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# Introduction

This BioIPM workbook is organized seasonally to provide a comprehensive, year-round self-assessment tool and reference on pest management and cultural practices in perennial strawberry production. This workbook is a practical tool for grower use throughout the entire perennial production cycle with an eye on biologically-based production decisions that are ecologically sound and economically profitable. It is intended to help growers advance in production and consider new environmentally-sensitive and profitable practices; it is not intended as an introductory or general strawberry production guide. A list of such guides is included in the **Appendix: References and Resources**.

At the beginning of each chapter, there is a set of statements about the farm's current production practices. This self-assessment section is formatted on a scale, with Category A being the minimal practices that could be used and Category D describing advanced, sometimes experimental approaches. For most topics, the bio-intensive approaches utilize all categories. By checking all the statements that apply, growers can use the section to assess where their production systems fall on various topics, such as selecting disease-resistant cultivars or managing a particular pest.

Each self-assessment is followed by detailed descriptions of the bioIPM production practices. Growers are encouraged to read about these practices and consider whether they might be appropriate advancements in their production systems in a way that advances environmental sustainability while maintaining crop profitability.

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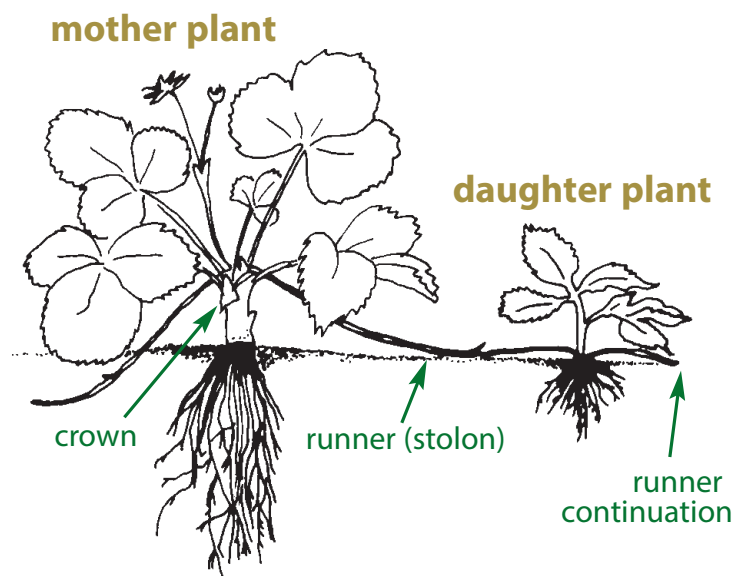
# Perennial Strawberry Growth And Development

Preplant



## General crop information

Strawberries (*Fragaria ananassa*) are shallow-rooted perennials that regenerate roots, leaves, stolons (the “runners”), branch crowns and flowers from the main crown of the plant.



The stolons generate from the main crown of the plant and form a daughter plant that becomes rooted itself. The flowers and fruit form on the main crown, daughter plants and branch crowns (crowns that initiate directly on the main crown instead of on stolons). Every growing season new roots and leaves grow from the crown, appearing to “raise” the plant from the soil. This raised crown, combined with the shallow roots in the top 6 inches of soil, make older strawberry plantings susceptible to drought, freezing and other stresses that eventually limit production.

There are three primary types of strawberry plants, distinguished by timing of fruit production that is dictated by day length:

- ▶ June-bearing strawberries account for the vast majority of Wisconsin strawberry production. They produce one crop per year, usually from mid-June to early-July depending on location and cultivar.
- ▶ Day-neutral strawberries fruit independent of day length and thus produce strawberries from late-spring to early-fall. These plantings tend to only be productive for one season.
- ▶ Everbearers produce two crops when day light is 12 hours or longer. They tend to be less hardy cultivars and last only 2 seasons at best.

# Field Selection and Crop Rotation

## Preplant



To ensure healthy strawberry plants, fields should be selected to optimize growth and quality. Careful selection of field location and proper crop rotations can aid in strawberry plant health.



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

- ☐ **A.** Rotations are selected to avoid common pest concerns in strawberries.
- ☐ **B.** Planting areas are chosen that are free of perennial weeds and herbicide carryover concerns.
- ☐ **C.** Soil characteristics, nutrient levels, and pH levels that are ideal for strawberry growth are monitored and maintained.
- ☐ **D.** Fields with good drainage and water holding capacity are selected while avoiding low spots that accumulate cold air.

## A. Rotations

In general, fields should be selected for strawberry production that don't harbor pests that are found in strawberries. Crop rotations should be followed that include non-hosts for common strawberry pests, such as *Verticillium* and nematodes. Growers should avoid rotations with solanaceous crops, vining cucurbit crops and other small fruit like raspberries and blueberries. A common rotation could include corn two years prior to strawberries and a small grain crop such as oats or wheat in the year prior to strawberries.

**★ Quick note:**

**Nematodes:** Pick fields with no known history of nematodes since these can seriously damage strawberry roots and can limit long-term productivity of the plants!

The root lesion nematodes (*Pratylenchus* species) are of concern because they may factor in black root rot while also interacting with *Verticillium* to cause poor growth and early death of the plants.


## Select rotations to encourage optimum growth

Do not rotate with solanaceous crops, vining cucurbit crops and other small fruit like raspberries and blueberries.

Good rotational options are corn two years prior to strawberries and a small grain crop such as oats or wheat in the year prior to strawberries.

## B. Weed and herbicide concerns

Fields chosen for strawberries need to be free of perennial weeds. Rotational crops should be kept clean of seed-producing weeds as much as possible. Perennial weeds should be controlled prior to planting. Fighting perennial weeds, such as Canada thistle, in perennial strawberries is labor and resource intensive and often not very successful. Make sure perennial weeds are controlled in prior crops and in or around field locations.



*Young Canada thistle plant*



*Young Canada thistle plant*

Herbicides used in rotational crops can cause problems if they still persist in the soil at strawberry planting. In particular, herbicides that provide “residual” or longer-term weed control can carry over in the soil from one cropping season to the next or longer. Keep track of which herbicides were used in the desired field for at least four years prior to strawberry planting and follow the rotational restrictions on the herbicide label.

**Notes:**

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

### C. Proper pH levels and nutrient levels

Strawberries grow best when soil pH is at least 6.5 for mineral soils and 5.6 for organic soils (mucky soils containing minimal amounts of sand, silt and clay). Lime should be applied in the year prior to strawberry planting so it has adequate time to react with the soil.

**★ Quick note:**


Pick a field with pH levels 6.5 for mineral soils and 5.6 for organic soils.

### Notes:

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## D. Ensure proper drainage and organic matter

While strawberries tolerate many soil types, they do best in well drained soils with moderate water holding capacity, such as a sandy loam. Soil organic matter of 2% or greater is ideal. Avoid low spots in fields as excess water may pond and where cold air may accumulate and damage strawberry plants. Also, consider the proximity to the irrigation water source to avoid the need for excess pumping and irrigation pipes.

A photograph showing a large field of strawberry plants in rows. The plants are green and healthy. In the background, there are trees and a cloudy sky. A small white vehicle is visible in the distance on the left side of the field.

*Locate fields near irrigation water sources to avoid excess pumping*

## Field selection checklist

In general, fields should be selected for strawberry production with the following attributes:

- ☐ Limited pest concerns for strawberries
- ☐ Are free of perennial weeds
- ☐ Do not have residual herbicide carryover
- ☐ Have well drained soils and with moderate water holding capacity
- ☐ Have soil organic matter of 2% or greater



# Variety Selection

Preplant



Choosing the most appropriate strawberry variety is critical, particularly given the perennial nature and long term commitment of a new planting.



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

- ☐ **A. Variety is valued by consumer.**
- ☐ **B. Variety is resistant to common strawberry pest concerns and/or has herbicide tolerance.**
- ☐ **C. Variety and stock are winter hardy and come from a reputable source.**
- ☐ **D. Multiple varieties are grown to vary seasonal development and harvest timings.**

## A. Consumer preference

One of the most important characteristics of a good strawberry variety is that it is desired by the consumer, with good fruit flavor, size, color and firmness, along with longer picking seasons and optimized storability. Remember, your consumers will return if there is quality and good taste!



*Different strawberry varieties*

### ★ Quick note:

Variety choices change fairly often. Consult local plant nurseries, reputable plant producers and local Extension staff for the optimal choices in the local production region.

## B. Pest resistant and/or tolerant

Since diseases, weeds and insects can cause concerns for strawberry production, it is important to look for resistant varieties to help combat these concerns with minimal additional inputs. Varietal resistance to most common local strawberry diseases can be found and should be explored when possible. For example, many varieties resist red stele, a fungal root disease. Choosing disease-resistant varieties can greatly reduce inputs needed to avoid crop production and quality issues.

Strawberry varieties can differ in their tolerance to some herbicides commonly used in production. Check with the nursery supplier prior to purchasing to determine if the desired variety has any known herbicide tolerance issues.

## C. Winter hardiness and plant sources

Winter hardy varieties that are appropriate to the production climate should be chosen to ensure Midwest winter survival. Many varieties are adapted to or developed for local growing regions and should be discussed with your nursery source. Given the long-term commitment to a new planting, consider trying new varieties on a small scale first.



*Winter-killed strawberries*

Most importantly, buy plant stock from a reputable nursery that produces plants certified to be free from diseases, including viruses. True-to-type is also important to ensure consistent and uniform production.

## D. Maturity timing

June-bearing varieties differ in fruit maturity timing; some produce earlier in the season, while some produce later as dictated by day length and air temperature. To lengthen the picking season, choose multiple varieties of differing maturity times.

### Pollination and variety choice

Some varieties will require pollinators to produce fruit, others are self-fertilizers. Check variety guidelines for specific information.



*Some varieties require pollinators*

# Field Preparation

## Planting



Proper field preparation will ensure strong strawberry establishment and also will encourage healthy, long-term growth and crop maintenance.



