and moisture from the product, decreasing product appearance, salable weight, and nutritional quality. Depending on the type of tissue and physiological age of a product, the respiration rate can vary from very low to very high and determines the length of time that a product can spend in transit and in storage. Peppers have a moderate rate of respiration after harvest and require proper harvest and storage management to optimize fresh quality.

B. Pepper Harvest

Harvesting of a product at proper maturity greatly influences product quality and post-harvest life. Determination of pepper harvest varies depending on the type of pepper grown. Peppers will generally be ready to pick 65-85 days after transplanting. Bell peppers, jalopenos, and Anaheim types harvested at the green stage should be harvested when the peppers are of adequate size, with thick, firm walls. Red colored peppers (both bell and chile peppers) should be harvested when the fruits are at least 50% colored. Damaged, diseased, or sun-scalded peppers should not be harvested.

Peppers are generally hand-picked. To maximize yields and harvest efficiency, pick two to four times during the season at 10-14 day intervals. Harvest during the coolest part of the day, usually during the morning, to minimize the field heat of the crop brought into storage. Peppers should be cooled within one hour of harvest because of their susceptibility to heat damage, sun scald, and water loss after picking.

Efforts should be made during picking to handle the peppers with care to prevent bruise and damage to the exterior of the fruit. Harvested fruit should be shaded and not be allowed to sit in the sun for even short times after picking. Peppers may be hand-packed in the field or transported to a packing shed.

Peppers may be washed with water containing 75-100 ppm of chlorine in order to prevent disease movement through the stem into the internal cavity. Fruit should be air-dried after washing and before packing. If washing facilities are unavailable, dirt and debris should be removed from the peppers prior to packing.

C. Storage of Peppers under Optimal Conditions

Peppers should be stored at 45-50 degrees F and 90-95% relative humidity to maintain fruit quality. These conditions are warm enough to prevent chilling injury, but cool enough to minimize disease development, respiration, and water loss. Peppers stored at higher temperatures will have more water loss and shrivel leading to decreased shelf life. Temperatures below 45 degrees F should be avoided to prevent chilling injury. Green peppers are more sensitive to chilling injury than red or colored peppers. If stored correctly, peppers can be stored for three weeks or more with little quality loss.

Chilling Injury

Proper storage temperatures are essential for the prevention of chilling injury on peppers. Symptoms of chilling injury include surface pitting, water-soaked areas, decay (especially Alternaria), and discoloration of the seed cavity.

D. Ethylene Management

It is generally recommended that pepper fruits be stored in the absence of ethylene-producing sources (i.e. ripening fruit or engine exhaust). Ethylene can cause quality loss of the peppers during the postharvest period. Storage areas for peppers should be well-ventilated to prevent the build up of ethylene in the atmosphere. In addition, peppers should not be stored with other fruits and vegetables that produce ethylene such as tomatoes, bananas, apples, and others.

Keys to Post-harvest Quality:

- Harvest at appropriate maturity for desired product.
- Harvest at the coolest part of the day (usually morning).
- Only harvest fruits free of disease and damage.
- Cool harvested product within one hour of harvest.
- Keep harvested product out of the sun.
- Handle peppers carefully during harvest and storage to minimize damage and bruising.
- Maintain proper storage temperatures and relative humidity.

Quick Note

The rate of deterioration doubles or triples for each 18 degrees F increase above the optimum storage temperature for any given fruit or vegetable.

Notes:

Ethylene

Ethylene is a naturally occurring plant hormone that affects the ripening of some fruit. Fruit can either be classified as "climacteric" (ethylene regulates the ripening process) or "nonclimacteric" (ethylene does not regulate the ripening process). Peppers are classified as nonclimacteric.

Ethylene is produced as a gaseous form by the fruit, but is also produced as an exhaust product of combustion engines.

PEST PROFILES

Pepper Anthracnose *Colletotrichum spp.*

peak activity occurs during warm, wet weather

April	May	June	July	August	September	October

Anthracnose is a common disease of tomato and pepper fruit, caused by fungi in the genus *Colletotrichum*. There are many species of *Colletotrichum* that cause anthracnose on a wide range of cultivated vegetables, berries, and tree fruits. Anthracnose is a general term used to describe the typical symptoms of sunken circular lesions on fruit. Infection occurs when the fruit is still green, but symptoms generally appear when the fruit begins to ripen.

Anthracnose develops during periods of warm, wet weather. The fungus infects the fruit directly, causing multiple sunken, water-soaked lesions that coalesce when disease is severe. Fruit that comes in contact with the soil is most likely to become the initial point of infection. The fungus is capable of abundant spore production, and heavy yield losses can occur when environmental conditions are favorable.

Colletotrichum fungi survive as overwintering spores on infested plant debris in the soil, although generally not for more than one or two seasons. The fungus can also be seed-borne. Once fruit infection occurs, masses of pink to orange spores on the surface of the lesions are produced and are spread by splashing and wind-blown rain.

Anthracnose is a fungal spot disease of pepper which typically appears when the fruit begins to ripen.

© Yuan-Min Shen, Taichung District Agricultural Research and Extension Station, Bugwood.org

Scouting: Monitor fields for signs of anthracnose during periods of warm weather, especially if the fruit remains wet. Sample 5 to 10 sites in each field, following a 'W' pattern across the field. Examine fruit for small, round, slightly sunken spots that are surrounded by concentric rings. During moist conditions the lesions may contain salmon-colored spores. Older lesions may contain black structures that look like dots. With a 10X hand lens, these will appear as tiny black hair-like structures which contain spores. Lesions may also appear on stems and leaves as irregularly shaped brown spots with dark brown edges.

Threshold: Once the fruit are infected, fungicides will not be effective.