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

- ☐ **A.** Difficult to control weeds are managed prior to planting.
- ☐ **B.** Field water moisture levels and water holding capacity are determined to ensure optimal planting conditions.
- ☐ **C.** Appropriate tillage practices are used prior to planting.
- ☐ **D.** Cover crops and/or organic amendments are used to encourage soil quality and health.

# A. Manage weeds prior to strawberry planting

Weeds in strawberries are difficult to control once the crop grows into a matted row. Thus, pre-planting is an important window for weed management. Many growers find the stale seedbed technique works well for pre-plant weed control. This technique works by stimulating the germination of seeds close to the surface so they can be managed prior to planting.

The stale seedbed is prepared by tilling and preparing the soil for planting, then letting it rest while non-dormant weed seeds germinate and emerge. Shortly before planting, eliminate the emerged weed seedlings by using a flame torch, very shallow cultivation, herbicides, or by mowing very near the ground. The key is to keep tillage to a minimum at this point to avoid stimulating further weed seed germination. The strawberry crop then can be planted without additional tillage into a seedbed that has been depleted of a good proportion of germinable weed seeds.

## ★ Quick note:

Eliminating weeds, especially perennial species, prior to planting strawberries is much easier than trying to control them in the crop.

# B. Rolled ball test for soil moisture

An easy method to estimate soil moisture levels is to use the ball test. To do this, simply take a handful of soil and try to form it into a ball. Use the chart below to estimate soil moisture levels. Optimal soil moisture is 50% water holding capacity.



Testing the soil for moisture

Feel Chart for Estimating Soil Moisture Percent (%):

	Sand or loamy sand soil texture	Loam, silt loam, clay loam soil texture
Below 20%	No ball forms. Single grained soil flows through fingers with ease.	Powdery, dry, will not form a ball; if soil is crusted, easy to break into powdery condition.
35-40%	Forms weak brittle balls. Finger print outline not discernible. No soil sticks to hand.	A ball can be formed under pressure, but some soil will fall or flake away when hand is opened. The ball is very crumbly and hardly holds its shape.
50%	Forms very weak ball. If soil is well broken up, it will form more than one ball upon squeezing. Fingerprint outline barely discernible. Soil grains will stick to hand. <b>Optimum for planting.</b>	Forms a ball readily, holds its shape. No moist feeling is left on hand nor will any soil fragments cling to palm. Ball is very brittle and breaks readily. Soil falls or crumbles into small granules when broken. <b>Optimum for planting.</b>
60-65%	Forms weak, brittle ball. Fingerprint outline not as distinct. Soil particles will stick to hand in a patchy pattern.	Forms firm ball; finger marks imprint on ball. Hand feels damp but not moist. Soil doesn't stick to hand. Ball is pliable. When broken, ball shatters or falls into medium-size fragments.
70-80%	Forms weak ball. Distinct fingerprint outline on ball. Soil particles will stick to palm.	Damp and heavy; slightly sticky when squeezed. Forms tight plastic ball. Shatters with a burst into large particles when broken. Hand is moist.
100%	Upon squeezing, no free water appears on ball but wet outline of ball is left on hand. Ball has some stickiness and a sharp fingerprint outline is left on it.	Wet, sticky, doughy, and slick. A very plastic ball is formed, handles like stiff bread dough or modeling clay; not muddy. Leaves water on hand. Ball will change shape and cracks will appear before breaking.



## C. Tillage

Tillage loosens the soil and prepares the seedbed for direct-seeding or transplanting. Soil is tilled to incorporate organic residues, fertilizers and lime, to eliminate weeds, and warm the soil in the spring.

When planning your tillage operation, pay special attention to soil stewardship practices. Avoid excessive tillage. Be sure you have a good reason to work the soil. Remember that tillage generally reduces soil quality by reducing soil aggregation and organic matter. Never till when the soil is wet and susceptible to compaction. Soil compaction ruins the structure of the soil, and restricts water infiltration and percolation, root growth, and oxygen concentration.

Many farmers use a form of mulch tillage, which mixes residues in the upper layers of the soil while a significant percentage remains on the soil surface to reduce erosion.

Follow these general guidelines for pre-plant tillage:

- ▶ Do not till if soil is too wet.
- ▶ Vary the tillage depth from year to year to prevent the buildup of a hardpan just below the tillage level.
- ▶ If using heavy equipment, distribute the weight over multiple tires and axles to spread the load over as large an area as possible. Adjust speeds, ballast, and tire pressure to minimize tire slippage.
- ▶ Clean tillage equipment of soil and plant residues when moving from field to field to prevent the spread of weeds and soil-borne pathogens.

## D. Incorporate cover crops and amendments

Cover crops grown prior to strawberry planting can build organic matter on coarse-textured soils, add nitrogen, suppress weeds and limit weed seed production and reduce soil pathogens that cause some strawberry diseases. These positive attributes vary by cover crop species, so consider prioritizing goals as a way to select the right cover crop.

### Good Cover Crop Options for Strawberries:

A few cover crops to consider include:

- ▶ **Spring oats:** planted in mid-August, spring oats will provide good fall growth and biomass and then will be killed by hard frosts. In the spring of strawberry planting, the oat organic matter is incorporated with regular tillage.
- ▶ **Annual ryegrass:** late summer plantings will establish rapidly, including expansive root growth. It is occasionally difficult to kill annual ryegrass as it re-sprouts from below ground growing points or seed that didn't germinate at the initial planting, but it can be killed with a post-emergent grass herbicide registered for use in new strawberry plantings.
- ▶ **Clovers, such as ladino, red and crimson:** clovers can contribute a significant amount of nitrogen prior to strawberry planting. Growers should ensure that plants are dead prior to planting strawberries as clover would be very difficult to control in-season.
- ▶ **Annual mustard cover crops, such as rape, canola and brassicas:** good choices because of their biofumigant properties that suppress nematodes, soil borne pathogens and weeds. New varieties bred specifically as covers crops (instead of as oil crops), such as *Brassica nigra*, contain higher levels of the natural chemicals that suppress pests. They can survive winter and therefore may need to be killed in the spring prior to strawberry planting.



Canola is a good cover crop choice

# Planting Process and Configuration

## Planting



Careful planning and attention to environmental conditions at planting time will contribute to the quality and health of your strawberries. Proper timing, weed management and nutrition will ensure a healthy crop.



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

- ☐ **A.** Planting occurs at proper timings, with plants in good condition and at the desired spacing.
- ☐ **B.** Soil moisture is monitored and maintained at adequate levels to support plant establishment.
- ☐ **C.** Weed management practices are considered during planting and establishment.
- ☐ **D.** Adequate plant nutrition is available during strawberry establishment.

## A. General process

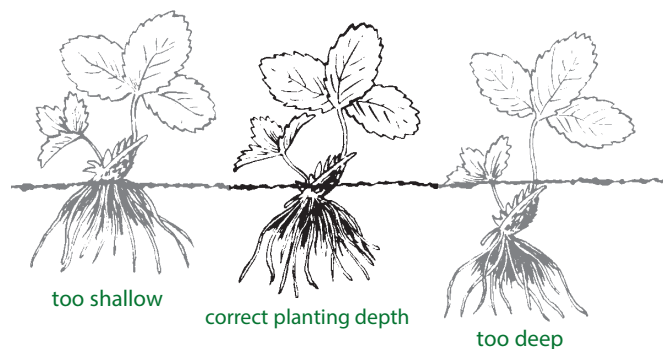
The vast majority of strawberries grown in Wisconsin are planted in a perennial matted row system, where rows are established about 36 to 45 inches apart in most cases. Plant spacing within the row is generally 12 to 24 inches, but should be adapted based on time of planting:

- If planting early (mid-April through mid-May), in row plant spacing can be wider as the plants will produce many runners that fill in the space.
- Later plantings do not send out as many runners and therefore need a denser original planting.

Planting after mid-June in Wisconsin typically results in few runners and low production in the year after planting. Varieties also differ in desired original spacing, so check with the nursery where you bought the certified plants prior to planting. **In general, aim for 5,000 to 9,600 plants per acre.** Be sure to look at varietal guidelines for proper spacing and row widths.

Proper planting depth is absolutely critical. The transplant hole should be deep enough to accommodate the roots without balling them up at the bottom. The plant should be set so that the roots and base of the crown are buried, but no deeper.

*Proper planting depth*



### First year plants:

While it is tempting to allow the first year crop to produce berries, flowers should all be removed and no fruit is produced. Removing the first year flowers stimulates greater runner and daughter plant production and greatly improves the establishment and lifespan of the planting.

## B. Soil moisture

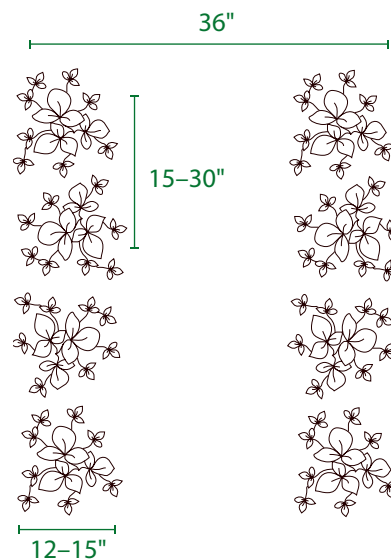
Adequate soil moisture, at about 50% of water holding capacity, needs to be available to new transplants for several weeks after planting. An inch of moisture per week is usually adequate on most soil types, but keep in mind that strawberries root shallowly, so frequent light irrigation may be necessary on coarser textured soils to prevent plant drying.

Detailed irrigation management can be found in **In-Season: Irrigation.**

### ★ Quick note:

**Careful preparation is the key!** A well planned, prepared and properly located bed of strawberries, if managed correctly, can be maintained for up to 5 years so start off right!

*Matted row system (for June bearing cultivars)*



## C. Weed management

There are now several herbicides available for use in new commercial strawberry plantings in Wisconsin that are applied while the crop is still dormant after planting, before weeds emerge. These herbicides provide residual weed control for several weeks after planting and can greatly assist in establishment of a competitive and productive crop. Consult the Midwest Small Fruit and Grape Spray Guide (<http://learningstore.uwex.edu>) for available options, and as always, read and follow the pesticide label as they change often.

Residual herbicides in the planting year will not provide season-long weed control, therefore shallow cultivation should be used to eliminate weeds when they are very small, easy to remove and less competitive. Cultivation at this time can also train strawberry runners to maintain a crop row about 18 inches in width. Some hand-weeding will likely be necessary to eliminate weeds in close proximity to the strawberry plants and after runners have been established.

### ★ Quick note:

**REMEMBER:** Even though this is a non-harvestable cropping year, to ensure a quality crop, you will need to follow proper overwintering practices, including using mulches and frost management practices. These sections are found in the **Harvest/Post Harvest Mulches and Frost** section.



*Mother and daughter plants need good plant nutrition during the establishment year*

## D. Plant nutrition

Strong plant nutrition management is needed at two times in the strawberry establishment year. Ensure adequate nitrogen:

1. To assist in the production of runners and daughter plants.
2. To assist with the production of the flower buds that will produce the fruit in the following spring.

Inadequate nitrogen (N) in particular during these times will limit fruit production in the following year and shorten the lifespan of the planting. Therefore, a split application of nitrogen is most often appropriate, with fertilizer applied when runners start to form (mid-June in most years) and fertilizer applied when flower buds begin to form in early- to mid-August.



*Urea fertilizer*

The total amount of N per acre in the establishment year should be no more than 30 pounds per acre. Make sure to account for previous legume or cover crop nutrient credits when determining N rate at planting.

See **In-season: Soil Fertility and Plant Nutrition** for more Information.

### Handling of nursery plants:

Dormant strawberry plants should be handled with care after arriving from the nursery. Plants can either be heeled in the ground in a cool, protected spot for storage until planting, or more preferably, kept in refrigerated storage. Refrigerated plants can often be held for up to 6 weeks after arrival, assuming that moisture around the plants is adequate but not in oversupply. It is best to keep the refrigerated plants in their original shipping bag. In this case, the plants themselves will provide enough moisture to stay alive but not so much that they rot.



# General IPM

## In-Season



Integrated pest management (IPM) is a long-term approach to managing pests that makes use of all available pest management tools in a way that minimizes economic, health, and environmental risks. Progress along the IPM continuum is made possible by greater reliance on pest management practices that are inherently prevention-oriented, which reduces the need for pesticides.



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.**
- ☐ **C. Pests are properly identified and life cycles and ecology of pests, diseases, and weeds of strawberries are reviewed and understood.**
- ☐ **D. Biologically-based, preventative IPM strategies are used throughout the season. These include cultural and mechanical controls, host resistance, and biological control.**

## A. IPM 101

A practitioner of IPM anticipates the pest, disease, and weed problems likely to occur in the crop and combines multiple pest management strategies, including cultural practices, physical and mechanical controls, biological control, host-plant resistance, and chemical control.

Implementing multiple strategies throughout the growing season, often in order to prevent pest problems, is the basis of biologically-based pest management or bioIPM for short. Strategies to prevent resistance to pesticides are also an important component of IPM programs.

Practicing IPM means looking at the cropping system as a whole, and giving year-round attention to preventing and managing pest problems. This is different than taking a single-season, single-pest approach to management.

The principal components of IPM programs are:

- ▶ Understanding the ecology and dynamics of the crop
- ▶ Understanding the ecology and dynamics of pests and their natural enemies
- ▶ Using a monitoring program such as scouting
- ▶ Using economic thresholds and other decision-making tools
- ▶ Considering all available pest management strategies and determining the most appropriate throughout the season

### Record Keeping

Keep a record of crop production practices and other pest control strategies used throughout the season, as well as scouting information, weather, crop conditions and yield. Good records will help determine which pest control strategies are working and where. It is recommended that scouting data and field records be kept for 10 years for long-term analysis.

## B. Scouting

Scouting is the regular examination of the crop condition and is the cornerstone of IPM. It involves walking through a field and stopping at a number of locations to observe crop growth and to check for the presence or signs of insect pests, beneficial insects, diseases, and weeds. Accurate and timely scouting helps you identify potential problems before they become difficult to manage and will probably prevent unnecessary pesticide treatments.



*Scouting helps identify potential problems*

The information recorded during scouting is useful in several ways. It aids in day-to-day decision-making, especially when combined with knowledge of pest life cycles and crop development. The field data collected during scouting is also extremely useful when planning for the next growing season.

How you scout depends on the crop growth stage and the insects, diseases, and weeds likely to be present. Specific details are described in the **Scouting and Troubleshooting** section of this workbook.

## C. Pest ID and life cycles

Greater knowledge about the common pests, diseases, and weeds of a crop increases your effectiveness in preventing pest problems and managing those that do occur. It helps anticipate which are likely to be a problem, to recognize them quickly, and to target the most vulnerable pest stages. Proper identification and knowledge of pest life cycles also allows for multiple strategies to be integrated during the growing season.

Accurate pest identification is a crucial first step for effective pest management. Misidentification of insect pests and diseases is a common cause of poor pest control. The following chapters describe the details of crop scouting and common strawberry pests.

## Key Weed Identification

For weeds, understanding the difference between broadleaf and grass weeds is key to managing their control.

Broadleaf weeds are dicots with broad leaves and 2 cotyledons, or seed leaves. Seed leaves or cotyledons are 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 vary by 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 whorl about the stem.

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

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

**The blade:** the flattened portion of the leaf.

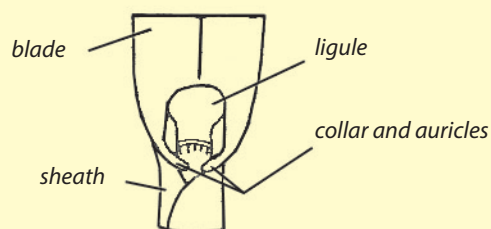
**The collar:** the junction between the blade and the sheath.

**The sheath:** the portion of the leaf surrounding the stem.

**The ligule:** 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



### Notes:

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## D. Biologically-based IPM (BiolPM)

In general, as IPM systems become more complex and prevention-oriented, pest managers will need to be as knowledgeable as possible about the pests, their natural enemies, and all possible control options.

Pest management strategies include cultural, mechanical, physical, genetic, and biological controls that help prevent insect pest problems, and chemical controls when additional control measures are needed. Implementing a variety of pest management strategies throughout the growing season is the basis of biologically-based pest management (biolPM).

- ▶ Cultural controls are decisions made in the production system that will avoid or suppress the build-up of pests, diseases and weeds. There are many examples of cultural controls, including crop rotation, site selection, modifying the planting date to avoid peak pest periods, improving the water-holding capacity and fertility of the soil, using disease-free seed and transplants, and many more.
- ▶ Mechanical and physical controls are methods that exclude, bury or kill pests to prevent population build-up. Some examples are the use of row covers to exclude insects, mulches to prevent weeds, trap crops, plowing and cultivation to smother weeds and bury pathogens, cleaning machinery to prevent spread of pathogens and weeds from field to field, maintaining proper temperatures and air flow in greenhouses and storage facilities to prevent the growth of disease organisms, and many more.
- ▶ Genetic control by selecting crop varieties with resistance or tolerance to insects and diseases is a highly effective strategy. Selecting varieties that have good horticultural characteristics that favor vigorous growth, such as rapid emergence and heat or cold tolerance, or that are not prone to physiological disorders will also contribute to a healthy crop and high yield.
- ▶ Biological control is allowing naturally-occurring or introduced beneficial organisms to control or suppress pest populations. Common examples of beneficial organisms are parasitic wasps and predatory bugs, beetles and spiders. Natural enemies of pests are common in the field and should be preserved.

### Biological controls:

Biological control is the use of living beneficial organisms, sometimes called natural enemies, for the control of pests. Biological control can be easily and effectively supplemented with cultural and carefully-chosen chemical controls when necessary for a truly integrated pest management approach.

To encourage natural enemies, you will need to provide food, water and shelter in or around your fields to encourage them to stay in the crop area to feed and reproduce. Beneficial insects often need an alternate food supply in addition to the pest prey. More diverse landscapes with multiple species and flowers will help maintain healthy populations.

Another biocontrol method is known as augmentative release, which is the process of introducing beneficial species into your cropping system. For example, green lacewings are available from many commercial suppliers and are general predators of many pest species.

Although this method needs to be precise, when applied correctly, it can help build up beneficial populations within your fields.



*Green lacewing larvae are available commercially*

- ▶ Chemical control by applying pesticides should be used together with preventative control measures, and only when pest populations are at a level to cause economic damage. When possible, choose a selective insecticide that is specific for the pest you are trying to control, with little or no detrimental effects on beneficial insects. Another category of pesticides are called biorational products, which have additional attributes that make them less harmful to the user and the environment.



# Scouting and Troubleshooting

## In-Season



Monitoring the pest level in your fields is a crucial aspect of IPM. Scouting helps you identify potential problems before they become less manageable. Scouting also prevents unnecessary pesticide treatments by providing the information you need to treat only when pests reach economically damaging levels. Accurate scouting helps ensure that treatments are effective.



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 occasionally scouted during the season.
- ☐ **B.** Fields are scouted weekly during the season and twice weekly at critical crop growth stages and peak pest emergence. Efforts are made to accurately identify pests and diseases.
- ☐ **C.** Good scouting methods are used. Field notes are taken for later management decisions.
- ☐ **D.** Field records are created for long-term comparisons of pest pressure and evaluation of management strategies.