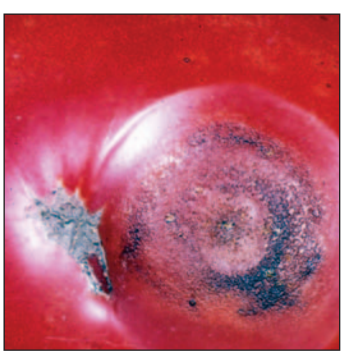
Management Strategies

Cultural control

- Crop rotation away from solanaceous crops (tomato, potato, eggplant, or pepper) and strawberries for 2 or 3 years is very effective in reducing the amount of pathogen in the field.
- Plant in a sunny site where dew dries quickly in the morning.
- Plant certified, disease-free seed or treated seed. Pepper seed can be disinfested with a 30-minute soak at 125degrees F.
- Plant only disease-free transplants.
- Choose varieties with some resistance or tolerance to anthracnose
- When possible, mulch the soil or stake or cage the plants to prevent the fruit from coming into contact with the soil.
- Plow under crop debris soon after harvest.

Chemical control

- None recommended.



© Clemson University - USDA Cooperative Extension Slide Series, Bugwood.org

Rings inside the lesion are characteristic of anthracnose disease.

Bacterial Soft Rot *Erwinia, Pseudomonas, & other bacteria*

peak activity occurs during in-season if fruit is damaged, but mostly occurs post-harvest

April	May	June	July	August	September	October

Bacterial soft rot is a common disease that can cause serious losses in the field, in transit, and in storage. The bacteria that cause soft rot have a wide host range that include many cultivated vegetables and fruit. Soft rot bacteria are secondary invaders that require some kind of wound to enter plant tissue. In pepper, bacterial soft rot is mainly a post-harvest problem except when fruit is injured in the field by insect feeding.

Bacterial soft rot is caused primarily by *Erwinia carotovora*, a common organism in plant residues, in the soil, on contaminated equipment and containers, and on insects. The bacteria are spread by hands and tools, splashing rain or irrigation, and insect feeding. Once the bacteria gain entry to plant tissue, they multiply rapidly and liquefy all surrounding tissue. Severe losses can be avoided if the disease is identified quickly and steps are taken to prevent spread.

Bacterial soft rot is characterized by soft, moist, mushy appearance of the fruit.

© Ontario Ministry of Agriculture Food and Rural Affairs- Ontario CropIPM

Scouting: When walking fields, looks for signs of soft rot. Monitor closely during periods of insect feeding, disease outbreaks, or if mechanical injury or hail has occurred as these can provide the wounds needed for the bacteria to enter plant tissue.

The first indication of bacterial soft rot is a moist, mushy appearance on the fruit. The affected tissue often turns brown, and there can be a definite foul odor associated with the rot. Remove any plants with signs of soft rot. Monitor crops in storage areas regularly for signs of soft rot and remove any infected produce.

Threshold: There is no treatment for soft rot once the disease is present.

Management Strategies

Cultural control

- Grow peppers in a sunny, well-drained location with good air circulation.
- Choose varieties with some resistance to soft rot.
- Avoid plant injury.
- Control other insects and diseases that provide a source of entry.
- Avoid planting near corn fields to reduce populations of European corn borer.
- Harvest in a timely manner.
- Do not wash fruit before storage as the wash water can spread bacteria from diseased to healthy fruit.
- Discard fruit that has been bruised or wounded, or have signs of soft rot.
- Keep storage temperature below 39 degrees F. Provide good air circulation.
- Practice good sanitation in storage facilities. Remove all debris from the warehouse, and disinfect walls and containers.

Chemical control

- If wash water is used, maintain 25 ppm chlorine in the wash water (1 TBS of Clorox®, 5.25% sodium hypochlorite, per 8 gallons of water). Make sure that the wash water is not cooler than the fruit temperature, or bacteria will move into the fruit or stem end.

Bacterial leaf spot *Xanthamonas campestris*

peak activity occurs during warm, wet weather

April	May	June	July	August	September	October

Bacterial leaf spot, caused by *Xanthamonas campestris,* is a common and potentially destructive disease of pepper and tomatoes. Once bacterial spot is established in a plant bed, field, or greenhouse, control is very difficult, especially when conditions are wet. Fortunately, there are effective strategies to prevent the occurrence and spread of the disease. Bacteria-free seed and transplants, as well as host resistance, are the cornerstones of bacterial spot control.

The pathogen is capable of infecting all above-ground plant parts. Once initial infections take place, bacterial leaf spot can spread rapidly through an entire field during rainy weather from a few infected plants. Spread in plant beds or greenhouses and during planting operations is especially serious. Plants infected early are often killed. Infection later in the season results in blemished fruit of poor quality and marketability.

Xanthamonas campestris overwinters in plant debris and in seed, both within the seed and on the seed surface. Cotyledons become infected as the seed germinates. The infection then spreads to the leaves, where the bacteria enter the foliage directly through stomates or wounds, or they may be translocated upward in the plant through the water-conducting tissue from sites of root infection. Once established in the field, the bacteria are spread from plant to plant by wind, rain, dust, animals, and human activity.

On pepper, bacterial spot is marked by prominent brown, raised lesions on fruit and sunken, straw-colored spots on leaves.

© Howard F. Schwartz, Colorado State University, Bugwood.org

Scouting: Scout at least weekly from transplanting until pepper harvest for signs of bacterial spot. The blight develops rapidly under relatively high air temperatures (75 to 90 degrees F) and high humidity. Sample 5 to 10 sites per field following a 'W' pattern across the field. On peppers, look for small, circular, pimple-like spots on the underside of the leaf with a corresponding depression on the upper leaf surface. As the spot enlarges, the center dies, leaving a straw-colored area surrounded by water-soaked tissue. As the disease becomes more severe, the plant may show a more generalized yellowing. Note that the fungal pathogen Cercospora, can cause leaf spots in dry weather that resemble bacterial spot.

On pepper fruit, bacterial spot lesions are very prominent. They appear as brown, raised spots with cracked, roughened surfaces. Soft rot organisms may enter the pepper through these cracks and destroy the fruit.

Threshold: Any chemical treatment must be applied as seed disinfectant or to protect healthy plants when symptoms first appear in the field.