# A. Crop scouting 101

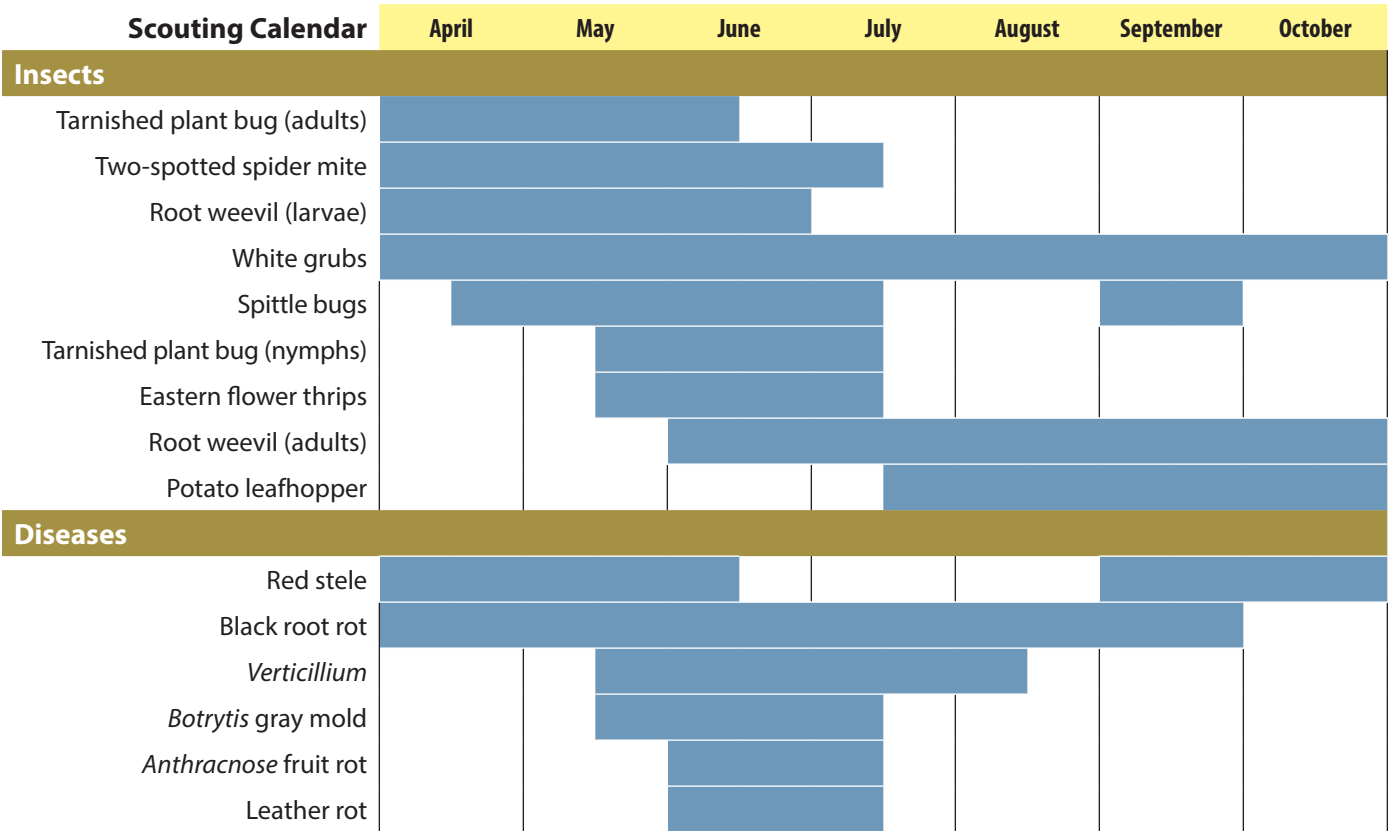
Scouting is the regular monitoring of the crop condition and is the backbone of a successful IPM program. Scouting involves walking through a field and stopping at a number of locations to observe crop growth and to check for the presence or signs of insect pests, beneficial insects, diseases, and weeds. Accurate and timely scouting may prevent unnecessary pesticide treatments, and it helps you to identify potential problems before they become less manageable. The recorded information is also useful to evaluate the effectiveness of current management practices and to determine what is needed in the future.

Implementing the University of Wisconsin-recommended scouting procedures will help you gain an accurate account of pest populations found in your fields. Crop scouts must be able to properly identify pests and diseases, use proper techniques, and provide an accurate analysis of field pest concerns and overall crop health.

## Notes:


# B. Scouting calendar

Scouting for pests in strawberries should occur weekly throughout the growing season. Note if there is any observed crop damage and work to properly identify pests you may find. Specific pests (insects, diseases and weeds) are described in detail in the following chapters (**In-Season: Disease BMPs, Insect BMPs, and Weed BMPs**).



### C. Scouting methods

Scout strawberries by walking the field in a systematic manner, such as a W-shaped pattern, that adequately covers the field. Choose 5 representative sites throughout the field. Look for the presence and signs of insect pests, diseases, weeds and beneficial insects. Bring a hand lens if you have one. A 10X magnifying hand lens will enlarge tiny insects to help in distinguishing key identifying characteristics, and will help you determine if leaf spots are caused by a fungal pathogen or environmental causes.



*A 10x hand lens*



*A 10x hand lens*

As you walk from site to site, remain alert for signs of insect, weed or disease problems that may be sporadic in the field. Be aware of yellowing or wilting plants or heavy insect feeding and examine these plants more closely. Do your best to accurately diagnose the cause. Check the field edges as well as low-lying areas of the field where pests or diseases have been a problem in the past.

### Notes:

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

## D. Field records and maps

As IPM systems get more complex and prevention-oriented, pest managers will need to keep good records about their production system and pest management strategies. Field records on cropping practices, combined with field scouting data, will provide a way to continually assess and improve the effectiveness of pest management strategies.

Many growers find it useful to make farm and field maps which can be used as a basic template each year to keep track of rotation history, crop inputs, and production practices. During the season, growers often find it useful to keep track of what they do in a pocket notebook or other form of recording. Field notes during tillage and planting, such as equipment settings and row spacing, and general observations made on plant health, specific weed populations or problem locations, as well as weather conditions such as heavy rains or soil erosion are useful aspects to note during the season.

A weed map is particularly effective as a long term management tool. The weed map should include notes on specific weed species present, the locations of perennial weeds, and any severe infestations of annual weeds. Also note the weeds located in fence rows, near the edges of the field, and along waterways.

Keep the records relevant and simple. They should be useful to you in making management decisions. At the end of the year or season, gather all the field maps, activity logs, scouting data, and field notes in one place. Be sure to review last year's records when making plans for the coming season. It is recommended that scouting data and field records be kept for 10 years for long-term analysis.

## Hot spots

By watching changes in pest problems over time, you will probably find that there are areas within a field that are prone to insect pests, weeds, or diseases. These areas of the field are known as “hot spots”. Hot spots may require more scouting or specific management strategies. You can map your field by hand, or with GPS systems, to assess the patterns and changes in these “hot spots” over time. Weed maps are effective as a long-term management tool and should be kept over time to manage weed “hot spots”.

# Disease BMPs

## In-Season



An integrated disease management program which incorporates cultural, physical, mechanical and biological control strategies should be utilized for strawberry production.



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

- ☐ **A.** Proper growing practices are used to support crop vigor and resistance to plant disease.
- ☐ **B.** Scouting for specific diseases occurs weekly during susceptible crop growth stages and during periods of conducive weather conditions.
- ☐ **C.** Diseases are managed preventatively using a combination of crop rotation, resistant varieties, and sanitation.
- ☐ **D.** Long-term records are kept to assess the effectiveness of plant varieties and other management strategies.



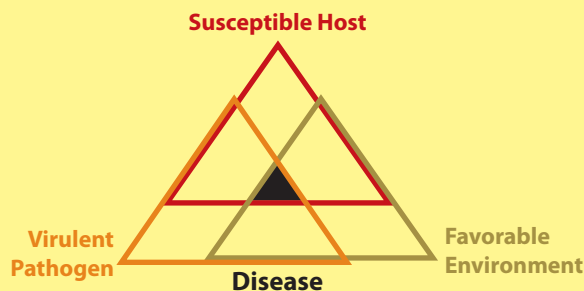
## A. Plant vigor & disease resistance

Strawberries are susceptible to a wide range of diseases that afflict roots, leaves, and fruit. Overall plant health should be monitored to ensure healthy, disease free growth and development. The following describes general disease management strategies to prevent introduction of diseases, while also describing some common diseases which can occur in Wisconsin.

Diseases in plants occur when a pathogen is present, the host plant is susceptible, and the environment is favorable for the disease to develop. Altering any one of these three factors can slow the development of a disease, or prevent it from occurring. For example, if a pathogen is present, then choosing a resistant variety (removing the host) can effectively prevent the disease. You'll find that choosing resistant varieties is the key to managing many important strawberry diseases.

### The Disease Triangle

Diseases in plants occur when a pathogen is present, the host plant is susceptible, and the environment is favorable for the disease to develop. This is called the disease triangle. Altering any one of these three factors can prevent the disease from occurring.



There are strategies you can do to make the environment less favorable for disease. A key strategy to prevent leaf diseases is to maximize air movement and leaf drying in the crop canopy. You can do this by selecting fields with good air circulation.

To ensure good vigor in plants, it is recommended that you fertilize based on tissue and soil analysis. Too much nitrogen in particular makes tissues soft and prone to infection by several pathogens.

**Healthy strawberries can prevent disease.** Many pathogens are opportunistic and will infect plants that are already stressed by poor soil conditions,

inadequate fertility or by insect feeding. Providing good growing conditions, particularly good soil conditions, will promote healthy root growth and more resistance to plant disease. Plant into fields that have well-drained soil ready to support vigorous strawberry establishment and growth. Be sure soil has adequate, balanced fertility and continue to improve soil structure and till each year.

## B. Scouting for diseases

Scouting is particularly important in managing strawberry diseases. As you become familiar with the crop, learn to anticipate which diseases are likely to be a problem, and scout weekly for them. Be ready to take action. Accurate identification of disease symptoms is essential for choosing effective control strategies. Don't hesitate to seek help if you are not sure what is causing a problem.

### ★ Quick note:

Where to get help diagnosing plant diseases:

- 1) Crop consultants
- 2) County-based Extension staff – find your office in the county government listings of your local phone book or online at [www.uwex.edu/ces/cty/](http://www.uwex.edu/ces/cty/).
- 3) UW-Madison Plant Diagnostic Clinic— samples may take two weeks to process
- 4) Knowledgeable growers in your area

## C. IPM disease mgmt strategies

Integrated disease management in strawberries requires coordinated use of multiple tactics. General integrated strategies, as well as those specific to strawberry diseases, are outlined below.

### Crop rotation

Crop rotation is an effective strategy to control pathogens that overwinter in crop debris. Crop rotation allows enough time for the residue to decompose completely and the pathogen to die out before the next susceptible crop is grown. A good rule is to rotate strawberries with plants that are not hosts for *Verticillium* or *Rhizoctonia*.

Host resistance

Choose resistant strawberry varieties as much as possible, especially if you have had a specific disease problem in the past. Consult your nursery catalogs, nursery company representatives, Extension specialists and other growers about locally recommended and available resistant varieties.

Sanitation/Exclusion

Sanitation is the removal of a pathogen from transplants or equipment. Excluding a pathogen from a field, or preventing it from spreading, is one of the best ways to prevent disease problems. One of the best ways to do this is to purchase certified, pathogen-free nursery stock.

Another tactic to prevent disease proliferation is to limit soil-borne pathogen spread from field to field in soil left on equipment. If you know a field is infested with one of these pathogens, take care to clean machinery after working in that field.

Fungicides to prevent infection

Fungicides can be used to prevent some fungal diseases, but they are ineffective in controlling bacteria, viruses, and nematodes. Keep in mind that fungicides only work for diseases caused by fungal pathogens. Consult the *Midwest Small Fruit and Grape Spray Guide* (<http://learningstore.uwex.edu/>) publication for fungicides currently labeled for strawberries. Proper timing and adequate coverage of fungicides are essential for efficacy.

D. Keeping records

Keep records of diseases that occur in each field, the growth stage of the plant, and the weather conditions. Include field maps that indicate where particular diseases tend to occur – this will often be low spots, or places where dew dries more slowly. Include insect and weed infestations on the field maps.

Include the planted variety, soil amendments, crop rotation history, and other cultural practices in your records. Relate this information to yield at harvest. In this way, you will learn over time what to expect and how diseases affect your crops. You will have the information you need to adjust your management practices each year to minimize the damage caused by disease.

Cultural Disease Management Strategies Quick Guide

In the Upper Midwest, the integration of several cultural practices minimizes berry losses from disease. These include:

- 1. Use disease-free stock.
- 2. Plant disease resistant or disease tolerant varieties.
- 3. Plant in sites with good soil drainage and air circulation.
- 4. Choose sites that do not have a history of *Verticillium* or nematode diseases.
- 5. Fertilize based on tissue and soil analysis.
- 6. Control weeds.
- 7. Provide a clean layer of straw mulch.
- 8. Pick fruit frequently and early in the day.
- 9. At renovation, remove leaf debris or shred it so that it decomposes.
- 10. Rotate strawberry with plants that are not hosts for *Verticillium* or *Rhizoctonia*.

Notes:

## Diseases of Strawberry

These are the main diseases of strawberry that you and your scout should be able to recognize.

### FOLIAR DISEASES

Common leaf spot  
Leaf scorch  
Leaf blight

Common fungal leaf spot: *Mycosphaerella fragariae*  
Leaf scorch: *Diplocarpon earlianum*  
Leaf blight: *Phomopsis obscurans*



These diseases are caused by distinct fungi and have somewhat different symptoms, but they are similar in the damage they cause and in measures taken to control them.

**Symptoms and damage.** All three diseases first appear as small reddish-purple spots on leaves, and occasionally on calyces (fruit caps), stems, and fruit. As lesions develop, the three diseases become more distinct. Leaf spot lesions (top photo) develop white or light tan centers and distinct red margins. Leaf scorch lesions (middle photo) become dark purple to black, but do not develop white centers. Leaf blight lesions (bottom photo) appear similar to those of leaf spot, but they tend to show up later in the season and enlarge to kill large sections of leaves, including V-shaped sections at leaf margins. Most strawberry plantings in the Upper Midwest show symptoms of one or more of these diseases every year without causing economic losses. However, if leaves are severely affected, then fruit will not ripen and plants will be more susceptible to winter kill.

**Prevention and control.** Varieties differ greatly in their susceptibility to the three diseases, but susceptible varieties can generally be grown if cultural practices are used to make the environment less conducive to disease. The planting site should have good soil drainage and air circulation, and weeds should be controlled so that strawberry foliage will dry quickly after rain or irrigation. Nitrogen fertilizers should be used judiciously, as soft, succulent tissues are highly susceptible to disease. At renovation, removing leaf debris or shredding it to enhance decomposition will reduce pathogen survival. Fungicides are effective if applied during spring and/or after renovation.

## Angular leaf spot (bacterial)

### *Xanthomonas fragariae*



Angular leaf spot is the only important bacterial disease of strawberry. The pathogen can be carried on nursery stock, and once established in a planting, it persists for the life of the planting. Symptoms can appear anytime during the growing season, but they are more common in the spring following cool periods with nighttime temperatures near freezing.

**Symptoms and damage.** Leaf spots appear as water-soaked lesions that are delimited by veins. The angular spots appear dark green when viewed from above but pale green or yellow when held up to light. Under wet conditions, slimy, white masses of bacteria develop on the undersides of leaves in wet conditions; upon drying the bacterial slime turns scaly and flakey. Infected calyces, or fruit “caps,” turn black and make the fruit unattractive.

**Prevention and control.** Purchase plants from a reputable nursery and inspect them for symptoms prior to planting. Highly resistant varieties are not commercially available, but certain varieties, including Annapolis, Cavendish, Honeoye, and Kent, are especially susceptible. To prevent spread of the pathogen, minimize movement of people and equipment in the field when plants are wet. Because the pathogen is systemic, chemical control is not highly effective.

## ROOT AND SOIL-BORNE DISEASES

### Red stele

### *Phytophthora fragariae*



The red stele pathogen is a water mold that is highly destructive to strawberry roots in soil that is saturated for prolonged periods. Red stele tends to be worse in low-lying areas of a field and during spring and fall in the Upper Midwest.

**Symptoms and damage.** Plants wilt immediately prior to and during the fruiting period. The central core (stele) of one or more main roots is brick red instead of creamy white in color. Lateral roots are sparse, giving the main root a “rat tail” appearance. Plants are generally stunted, and new leaves sometimes take on a bluish hue. Severely infected plants collapse and die prior to harvest time.

**Prevention and control.** Avoid sites with heavy and/or poorly drained soil. Cultivars vary in their resistance or tolerance to red stele. The more resistant varieties include Annapolis, Brunswick, Cavendish, Mesabi, Mira, and Winona; the more susceptible varieties include Glooscap, Honeoye, Jewel, and Kent. There are a few fungicides with efficacy against *P. fragariae*, but they do no good if applied to plants in poorly drained soil.

SCRI-Dundee Archive, Scottish Crop Research  
Institute, Bugwood.org



## Black root rot

## Disease complex



Black root rot is a general term for strawberry root decline. The factors contributing to black root rot are not well defined and vary from site to site. In many cases fungi such as *Rhizoctonia* and *Fusarium* and nematodes play a role. Possible abiotic factors that interact with fungi and/or nematodes include winter injury, compacted or heavy soil, drought, herbicide injury, and improper soil pH.

**Symptoms and damage.** Strawberry roots afflicted by black root rot show one or more of the following: stunted root system; main roots with dark lesions; feeder roots either absent or dry, brittle, and dark; cross sections of the tips or entire main roots show blackened tissue throughout.

**Prevention and control.** Rotate a site out of strawberries for at least three years before planting strawberries again. Prepare the site by correcting soil pH and compaction. Prior to planting cut into roots of a few representative plants to ensure that internal tissues are yellow to white and not dark.

## Verticillium wilt

## *Verticillium* spp.



*Verticillium* species reside in the soil and infect the vascular system of more than 400 different plant species. The fungal pathogen is most active during cool weather, but wilt symptoms in strawberry typically appear in early summer, when warm weather and developing fruit heighten the demand for water.

**Symptoms and damage.** Outer leaves wilt and dry at the margins and between veins. Few new leaves emerge. In severe cases, entire plants collapse and die. Less severely affected plants are susceptible to winter kill.

**Prevention and control.** *Verticillium* can persist for many years in the soil. Therefore, strawberries should not be planted in sites recently cropped to highly susceptible plants, including members of the nightshade family (e.g., tomato, potato, pepper, eggplant), members of the curcubit family (e.g., melons, pumpkins, gourds), stone fruits, and raspberry. Sites should be planted for at least four years with resistant or less susceptible plants (e.g., grasses, legumes) before replanting with strawberries.



Brian Perchtel, Bugwood.org



## FRUIT DISEASES

### Gray mold

#### *Botrytis cinerea*



Gerald Holmes, California Polytechnic State University at San Luis Obispo, Bugwood.org

Gray mold is a common disease of soft fruits and vegetables, including strawberry. In the spring, the previous season's dying leaves become infected and serve as a source of spores to flowers and fruit. Gray mold is highly contagious and develops very quickly in the field as fruit ripen as well as after harvest.

**Symptoms and damage.** Initial symptoms on green berries are soft, tan spots. As fruit ripen, the rot rapidly expands and berries become covered with grayish-white moldy growth.