Management Strategies

Cultural control

- Rotate fields out of solanaceous crops for at least 2 years.
- When possible, plant cultivars with resistance or field tolerance to bacterial spot. Evaluate small plantings of new resistant varieties.
- Always plant certified disease-free seed or treated seed. This is a critical step. A hot water seed treatment is the most effective treatment of bacteria on or within seed. Place the seed in a mesh bag and dip into water heated to 122 degrees F; treat for 25 minutes. Immediately transfer to cold water to cool the seed. There will be some reduction in germination rate of treated seed. Sow additional seed to compensate.
- Always plant disease-free transplants. Inspect plants very carefully at transplanting and reject infected lots – even if you grew them yourself.

Continued on next page...

- Prevent bacterial leaf spot in the plant beds and greenhouse by practicing strict sanitation. Produce plants in sterilized soil or commercially prepared mixes. Clean pots and flats. Keep the greenhouse as dry as possible.
- Don't work in the field when plants are wet.
- Plow under crop debris soon after harvest.

Chemical control

- Seeds can be treated to remove bacteria on the surface. Refer to A3422 *Commercial Vegetable Production in Wisconsin* for labeled products.
- Foliar applications of copper-containing pesticides are available for use in controlling light infestations of bacterial spot. Refer to A3422 *Commercial Vegetable Production in Wisconsin* for labeled products.
- Repeated use of copper-based materials or antibiotics can select strains of the bacterial spot pathogen with high levels of resistance.
- Never use antibiotics such as streptomycin sulfate in the field because of risk of exposing humans to an antibiotic that is used in human medicine.

PEST PROFILES

Phytophthora Blight *Phytophthora capcisi*

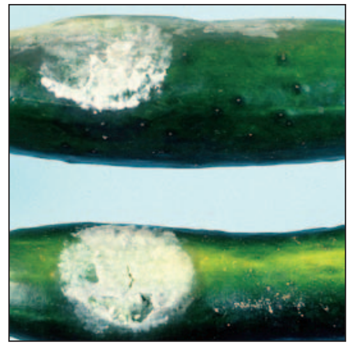
			peak activity			
April	May	June	July	August	September	October

Phytophthora blight does not occur every year in Wisconsin, but it is one of the most damaging vegetable diseases when it does occur. The fungal pathogen, *Phytophthora capsici*, has a wide host range that includes pepper, eggplant, tomatoes, and the entire cucurbit family. The disease has two distinct phases: a destructive root and stem rot phase, and an aerial blight phase in which spores from diseased plants are dispersed by wind-driven rain to stems, leaves, and fruit.

Phytophthora is capable of extensive rotting of lateral roots, tap roots and stem tissue. Lesions may girdle the stem. Often the first obvious symptom of the disease is sudden wilting and death as plants reach the fruiting stage. Fields infected early and severely may have 100% plant loss. Infections that occur later in the season may reduce the vigor and yield of plants without killing them. Plants continue to wilt during the hottest time of day, exposing fruit to sunburn.

Phytophthora capsici overwinters on infected debris in the field. Overwintering spores called oospores may be able to survive in the soil without a host for up to 10 years. Infected transplants and contaminated water or soil are common sources of initial inoculums in a field. Oospores germinate in the spring to form structures called sporangia that release zoospores. Zoospores are single-celled spores that can swim in the soil water and lodge on host roots. The fungus requires at least 5 to 6 hours of saturated soil to produce and release the zoospores that infect roots. Therefore, the disease is most likely to be found in wet or poorly-drained areas of the field and from there spread to adjoining areas of the field. Once a plant is infected, more sporangia are formed and zoospores released. The amount of rainfall has a dramatic influence on disease incidence.

© Howard F. Schwartz, Colorado State University, Bugwood.org



© Charles Averre, North Carolina State University, Bugwood.org

If inoculum is present in the soil and a susceptible pepper/cucurbit variety is grown, the disease can spread rapidly under conditions of heavy rainfall, despite best management practices.

Scouting: Phytophthora can develop at any stage of plant growth, but symptoms usually appear on older plants following a warm, wet period in July and August. Scout areas where water does not drain well as plants growing in low-lying areas or flooded fields will show symptoms first.

Look for black lesions forming just above the soil line. Affected pepper plants wilt and die. Often a number of plants in a row or in a roughly circular pattern will show these symptoms at the same time. Inspect the roots and stems of wilted plants for water-soaked, dark brown discoloration of both inner and outer root tissue. Infected plants may have very few lateral roots remaining. If the aerial blight phase occurs, look for large black lesions formed along stems and circular yellow lesions on the leaves. Infected fruits initially develop dark, water-soaked patches that become coated with white mold and spores of the fungus.

Threshold: If fungicides are considered, they must be applied to protect healthy plants when symptoms first appear in the field. There is no treatment for Phytophthora once infection has occurred.

Management Strategies

Cultural control

- The focus of Phytophthora management should be on water management that prevents the initiation and spread of the disease. Plant in well-drained soils. Do not plant in low-lying areas prone to flooding. Consider planting in raised, dome-shaped beds. Do not allow planting depressions that collect water to form near plants. However, do not plant vining cucurbits on a bed or ridge that would result in fruit lying in row middles that collect water. Provide drainage at the end of the field to allow excess water to flow out of the fields.
- Avoid or reduce soil compaction.
- Rotate fields out of peppers and other susceptible crops including cucurbits, eggplants, tomatoes, and lima beans for a minimum of 3 years.

Continued on next page...

- Plant certified disease-free seed from a reputable commercial seed dealer. No resistant varieties are currently available.
- Avoid working in the crop when the leaves are wet.
- Thoroughly clean equipment and boots after working in infested fields. Remove all soil from the implement and tires by pressure washing, and then spray all equipment parts that come in contact with the soil with a disinfectant. Apply disinfectant with a simple hand sprayer before entering each field.
- Remove infected plants to avoid production of spores leading to the aerial phase of the disease

© Howard F. Schwartz, Colorado State University, Bugwood.org

The Phytophthora fungus needs saturated soil to infect plant roots and is most likely to begin in wet or poorly-drained areas of fields, like in this zucchini field.