**Prevention and control.** Gray mold usually develops in shaded areas of the crop canopy where conditions are humid and fruit dries slowly after rain or irrigation. To promote rapid drying and reduce canopy humidity, avoid overly wide rows with high plant densities, control weeds, and irrigate in the morning rather than at night. Berries should be harvested frequently so that they do not become overly ripe, and after harvest they should be utilized quickly. During renovation, leaf debris should be removed from the planting to reduce the amount of *Botrytis* that overwinters. Where disease pressure is high, fungicides should be applied during bloom and again as fruit turn red.

### Anthracnose

#### *Colletotrichum* spp.



Different species of the fungus *Colletotrichum* can infect strawberry leaves, crowns, and fruit. In the Upper Midwest, anthracnose fruit rot develops quickly if conditions are warm and rainy just prior to harvest.

**Symptoms and damage.** On green fruit, water-soaked spots quickly turn brown and expand to cover large portions of the berry. On ripe berries, the spots are sunken and brown, and under wet, humid conditions, spots become covered with slimy, pink to orange masses of spores.

**Prevention and control.** The spores in the slimy matrix are easily spread by splashing rain and on equipment and people passing through a wet field. A clean layer of straw mulch minimizes spore splash and helps keep ripening berries clean, dry, and disease-free. Berries should be harvested frequently so that they do not become overly ripe, and after harvest they should be utilized quickly. Certain fungicides are effective if applied to green fruit and again as they turn red.

## Leather rot

### *Phytophthora cactorum*



Leather rot, caused by a soil-borne water mold, usually occurs in patches in the field rather than in field-wide epidemics. However, berries with leather rot are very bitter in taste, and just a few bad berries can taint an entire batch of jam or jelly. Leather rot berries literally leave a bad taste in customers' mouths, such that they will not make return visits.

**Symptoms and damage.** On green fruit, affected tissues are brown and firm. Mature berries with leather rot are often lavender to brown and have a matte rather than shiny appearance. In some cases white mold is visible on diseased surfaces. Diseased berries are softer than healthy berries, but they are leathery and firmer than berries with anthracnose.

**Prevention and control.** Water molds flourish in saturated soil. Therefore, to minimize leather rot, plant in well-drained soils to prevent the pathogen from growing and producing spores. A clean layer of straw mulch prevents splash and helps keep ripening berries clean, dry, and disease-free. Certain fungicides are effective if applied to developing fruit.

**Notes:**

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# Insect BMPs

## In-Season



An integrated insect management program should be prevention based and utilize proper identification, scouting and thresholds for insect management.



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 or without regard to threshold levels.
- ☐ **B.** Insecticides are applied only when populations have reached economically damaging levels at critical crop growth stages.
- ☐ **C.** Insect pests are managed preventatively using a combination of host resistance and cultural practices to avoid in-season pest problems.
- ☐ **D.** The impact of pesticide sprays on beneficial insects are known and considered when selecting and applying a chemical treatment.

## A. Calendar spray program

Strawberry pests attack the fruit, flowers, buds, leaves, roots and other parts of the plant. Feeding by insects and mites can also increase the susceptibility of strawberry plants to diseases and other pests.

For many decades, insecticides were the primary form of insect management by growers, and sprays were made according to calendar schedules, not due to the specific presence and populations of insect pests. Current IPM recommendations take a broader, more preventative approach to insect control and include cultural controls, host plant resistance, and biological control.

Insect management recommendations now include scouting and precise timing of insecticide sprays. Insecticides are only applied when the insect pest is present at damaging levels at a vulnerable stage of a pest's life cycle or a critical stage of crop development. One of the goals of IPM is to reduce pesticide use to the bare minimum.

### Insect concerns for strawberry

Several insect and mite pests attack strawberries in Wisconsin, and, in general, damage is relatively minimal. However, sporadic outbreaks of some pests happen during some years or at some locations and, if not properly managed, can cause serious damage to the crop. Not all insects and mites found in strawberry plantings are pests though. Many, such as lady beetles, spiders, and predatory mites, are beneficial as they feed on pest insects and mites.

## B. Determining threshold levels for key pests

Best management practices for insect and mite pests begin with being able to recognize the pests affecting strawberry, their damage symptoms, and understanding a little about their life cycle. Proper identification of the pest causing the damage is critical to making the most appropriate management decision.

Chemical controls should only be considered when insect populations have reached or exceeded a level

that will cause economic damage if left untreated. This is commonly called the economic threshold level. Economic thresholds have been scientifically established for some pests of strawberries to help growers weigh the costs of their pest management strategies against the potential economic impact of each pest.

It is impractical and usually impossible to have the crop completely pest-free. The financial and environmental cost of the controls would far exceed the benefit of controlling the last few insects. That's why it's important to carefully and routinely scout the field for pest activity, record the presence of each pest through the growing season and note the threshold levels for that pest. Keeping records of weekly pest activity and relating these to actual insect damage at harvest is extremely useful management information for future years.

## C. IPM for insect pests

Integrated pest management is the sound use of all available methods for insect control. These include cultural controls, mechanical controls, host plant resistance, biological control and application of insecticides. A summary of current recommended management options for specific insect pests of strawberries is in this section.

## D. Impact of insecticides on beneficial species

The choice of pesticides and timing of applications can have a big effect on beneficial insect species. Keep treatments to the bare minimum and consider the effects of pesticides on non-target species when choosing a product. When possible, choose a selective insecticide that is specific for the pest you are trying to control, with little or no detrimental effects on non-target insects. Applying broad-spectrum materials, especially early in season, can lead to a resurgence of pest populations due to a lack of natural controls, or to secondary pest outbreaks.

Choosing pesticides with little or no residual activity helps preserve natural enemies. Consider the timing and placement of the application. Spot-treating or banding rather than broadcasting the application helps to minimize non-target effects. In addition, avoid spraying insecticides during bloom to protect both managed and wild pollinators.



## Specific Insect Pests of Strawberry

These are the main insect pests of strawberry that you and your scout should be able to recognize.

### FRUIT OR FLOWER FEEDING PESTS

#### Tarnished plant bug

*Lygus lineolaris* (Hemiptera: Miridae)



Tarnished plant bug is the most important insect pest of strawberry in Wisconsin. It has 2-3 generations per year. The adult is ~1/4" long, oval and flattened, bronze in color with yellow and black markings on the wings. They overwinter as adults in protected areas in and around strawberry. The adults emerge in the spring when temperatures reach and remain around 49°F.

Damage occurs on the fruit from adults and nymphs feeding on the flower buds, developing fruit, and receptacle. Feeding on the berries can result in deformed and stunted berries with a concentration of seeds at the tip, called button berries or cat-faced berries (see photo).



<http://www.omafra.gov.on.ca/>

**Monitoring and Control.** Tarnished plant bugs feed on many different plants. Controlling weeds in and around strawberry fields can reduce overwintering populations in strawberry plantings and remove sources of attractive flowering plants in the spring. Avoid mowing weeds when strawberry buds are swelling, flowers are beginning to open, or early fruit set. Monitoring can be done with sweep sampling (economic threshold at 2 adults per 10 sweeps) and tapping flower clusters over a white pan or paper (economic threshold at 1 adult or nymph per 4 clusters). If economic thresholds are reached, application of an insecticide is warranted and should be applied soon after blossom buds become visible and again towards the end of flowering if needed.

#### Strawberry bud weevil

*Anthonomus signatus* (Coleoptera: Curculionidae)



Tom Murray, BugGuide.net

Strawberry bud weevil, aka strawberry clipper, is a pest of strawberry. The adult beetle is ~1/10" long, dark, reddish/brown, with 2 large black spots, and a head prolonged into a snout. Strawberry clipper has 1 generation per year. They overwinter as adults in wooded areas and fence-rows and move to strawberry fields once temperatures reach 60°F, just before strawberry blossom time.

Damage is caused by the adult female beetle. Females puncture flower buds with their mouthparts and insert eggs in the punctures. After the eggs are laid, the female girdles or clips the bud stem, causing the bud to hang limp or fall to the ground. Eggs hatch about 1 week later and adults emerge 3-4 weeks thereafter (late June-July).

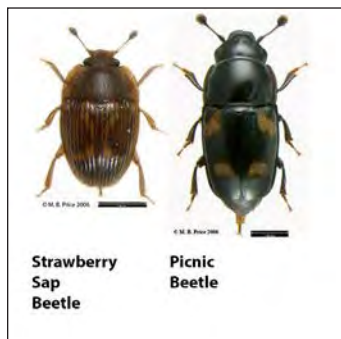


<http://ncsmallfruitsipm.blogspot.com/>

**Monitoring and Control.** Visual inspections of flowers for the presence of adults and clipped flower buds (see photo) should be done as soon as flower trusses are visible. Because strawberry bud weevil move into strawberry fields in the spring, monitoring should focus on field edges. At the first sign of bud damage and when 1 clipped bud per 2 ft. of row is found, treatments should be applied.



## Strawberry sap beetle Picnic beetle



Michelle Price, University of Wisconsin



Kristen Rutherford, Iowa State University

### *Stelidota geminate*, *Glischrochilus quadrisignatus* (Coleoptera: Nitidulidae)

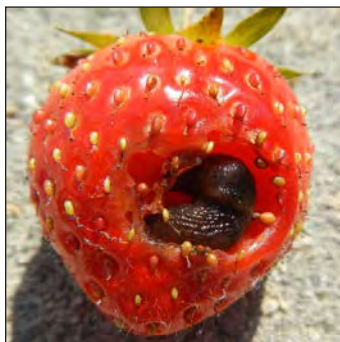
Strawberry sap beetles and picnic beetles are both sap beetles that may be found in strawberry plantings. Strawberry sap beetles are small, 1/10" long, oval, and dark brown. Picnic beetles are ~2/10" long, oval, black with four orange markings on the back. Both species have one generation per year and overwinter as adults in organic matter in protected areas.

Damage occurs from direct feeding by adults on damaged ripe fruit or overripe fruit and from their introduction of fungal pathogens into the fruit. Adults can be found tunneling in the berries during harvest (see photo).

**Monitoring and Control.** Since sap beetle are attracted to overripe fruit and fermenting plant fluids, remove overripe, damaged, or diseased fruit regularly. Avoid placing compost piles near the planting. Trapping can be accomplished by placing containers baited with stale beer, molasses-water-yeast mixtures, vinegar, or any overripe fruit a few feet outside the edge of the strawberry planting. Since sap beetles occur when fruit is ripe, chemical control is discouraged.

## Slugs

### *Deroceras (Agriolimax) species (Limacidae)* and *Arion species (Arionidae)*



<http://msfruitextension.wordpress.com/2012/04/17/strawberry-slugs/>

Slugs are not insects but are common pests of many vegetable and fruit in North America. Various species of slugs can be found in strawberry. Slugs are soft-bodied, slimy molluscs that do not have a shell. They are usually mottled gray, brown, yellow, or black, and measure 0.5" to 5" long. Slugs overwinter as eggs laid the previous fall in the soil or plant debris. Slugs prefer plantings covered with continuous straw mulches. Slugs feed at night on berries and leaves, leaving a glistening trail of slime behind.

Damage occurs when slugs feed on ripe berries, eating large irregular areas out of berries (see photo). Often, damage is minimal.

**Monitoring and control.** Slug presence and activity may be detected by the presence of slime trails on leaves and the ground nearby. Slug baits are commercially available and should be placed between rows. Homemade traps made of shallow dishes baited with beer can also be used.

## Eastern flower thrips

### *Frankliniella tritici* (Thysanoptera: Thripidae)



Kelvin Lynch, <http://www.omafra.gov.on.ca/>

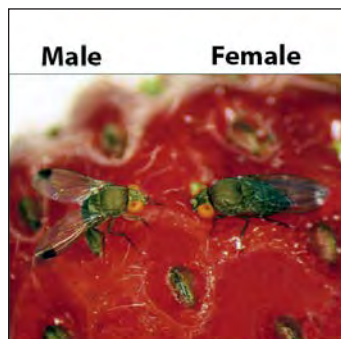
**Eastern flower thrips are occasional pests in Wisconsin, as they do not overwinter here.** Adults migrate on air currents each year from the south and population densities vary each year. Adults are very small, ~1/25" long, from yellow to brown with feathery wings.

**Damage results from thrips feeding on blossoms causing premature wilting of flower parts and blossom drop.** During fruit development, the rasping feeding by thrips may cause russetting and deformities on the fruit. Thrip damage may ultimately result in brown, small, tough, seedy berries with little flavor.

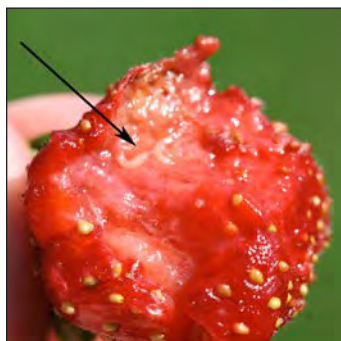
**Monitoring and Control.** Sample when earliest flowers of earliest varieties begin to open. Shake or tap blossoms in a white bowl or a Ziploc bag. Treatments should be applied when 2-10 thrips per blossom or small berry are found. Yellow sticky cards can also be used to detect thrips presence. To protect pollinators, treatments should be applied before bloom or before 10% of plants have open blossoms. Because thrips do not overwinter in Wisconsin, preventative sprays based on prior year's infestation levels are not relevant.

## Spotted wing drosophila

### *Drosophila suzukii* (Diptera: Drosophilidae)



Beverly Gerdeman, WSU NWREC



Hannah Burrack, North Carolina State University, Bugwood.org

Spotted wing drosophila is an invasive vinegar fly that is a major pest of small fruit in North America. It has not yet been reported as a pest of strawberry in Wisconsin, but, as it is a significant pest of strawberry in southern states and is present in Wisconsin, it is important for strawberry growers to know about this pest. Several generations probably occur in Wisconsin from late June until November. Spotted wing drosophila is 1/16 to 1/8" long. Males have a single dark spot on each wing. Females have a serrated ovipositor that allows them to lay eggs under the skin of ripening and ripe fruit. Larvae are creamy-white legless maggots ~1/10" long when mature (see photo).

Damage occurs from the larvae feeding inside ripening or ripe fruit. Larvae feed on the flesh of the fruit, causing the flesh to turn brown and soft, resulting in a small depression around the oviposition hole. Damage by spotted wing drosophila compromises the fruit, allowing common vinegar flies to oviposit in the fruit and providing an entry site for secondary fungal and bacterial pathogens.

**Monitoring and Control.** Monitoring should be conducted with clear plastic deli cups and bait made of apple cider vinegar or a yeast, sugar and water mixture. As soon as a spotted wing drosophila is detected in traps and the fruit is at a susceptible stage (ripening or ripe), control measures should be applied on a weekly basis until harvest is completed. Timely harvest of ripe berries should be performed. Removing overripe, damaged and fallen berries can help reduce populations. Damaged fruit should be buried or solarized to kill the larvae. Do not compost damaged fruit.

## FOLIAGE OR STEM FEEDING PESTS

### Meadow spittle bug

*Philaenus spumarius* (Hemiptera: Cercopidae)



Spittlebug is a very common insect that feeds on many different plants and can be a pest of strawberry. Adults are 1/4" long, bright green when they first emerge and then turn dull brown to mottled gray. They overwinter as egg masses in strawberry stubble and other hosts such as field crops. They have one generation per year. Nymphs emerge in April-May and produce a frothy spittle (see photo) in which they remain protected for 5-8 weeks until they become adults.

Damage occurs when nymphs feed by piercing the plant and sucking on plant juices. This feeding may result in reduced plant vigor, stunted berries, and reduced yield. Populations are usually larger in weedy plantings and throughout the summer. Leaves do recover after the insects leave the plant.



**Monitoring and control.** Although spittlebugs usually do not cause significant yield loss, the spittle masses tend to bother pickers, especially in Pick-Your-Own operations. Visual inspections for spittle masses should be performed. One spittle mass or more per square foot of canopy may warrant the use of an insecticide. Removing weeds in plantings may reduce spittlebug populations. Often, spittle masses can be washed off by heavy rains or irrigation.

### Strawberry rootworm

*Paria fragariae* (Coleoptera: Chrysomelidae)



Ilona L, BugGuide

Strawberry rootworm is a pest of strawberry and other plants. The adult is 1/8" long, oblong, shiny, brown to black, with four dark blotches on the back. They overwinter as adults in plant debris and there is one generation per year. The immatures are creamy-white grubs that feed on strawberry roots from late spring to early summer, but they do not usually cause significant damage to the plant.

Damage could occur from adults feeding on the leaves, causing small holes on the leaves (see photo). Feeding by adults occurs primarily at night. Some damage occurs in early spring from the overwintering adults. Most damage will occur in August from the new generation of adults. Heavy infestations can result in reduced plant growth and may kill plants.



Pam Fisher - Berry Specialist/OMAFRA

**Monitoring and control.** Yellow sticky cards can be used to monitor strawberry rootworm. Visual inspections for adults should be done after dark with a flashlight. Populations of 10-20 beetles per square foot is considered high and may warrant the use of an insecticide.



## Two-spotted spider mite

## *Tetranychus urticae* (Acari: Tetranychidae)



Two-spotted spider mites are the most common mites that can damage strawberry plantings in Wisconsin. Mites are not insects; they have eight legs and are related to ticks. Two-spotted spider mite adults are 1/50" long and are barely visible without a hand lens. They vary in color from pale yellow, green, to red with two large dark spots on the back. They have many generations per season and overwinter as mated adult females. Two-spotted spider mites make webs on the underside of leaves.

Damage is caused by mites feeding on plant sap on the underside of leaves, in a fine tangle of webbing. Feeding can cause discoloration of the leaves, which can turn coppery-bronze, starting on the underside of the leaves (see photo). Severely damaged leaves will die and drop, resulting in reduced plant vigor, fruit size, and yield. Mite populations tend to increase in prolonged periods of hot, dry weather.



Surendra Dara, University of California-Extension

**Monitoring and control.** Annual renovation of strawberry beds helps in reducing potential mite outbreaks the following season. Predatory mites are often effective at keeping two-spotted spider mite populations under control. Predatory mites move around much faster than two-spotted spiders and a ratio of 1 predatory mite to 10 two-spotted spiders is adequate for biological control. If two-spotted spider populations reach infestations of 25% or more of leaflets sampled, the use of a miticide may be warranted.

## Cyclamen mite

## *Phytonemus pallidus* (Acari: Tarsonemidae)



Cyclamen mites are smaller than two spotted spider mite, only 1/100" long, and are almost not visible with the naked eye. Adult cyclamen mites vary in color from pinkish-orange to white or green.

Damage symptoms consist of discolored distorted leaves (see photo), blossoms, and fruit, and result from feeding by cyclamen mites on young unfolding leaves in the plant crown and on blossoms. Cyclamen mites are more often found on greenhouse plants and can be seriously damaging when infested plants are transplanted to new plantings. During bloom, cyclamen mite populations increase and reach a peak during fruit development. Severe infestations will result in small, leathery, off-color fruit.



K. Lynch, New Brunswick Department of Agriculture and Aquaculture (both photos)

**Monitoring and Control.** Cyclamen mites are difficult to control once established. The best approach is to insure that mite-free transplants are planted. When an infestation is detected, use a registered pesticide one to two days prior to bloom and again 10-14 days later.

## Strawberry leafroller

## *Ancylis comptana fragariae* (Lepidoptera: Tortricidae)



Ruedi Bryner, <http://www.lepiforum.de>



T. McCamant, Northland Comm. College

Several leafroller species may occur in strawberry in Wisconsin. Adult strawberry leafrollers are moths that are specific to strawberry, raspberry, and blackberry. Adult moths are rusty red with distinctive brown and white markings. Their wingspan is about 1/2". Larvae are green with a brown head and are about 1/2" long at maturity. There are two to three generations per year and they overwinter as mature larvae or pupae in folded leaves or leaf litter. Adults emerge in April and May and lay translucent eggs usually on the underside of leaves.