Chemical control

- The decision to use fungicides depends on the history of the field and personal management decisions. Under heavy disease pressure, fungicides have not proven effective at limiting economic losses. This usually due to insufficient concentrations during the onset of disease due to soil or weather conditions or the timing and placement of the fungicide application.
- On farms with no history of Phytophthora and practicing good crop rotation, a fungicide program may not be necessary. Farms that have a history of the disease, that can employ rotation, and do not have a resistant population of the pathogen will likely benefit from a fungicide program. Refer to A3422 *Commercial Vegetable Production in Wisconsin* for currently labeled products.
- Phytophthora fungi have developed resistance to some systemic fungicides. Do not use products with the same mode of action in consecutive applications. Rotate with pesticides with different Resistance Group numbers.

Verticillium Wilt

			peak activity			
April	May	June	July	August	September	October

Verticillium wilt is caused by two soil-borne fungi, *Verticillium dahliae* and *Verticillium albo-atrum*, which colonize the vascular tissues of plants. *V. dahliae* has a very wide host range that includes solanaceous crop plants (pepper, tomato, potato, and eggplant) as well as hundreds of other cultivated fruits, vegetables, trees, shrubs and many weed species. The fungus is long-lived and persistent in soil.

Verticillium wilt can be a very damaging and often fatal disease when it occurs. Plants can be infected at any age. Pepper plants infected early in the season will be severely stunted or killed. Sometimes infected plants survive the season, but grow poorly with small yields and fruit.

Verticillium dahliae and *Verticillium albo-atrum* are commonly found in Wisconsin soils and in roots of infected plants. Both pathogens are spread to new fields on infested transplants, seed, or the movement of soil on farm machinery. During the season, spores of the fungus in the vicinity of host roots germinate and enter the plant through young roots during cool weather. The fungus continues to grow into and up the water-conducting vessels of the roots and stem, blocking the water supply to the leaves and causing wilt. Eventually the fungus will produce overwintering structures called microsclerotia in the stems of infected plants. These structures can survive under field conditions for over 10 years in the absence of a host.

© David Gent, USDA Agricultural Research Service, Bugwood.org

***Verticillium dahliae* has a broad host range, causing vascular discoloration and wilt of many economically important crops (shown here on hops).**

© Howard F. Schwartz, Colorado State University, Bugwood.org

© Paul Bachi, University of Kentucky Research & Education Center

Symptoms of Verticillium wilt are yellowing and wilting of a few branches or the entire plant (shown here on sunflower).

Another diagnostic sign is brown streaking in the water-conducting tissue (shown here on maple tissue).

Scouting: Watch for symptoms of Verticillium wilt when scouting for other pests and diseases throughout the season. Early symptoms begin as a yellowing of the leaf tips and margins of older leaves, which gradually wilt and drop. As the wilt progresses, the plant becomes defoliated and stunted. Sometimes wilting does not occur until the plant is bearing heavily or a dry period occurs. Slit open a stem of a symptomatic plant and inspect carefully for tan streaks in the water-conducting tissue just below the stem surface. This discoloration is most pronounced near the soil line, but sometimes extends all the way up.

Verticillium wilt can be confused with Phytophthora root rot or Sclerotinia stem rot (white mold), two other potentially serious soil-borne diseases with similar foliar symptoms of yellowing and wilt. However, Phytophthora root rot causes extensive browning and rotting of the root cortex, while the roots of *V. dahliae* or Sclerotinia-infected pepper plants show no external discoloration or decay. If you suspect any of these diseases are present, send or bring a plant sample to your county Extension office or plant disease clinic for diagnosis.

Threshold: Management of Verticillium wilt is preventative.

Management Strategies

Cultural control

- Because of the broad host range *of V. dahliae* and the longevity of microsclerotia, crop rotation will not completely eliminate the disease. However, crop rotation of at least 2 years can reduce inoculum considerably and prevent buildup of the pathogen. Do not plant any solanaceous crop in the rotation, and avoid strawberries and raspberries, which are highly susceptible. Rotate with broccoli, corn, wheat, barley, sorghum, or safflower and other grasses when possible.

- Keep rotational crops weed-free (there are many weed hosts of Verticillium), especially host weeds such as nightshades.

Continued on next page...

- Resistance to Verticillium wilt is not common in commercial pepper cultivars and breeding efforts have been slow due to the difficulty in identifying resistance in pepper germplasm. However, peppers are resistant to isolates of *V. dahliae* from many hosts, and only certain strains of *V. dahliae*, such as those from eggplant and pepper, are pathogenic on peppers.
- Grow seedlings in pathogen-free soil or buy from reputable growers who practice good sanitation.
- Maintain a high level of plant vigor with appropriate fertilization and irrigation, but do not over-irrigate, especially early in the season.
- Whenever practical, remove and destroy infested plant material after harvest.

Chemical control

- None recommended.

PEST PROFILES

Corn Earworm *Helicoverpa zea*

peak activity

April	May	June	July	August	September	October

Also known as the tomato fruitworm, the corn earworm is a common and serious annual problem in sweet corn plantings, and occasionally in peppers, tomatoes, and snap beans. The corn earworm also feeds on many types of weeds. In peppers, the female moths lay single eggs on young leaves around developing fruit. Control is difficult because of the short period between egg hatch and when the larvae begin tunneling into the fruit.

Because it is larger than the European corn borer, the corn earworm can eat large holes in fruits, causing injury that is likely to be visible at harvest. Feeding cavities are often colonized by secondary soft-rot organisms. Feeding injury is often worse later in the season when earworm populations increase and mature corn, the favored host, is less available. Damage tends to be more severe on late plantings of peppers as the larvae prefer green fruit and rarely enter ripening fruit.

Corn earworms do not overwinter in the upper Midwest. Adult moths overwinter in the south and migrate northward each year. The moths typically arrive in southern Wisconsin in late July, although timing will vary based on wind and weather patterns in the Gulf Coast region. The moths fly mainly at dusk or during warm, cloudy days. When susceptible sweet corn is not available, female moths are attracted to reproductively mature tomato plants, peppers and other crops, where they lay eggs near the fruit. Each fertilized female can lay up to 1000 eggs. The amount of time for egg hatch varies with temperature, but during periods of hot summer days and nights, eggs can hatch within 24 hours after they're laid.

Eggs are tiny, flattened spheres with prominent ridges. When deposited, the eggs are light yellow, but they darken to dusky brown before hatching. Full-grown larvae of the corn earworm are close to 2 inches long, olive-brown, tan, maroon, pink, or black with three or four dark stripes down their backs. The head is yellow and not spotted.

The adult corn earworm is a robust, grayish-brown moth with dark spots on the outer edges of the forewings and a wingspan of 1½ inches.

© Steve L. Brown, University of Georgia, Bugwood.org

Scouting: Monitor the nightly flights of adult moths with pheromone traps, which use a specific scent to attract male moths. Growers with large plantings of tomatoes or peppers should set up and monitor their own traps. Small-scale growers can use the monitoring information in weekly reports provided by the Wisconsin Department of Agriculture Trade and Consumer Protection (DATCP) during the growing season.

Place a trap 4 to 6 feet above the ground on the south or west side of fields when corn is in the green silk stage, pepper fruits are forming, or when DATCP monitoring indicates that moths are in the state. Pheromone traps should be the Hartsack type. Sticky traps do not work well. Hercon® pheromone lures have been very effective at attracting earworm moths. Pheromones should be changed every 2 weeks with the unused lures kept frozen until needed. For accurate counts, be sure to remove used lures from the trap area.

A blacklight trap can also be used. Blacklight traps use ultraviolet lights to attract flying insect pests at night. European corn borer, corn earworms, and other night flying moth populations can all be determined using this method. However, blacklight traps are more expensive, and they are considered less effective and more difficult to monitor than pheromone traps. Scouts need to count and monitor the number and variety of species that are collected in the traps. Counts in blacklight traps are consistently lower than those in pheromone traps in adjacent fields.

Threshold: Catches of 5 to 10 moths in a pheromone trap or 3 to 5 moths in a blacklight trap, per night for three consecutive nights indicate that moths are probably laying enough eggs to warrant treatment of fields that are in vulnerable stages. Consider the presence or absence of other attractive crops in the area such as pollinating corn when interpreting trap counts for treatment decisions. To add precision to your scouting, check plants for eggs, larvae or damaged fruit. Treatment is recommended if signs of the corn earworm is detected.

Continued on next page...

Management Strategies

Cultural control

- Avoid planting peppers near corn.
- In smaller plantings, pick the larvae off the fruit and destroy them.

Biological control

- Larvae are cannibalistic and therefore only one larva is usually found per fruit.
- Corn earworm eggs are parasitized by several species of *Trichograma* wasps. Experimental releases of commercially-available *Trichogramma* have resulted in control of corn earworm on tomatoes and may be a viable option in the future.
- Generalist predators such as lacewing larvae, minute pirate bugs, and damsel bugs feed on eggs and small larvae. Conserve existing populations of beneficial insects by treating fields with insecticides only when needed and avoiding broad-spectrum insecticides.
- Earworm eggs are susceptible to viruses, although the impact is not yet known.

Chemical control

- Corn earworms can often be successfully controlled with insecticides after threshold has been reached. Refer to A3422 *Commercial Vegetable Production in Wisconsin* for labeled products.
- Time insecticide applications to coincide with the peak moth flight and egg-laying period. Follow guidelines in the *Scouting* and *Threshold* section.
- The bacterial insecticide, *Bacillus thuringiensis* (Bt) is an option for controlling young larvae.
- Apply only when fruit is present.
- Thorough coverage is necessary.
- Some corn earworm larvae in the Midwest have been confirmed to be resistant to synthetic pyrethroid insecticides. Do not spray the same product or products with a similar mode of action in consecutive applications.

© Whitney Cranshaw, Colorado State University, Bugwood.org

Feeding by corn earworms create deep, watery cavities in the fruit.

© Jack Dykinga, USDA Agricultural Research Service, Bugwood.org

Avoid planting peppers near corn because tasseling corn is very attractive to corn earworm.

PEST PROFILES

European Corn Borer

April	May	June	July	August	September	October
		peak activity	peak activity	peak activity	peak activity	

The European corn borer is a frequent pest with a wide host range. Corn, peppers, eggplants, tomato, and potato are common hosts in the upper Midwest. Most damage is caused by larvae feeding on fruit in August. The borer is difficult to control because of the short time interval between egg hatch and fruit tunneling.

The European corn borer can cause significant damage to peppers. The larvae tunnel into fruit under the cap, or sometimes directly through the side, and they feed in the central seed mass, in the ribs, and in the wall of the fruit. If infestation occurs when fruits are small, the infested fruits are usually rotten by harvest. If infestation occurs when fruits are larger, the infested fruit can appear to be fine on the outside but is deteriorated on the inside. Infested fruit often ripens earlier than the rest of the crop. Sometimes the larvae will tunnel into the stem, causing wilting and breakage. Secondary bacterial infection at the point of entry is common.

© Frank Peairs, Colorado State University, Bugwood.org

© Clemson University - USDA Cooperative Extension Slide Series, Bugwood.org

The adult European corn borer is a night-flying, straw-colored moth with a 1-inch wing span.

Males are slightly smaller and distinctly darker than females.

Scouting: Monitor adult moth activity and peak flights using weekly reports provided by the Wisconsin Department of Agriculture Trade and Consumer Protection (DATCP) during the growing season. This information will help you know when to start looking for moths near your fields. You can also monitor them with black light traps. Traps should be operated in dense weedy areas on field edges or corners of the field where the adult moths congregate. They should be far enough from buildings to avoid interference.

Degree day accumulation may also be used to predict moth flights. Using a base temperature of 50 degrees F, peak flights in south-central Wisconsin will occur at 600 DD_{50} for the first generation (typically in mid-late June) and 1700 DD_{50} (mid-August) for the second generation.

When black light traps indicate increasing moth populations and/or DD_{50} accumulation has been reached, begin walking field edges during the day to gauge the level of European corn borer populations close to an individual field. If moths are seen in these areas, flight and egg-laying is likely reaching threshold levels on susceptible crops.

Threshold: Treat when eggs or larvae are observed OR when female European corn borer moths in nearby black-light traps exceed 4 per night on three consecutive nights when peppers are forming.

Management Strategies

Cultural control

- Keep pepper plantings as far away from corn plantings as possible.
- Remove grassy weeds from field edges where adult moths congregate.
- Some pepper varieties differ in their susceptibility, but there are no truly resistant varieties.
- Plow under crop stubble of all susceptible crops after harvest to destroy overwintering larvae.

© Clemson University - USDA Cooperative Extension Slide Series, Bugwood.org

European corn borers damage peppers by tunneling into developing fruit and plant stems.

Continued on next page...

Biological control

- A variety of natural enemies help suppress European corn borer infestations including predatory lady beetles, minute pirate bugs, lacewings, and fly and wasp parasitoids. Bird predation can also be important.
- The parasitic wasps *Trichogramma* have been effective in some experiments and may be available commercially in the future.
- Weather conditions greatly influence European corn borer survival, particularly during the egg stage and before young larvae enter the fruit. Heavy rains can wash the egg masses and young larvae off the plants. Very hot, dry weather causes desiccation of the eggs and young larvae. These climatic events kill a significant number of young larvae each year.

Chemical control

- Corn borers can often be successfully controlled with three treatments made at 7 day intervals after threshold has been reached. Refer to A3422 *Commercial Vegetable Production in Wisconsin* for labeled products.
- Time insecticide applications to coincide with the peak moth flight and egg-laying period. Follow guidelines in the *Scouting* and *Threshold* section.
- Be aware of resistance concerns and avoid consecutive sprays of the same class of chemistry.
- Insecticides must be applied before larvae burrow into the fruit where they are protected.
- Do not spray before fruit begins to form.
- Insecticide coverage must be thorough.
- *Bacillus thuringiensis* can be effective in controlling early instar larvae.

Check the WDATCP Cooperative Pest Survey Bulletin of black light trap catches regularly to follow the general population of European corn borer development and predict your local area more effectively.

© University of Georgia Archive, University of Georgia, Bugwood.org

Time insecticide applications to coincide with the peak moth flight and egg-laying period. Once larvae burrow into the fruit, they are protected from insecticide sprays.

Life cycle

The European corn borer overwinters as mature larvae in corn stalks and stems of weed hosts. They pupate in the spring when temperatures are over 50 degrees F. Peak moth emergence for the overwintering generation is usually in June in southern Wisconsin. The adult moths spend most of their time in moist grassy areas, where they rest during the day. Female moths lay egg masses in the evening. The first generation of larvae rarely damages peppers in southern Wisconsin unless the crop was planted unusually early.

The second generation moths peak in August when approximately 1700 DD_{50} have been reached (1550 -2100 DD_{50}). If there is corn in the fresh silk stage nearby, the moths are more likely to lay eggs on corn than on peppers. If nearby corn is past the fresh silk stage, then moths are likely to lay eggs on leaves of the pepper plant or other host. After egg hatch, larvae crawl immediately to fruit more than 1 inch in diameter and tunnel in. There are two generations in southern Wisconsin and only one in the northern part of the state.

The adult European corn borer is a night-flying, straw-colored moths with a 1-inch wing span. Males are slightly smaller and distinctly darker than females. The eggs are white, overlap like fish scales, and are deposited on the lower leaf surface near the midvein. 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 ¾ to 1 inch long, grey to cream-colored, with a small, dark brown head and dark spots covering the body.

Pale-striped Flea Beetle *Systena blanda*

	peak activity					
April	May	June	July	August	September	October

Flea beetles are very small, hard, active beetles with large hind legs that allow them to jump long distances when disturbed. There are many different species of flea beetles; the pale-striped flea beetle is most common on peppers. The pale-striped flea beetle will also feed on bean, beet, eggplant, lettuce, melon, pea, pumpkin, and radish.

Flea beetles feed on the leaves, creating small pits and a shot-hole appearance. The greatest damage occurs during the spring when flea beetles feed on cotyledons and first true leaves in the first weeks after emergence. Damage is generally greater to seedlings than to transplants. Heavily damaged leaves may dry out and die. Large populations of beetles can kill or stunt seedlings. Peppers can tolerate flea beetle feeding once they have passed the seedling stage.

Flea beetles overwinter as adults in leaf litter, hedgerows, and wooded areas. The beetles emerge in late April when temperatures reach 50 degrees F. Adults begin laying eggs in the soil at the base of host plants in May. Most flea beetle larvae feed on roots, but this activity is generally not of concern in peppers. A second and sometimes third generation of adults feed from July to September, but crops are usually mature enough that feeding damage is minimal.

Adult flea beetles feed on leaves, creating small pits and a shot-hole appearance.

Flea beetles can cause serious damage on young plants, but rarely on older plants.

© Whitney Cranshaw, Colorado State University, Bugwood.org

Scouting: Scout direct-seeded and transplanted crops twice per week during the seedling stages until plants are well-established. Begin scouting at the field margins and walk into the field, selecting plants at various random intervals. Most flea beetle damage is distinctive in appearance and looks like small, ragged holes or pits in the foliage. Pale-striped flea beetles are very small (less than ¼ inch), of various colors, and have a pale longitudinal stripe on each wing cover. They are most active on calm, sunny days, and less active during rainy or windy weather.

Threshold: Consider insecticide treatment if flea beetle populations exceed 4 beetles per plant on seedlings (Foster and Flood).

Management Strategies

Cultural Control

- Rotate fields with non-host crops.
- Remove early season hosts. Clean up weedy areas next to the field, especially grassy, solanaceous, and cruciferous weeds, or weeds that are drying up or growing poorly.
- In smaller plantings, spun-bonded row covers are an effective way to exclude the egg-laying adult beetle. Get the row covers in place at the time of transplanting or seeding and seal the edges with soil.
- Work in crop residues after harvest to reduce overwintering sites.

Biological control

- Predators such as lacewing larvae, big-eyed bugs, the western damsel bug, and northern field crickets feed on flea beetles, but their impact is not well known.

Chemical Control

- Foliar insecticides can be effective for quick control of large populations feeding on vulnerable seedlings. Check A3422 *Commercial Vegetable Production in Wisconsin* for currently labeled products.
- Choose a product with a short residual life that will not harm natural enemies of aphids. Unintended injury to beneficials may cause other insect problems to appear later in the season.
- Spot treating more heavily-infested field edges may be sufficient to control flea beetles. One insecticide treatment should be all that is required.

PEST PROFILES

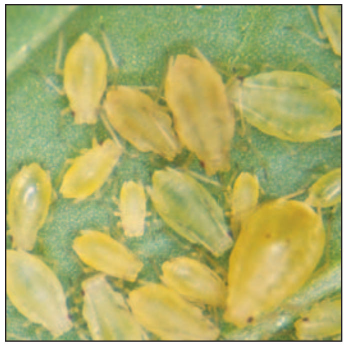
Green Peach Aphid *Myzus persicae*

	seedlings are most susceptible, scout weekly		peak activity			
April	May	June	July	August	September	October

Aphids are small, soft-bodied, pear-shaped insects. They can be distinguished from other types of insects by the presence of cornicles, which look like tailpipes on the back end of the insect. The green peach aphid and potato aphid are the two species that most commonly infest peppers. The green peach aphid has a wide host range which includes pepper, beet, celery, cole crops, cucurbits, lettuce, potato, spinach, and tomato. They feed primarily in groups called colonies on the underside of leaves, usually in the lower canopy.

Aphids feed by inserting a needle-like stylet between plant cells into the vascular tissue. Typically, this causes little direct injury to the tissues. However, large populations and extended feeding may extract enough sap to cause leaf curling, wilting, and plant death. Seedlings are most susceptible to aphid damage. Aphids excrete excess sap, called honeydew, which gives leaves and sticky texture and attracts ants. Black sooty mold fungi growing on the honeydew secretions can be a problem on fruit. The green peach aphid transmits a number of destructive viruses in peppers including pepper potyviruses and cucumber mosaic virus.

In Wisconsin, green peach aphids overwinter as eggs on the bark of Prunus species. After a couple of generations on these hosts, winged aphids leave for summer hosts, including peppers. Development of aphid populations on summer hosts can be very rapid because the adult female produces offspring without mating or laying eggs. In warm weather a female can give birth to as many as 12 female wingless nymphs per day and a generation may be completed in a week. Winged offspring are produced when colonies become overcrowded or when the day length begins to shorten. The winged offspring will fly short or longer distances to new fields. Late in the season, the females mate and produce the eggs that will overwinter on Prunus trees and shrubs.



© David Riley, University of Georgia, Bugwood.org

© Scott Bauer, USDA Agricultural Research Service, Bugwood.org

The green peach aphid has an elongated, smooth, soft, spindle-shaped body. Antennae are held to the side and are longer than the body. Coloration varies from green to reddish-pink. Winged forms are a pale green.

Scouting: Check transplants twice per week for aphids and weekly later in the season. Reduced plant vigor, stunting, and deformation of plant parts are common symptoms of aphid infestations. In some cases, honeydew or sooty mold will be present. Aphid activity is likely to occur in "hot spots" scattered throughout the field.

Because of the spotty nature of infestations, a number of plants in at least randomly selected areas in the field areas should be examined for aphids. Examine 10 plants and rate the plants as infested or uninfested. Repeat checks at weekly intervals to determine the need to treat. Aphid sampling should always include an evaluation of the presence and activity of natural enemies.

Threshold: Treatment thresholds for green peach aphid are not well established. If seedlings or young plants show signs of stress because of aphid feeding, an application of insecticide may be needed. Given the huge reproductive potential of aphids, an infestation level of 5 to 10% would indicate a potentially damaging infestation.

Management Strategies

Cultural control

- Planting resistant varieties is the most effective way to control aphid-transmitted viruses.
- Eliminate alternate hosts of both aphids and virus diseases. Control weeds along ditches, roads, farmyards, and other non-cultivated areas. These include virus hosts such as pokeweed, burdock, and other perennial broadleaf weeds, as well as milkweed, jimsonweed, pigweed, plantain, and field bindweed that harbor aphids.
- Inspect overwintered and imported plants in greenhouses since they can be a source of aphid infestation of spring transplants.
- Do not plant peppers near other pepper fields.

Continued on next page...

- Row covers can be used to exclude early aphid infestation.
- Aphids are less attracted to mulched plantings than bare-ground between plants. Reflective mulches will repel aphids.
- Plow in crop debris immediately after harvest.

Natural controls such as heavy rains, predators, and diseases help control aphid populations.

Biological control

- The green peach aphid has many natural enemies, including ladybeetles, syrphid flies, and parasitic braconid wasps. Natural enemies are often numerous enough to keep aphid populations in check, depending on environmental conditions. Sometimes wasp parasites are the most effective, sometimes generalist predators are most effective. There can be a lag period between when aphid populations first arrive and when their natural enemies build up.
- Be sure to evaluate predator and parasite populations when making treatment decisions. An increase in aphid populations can sometimes be caused by applications of insecticides that have killed natural enemies.
- Encourage the activity of beneficial insects by maintaining habitat for them around the field.
- Heavy rain can rapidly decrease aphid populations as well as produce ideal conditions for the development of fungal diseases which can rapidly reduce or wipe out entire aphid colonies.
- Natural enemies will not kill aphids in time to prevent the spread of viruses.

Chemical control

- If infestations are localized, spot spraying can be an effective way of reducing aphid numbers while maintaining predator populations. Treat 100 feet beyond the edges of the infestation. Refer to A3422 *Commercial Vegetable Production in Wisconsin* for labeled products.
- Use selective insecticides to conserve natural enemies (see **Biocontrol section** for details).
- Good coverage is critical for control of aphid infestations with insecticides.
- Initial virus infections cannot be controlled by spraying for aphids.
- Green peach and melon aphids have shown resistance to several insecticides, particularly organophosphates. Do not spray the same product or products with a similar mode of action in consecutive applications.

References

Boerboom. Chris et.al. 2006. Commercial Vegetable Production in WI- University of WI – Extension publication number A3422.

Boerboom, C.M.. 2002. Herbicide Mode of Action. Cooperative Extension, University of Wisconsin.

Commercial Vegetable Production Guides – Peppers. Oregon State University . Revised August 6, 2004. http://oregonstate.edu/Dept/NWREC/pepper.html

Delahaut, Karen and A.C. Newenhouse. 1997 "Growing tomatoes, peppers and eggplants in Wisconsin." University of Wisconsin – Extension publication A3687.

Delahaut, Karen and Walt Stevenson. 2004. "Tomato and Pepper Disorders: Bacterial Spot and Speck." University of Wisconsin – Extension publication A2604.

Florida. "Crop Profile for Peppers (Bell) in Florida" – July, 2006. http://www.ipmcenters.org/cropprofiles/docs/FLbellpepper.html

Foster, Rick and Brian Flood. *Vegetable Insect Management with emphasis on the Midwest*. Meister Publishing Company, 1995, revised 2005.

Foster, Rick, et.al. 1998. "Midwest Vegetable Production Guide for Commercial Growers" Purdue University Department of Entomology – Rick Foster, Entomology Department at Purdue University lead Editor. http://www.entm.purdue.edu/Entomology/ext/targets/ID/IDpdf/ID-56pdf/index.pdf

Hartz, Timothy K. Michelle LeStrange, Keith S. Mayberry and Richard F. Smith. 1996. "Bell Pepper Production in California". University of California, Division of Agriculture and Natural Resources Publication 7217.

Laboski, C.A.M, John B. Peters, and Larry G. Bundy. 2006. "Nutrient application guidelines for filed, vegetable and fruit crops in Wisconsin. University of Wisconsin – Extension Publication A2809.

Olsen, S.M. et.al, 2005. "Pepper Production in Florida". University of Florida Extension, IFAS. Horticultural Sciences Dept. Document HS732.

Pete, Mary. 2006. *Sustainable Practices for Vegetable Production in the South*. Focus Publishing. Purdue University. 2003. "Midwest Vegetable Production Guide for Commercial Growers – Peppers."

North Carolina. "Crop Profile for Peppers" – December, 1999. Revised June, 2005. http://www.ipmcenters.org/cropprofiles/docs/ncpeppers.html

Sanders, Douglas C., Charles W. Averre, Kenneth A. Sorensen. 1998. "Pepper Production (Bell, Small Fruit, and Pimento" – North Carolina Cooperative Extension Service, NCSU. http://www.ces.ncsu.edu/depts/hort/hil/hil-21.html

Sexson, D. and T. Connell. 2004. BioIPM Potato Workbook. Eds. Schmidt, Broeske, Tyron-Petith. University of Wisconsin Cooperative Extension, Nutrient and Pest Management (NPM) program.

Tennessee. "Crop Profile for Peppers in Tennessee" – February, 2005. http://www.ipmcenters.org/cropprofiles/docs/tnpeppers.html

Copyright © 2010 University of Wisconsin-System Board of Regents and University of Wisconsin-Extension, Cooperative Extension.

Authors: Deana L. Knuteson is the Biointensive IPM Coordinator/Researcher for the Nutrient and Pest Management Program, College of Agricultural and Life Sciences, University of Wisconsin-Madison; Walter R. Stevenson is a professor in the Department of Plant Pathology, College of Agricultural and Life Sciences, University of Wisconsin-Madison and University of Wisconsin-Extension, Cooperative Extension; Jeffrey A. Wyman is an emeritus professor in the Department of Entomology, College of Agricultural and Life Sciences, University of Wisconsin-Madison and University of Wisconsin-Extension, Cooperative Extension; Alvin J. Bussan is an associate professor in Department of Horticulture, College of Agricultural and Life Sciences, University of Wisconsin-Madison and University of Wisconsin-Extension; Jed B. Colquhoun is associate professor in the Department of Horticulture, College of Agricultural and Life Sciences, University of Wisconsin-Madison and University of Wisconsin-Extension, Cooperative Extension; Carrie A.M. Laboski is an assistant professor with the Department of Soil Science, College of Agricultural and Life Sciences, University of Wisconsin-Madison and University of Wisconsin-Extension, Cooperative Extension.

Produced by the Nutrient and Pest Management Program, College of Agricultural and Life Sciences, University of Wisconsin-Madison, University of Wisconsin-Extension, Cooperative Extension.

University of Wisconsin-Extension, Cooperative Extension, in cooperation with the U.S. Department of Agriculture and Wisconsin counties, publishes this information to further the purpose of the May 8 and June 30, 1914 Acts of Congress; and provides equal opportunities and affirmative action in employment and programming.

If you need this information in an alternative format, contact Cooperative Extension Publishing at 608-262-2655 or the UWEX Affirmative Action Office.

This publication is available from your Wisconsin county Extension office or from Cooperative Extension Publishing. To order, call toll free 877-WIS-PUBS (947-7827) or visit our web site at learningstore.uwex.edu.

BioIPM Pepper Workbook (A3844) R-08-2010