Damage is caused by larvae feeding on the leaves, after folding, rolling, and tying leaflets together around them with silken threads (see photo). Feeding may result in leaflets turning brown. First-generation larvae occur in May and June, and second-generation larvae in late July and August.

**Monitoring and Control.** Low levels of infestations (10-20% leaflets rolled, especially after harvest) do not cause reduction in plant vigor or yield, and thus, do not warrant control. At the early stage of infestation, rolled leaves can be removed and destroyed. Several registered insecticides as well as products containing *Bacillus thuringiensis* (Bt) provide effective control.

## Aphids

## *Aphids* (Hemiptera: Aphididae)



Several species of aphids can be found on strawberry plants in Wisconsin. Aphids usually occur along the veins on the underside of leaves, on new shoots, and on buds in the crown of the plant. Aphids are small, 1/16" long, soft-bodied insects. They vary in color from yellow, orange to green.

Damage occurs from the feeding of aphids on plant juices. High infestations can weaken the plant. Aphids also produce large amounts of honeydew, which promotes the growth of black sooty mold and can reduce the marketability of strawberries. Aphids are also vectors for several virus diseases.

**Monitoring and Control.** Examine the back of new leaves which have not yet uncurled for the presence of aphids. Registered insecticides are available to control aphids.





## Potato leafhopper

## *Empoasca fabae* (Hemiptera: Cicadellidae)



Michigan State University-Extension

Many species of leafhoppers can be found in strawberry in Wisconsin. Potato leafhoppers are the most damaging leafhopper in strawberry. Potato leafhoppers do not overwinter in Wisconsin; they migrate in air currents from the south each year. Adults are bullet-shaped, bright green and about 1/8" long. When disturbed, adults take flight quickly, and nymphs, who cannot fly, quickly walk in a distinctive sideways movement across the leaf.

Damage is caused by adults and nymphs feeding, primarily on the underside of leaves. They suck plant juices and inject a toxin into the plant. Damage results in yellowing of the leaves between the veins, curling and distorting of the leaves (see photo). Most damage occurs in late spring to early summer to new plantings.

**Monitoring and Control.** There is no threshold established for potato leafhopper. Insecticides may be applied when leaf curl is evident and nymphs are found.

## Variegated cutworm Black cutworm Dingy cutworm Darksided cutworm

## *Peridroma saucia*, *Agrotis ipsilon*, *Feltia ducens*, *Euxoa messoria* (Lepidoptera: Noctuidae)



Mark Dreiling, Retired, Bugwood.org



Purdue Cooperative Extension Service

Several species of cutworms can occur in strawberry plantings. Adult variegated cutworms are brownish moths with faintly outlined spots (see photo). They have a wingspan of 1¾". Cutworm larvae are stout, smooth, hairless, greasy looking and 3/8" long when mature. Larvae usually curl up when disturbed (see photo).

Damage occurs at night when larvae feed on the plant. They can cut off plants at or below ground level and feed on foliage and fruit. During the day, larvae hide in the soil.

**Monitoring and Control.** There is no specific threshold for applying control measures against cutworms. Monitoring at night with a flashlight could help confirm the presence of cutworms. Controlling weeds in and around strawberry plantings will help prevent serious cutworm infestations. Several insecticides and Bt formulations are effective at controlling cutworms in strawberry. Because damage is often localized, spot treating is recommended when foliar sprays are used.

## ROOT OR CROWN FEEDING PESTS

### White grubs



**Japanese beetle, *Popillia japonica*, May beetle, *Phyllophaga* species, and June beetle, *Cotinis nitida* (Coleoptera: Scarabaeidae)**

White grubs are the larvae of several species of beetle pests that may occur in strawberry. White grubs are characteristically C-shaped,  $\frac{3}{4}$  to 1" long, cream colored with brown heads. Grubs feed on plant roots. Adult beetles range from a little less than  $\frac{1}{2}$ " to  $1\frac{1}{2}$ " long and are green, tan, or brown. Adult females lay eggs in the soil and larvae will develop in the soil.

Damage occurs primarily from the feeding by grubs on roots (see photo). Adults also feed on strawberry plants, feeding on leaves between the veins (skeletonized leaves). Feeding by grubs will result in reduced plant vigor and provide an entry site for root diseases.



[www.omafr.gov.on.ca](http://www.omafr.gov.on.ca)

**Monitoring and Control.** Avoid planting strawberries on newly plowed sod or other grasses and avoid planting next to large grassy fields. Check roots of wilting plants for presence of grubs. Registered insecticides are available to control white grubs.

### Strawberry root weevil Black vine weevil



Tom Murray, BugGuide.net

***Otiorhynchus ovatus*, *Otiorhynchus sulcatus* (Coleoptera: Curculionidae)**

Strawberry root weevil and black vine weevil may be found in strawberry in Wisconsin. Strawberry root weevil adults are  $\frac{1}{5}$ " long, shiny black to light brown with rows of small pits along their back, and a prominent blunt snout (see photo). Black vine weevil adults are a little less than  $\frac{1}{2}$ " long, dull black with yellow small flecks on the back. Larvae of both weevils are C-shaped cream-colored grubs with a brown head. Adult females lay eggs in the soil where larvae develop, feeding on plant roots.

Damage is caused primarily by the larvae feeding on roots in early spring. Damaged plants are weakened, stunted, and more susceptible to winter injury and diseases. While adult weevils chew notches from the edges of leaves, their feeding usually does not result in economic loss.



Wikipedia

**Monitoring and Control.** Look at plantings in the spring for smaller, less vigorous plants and examine the roots for grub presence. If grubs are found, insecticides should be applied after harvest, when the adult weevils emerge.

# Weed BMPs

## In-Season



An integrated weed management program which incorporates cultural, mechanical, biological and chemical control strategies should be utilized during the strawberry cropping cycle.



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 herbicides.
- ☐ **B.** Herbicides are integrated with cultivation and tillage for weed control.
- ☐ **C.** Mulches are used for weed control between the strawberry rows.
- ☐ **D.** Advanced cultural management strategies are utilized when possible. These include the use of smother crops, tilling and mowing field edges, and controlling weeds during fallowing periods and in rotational crops.

## A. Weed control with herbicides

Herbicides can be effective tools for managing weeds in strawberries. However, over-reliance on herbicides as the sole means for weed control can increase the risk for selecting resistant weeds. Additionally, repeated use of the same few herbicides and no other tactics in strawberries shifts the weed spectrum toward an abundance of pests that escape control. With the integration of bioIPM strategies, growers can now manage weeds in a more comprehensive, year-round program.

### ★ Quick note:

Both annual and perennial weeds affect strawberries. Annual species live for a single growing season and die at the end of the year after producing seed. Perennial weeds live for several years and regenerate shoots each year from underground roots and rhizomes. They are not dependent on seed for dispersal.

## B. Herbicides integrated with cultivation and tillage

Cultivation and other forms of tillage are important strategies for several reasons in strawberries, often accomplishing beneficial outcomes in addition to weed control. In the establishment year, cultivation for weed control is important in bridging the gap between the herbicides used at the time of planting and the fall. Repeated shallow cultivation when the weeds are very small can not only effectively manage weeds but also help train strawberry runners into the proper row width. Be sure not to cultivate when the soil is wet; this leads to soil compaction and the weeds will readily regrow. Newer cultivators used in straw-



Cultivating weeds in strawberries  
<http://www.hillsidecultivator.com/>

### Resistance Management Guidelines

To prevent resistance developing in weeds in your fields, follow these guidelines:

- ▶ Reduce the need for herbicides by incorporating other preventative strategies as outlined in this chapter.
- ▶ Rotate herbicides by choosing products with a different mode of action than the one you used last year. The active ingredient will be listed on the label of each herbicide product. Some products are a combination of more than one active ingredient
- ▶ Rotate crops and use different strategies to manage weeds in rotational years
- ▶ Follow label instructions carefully
- ▶ Prevent weed seed production by cultivating and mowing weed escapes before they set seed

berry production can be manipulated such that the area within the crop row between recently-planted strawberry plants is tilled, reducing the need for costly hand-weeding in the crop row.

The rototilling used at renovation of established strawberries can also provide weed control. Keep in mind that rototilling perennial weeds can spread vegetative root structures that result in more weeds. Make sure perennials are controlled prior to the rototilling.

Many growers find that post-renovation light cultivation in late summer can help train the new runners and daughter plants into manageable rows, similar to during the establishment year.



## C. Between row mulches

The straw mulches used for protection from winter temperatures can also double as a weed prevention “blanket”. In spring, the straw pulled from on top of the strawberry plants can be placed between the crop row, smothering new weeds and protecting berries from water splash-back. This strategy can be very effective for summer annual weeds, but likely won’t prevent perennial weed growth. Just be sure that the straw itself is free of weeds!



*Mulching between rows*

## D. Advanced cultural management

Advanced cultural or mechanical weed management methods should be used when possible and when the situation dictates. These alternative strategies will help in weed control and may limit the need for herbicide application.

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

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

### Notes:

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**Control weeds in fallow periods.** Controlling weeds during fallow periods and in rotational crops will improve weed control in the strawberry season. Perennial weeds are also easier to control in other crops grown in rotation with strawberries.



*Controlling weeds during fallow periods is important*

**Proper weed identification.** As always, good weed control begins with proper plant identification. Tailor the weed control program to specific weeds, including your choice of herbicides. Oftentimes, fewer herbicides can be used once the weed is properly identified and its’ life cycle is considered relative to the strawberry crop. For example, many winter annual weeds that plague strawberries early in the following spring can be managed with an herbicide applied to dormant strawberries just prior to mulching in the prior fall.



# Identification of Common Wisconsin Weeds

## Annual Grass Weeds

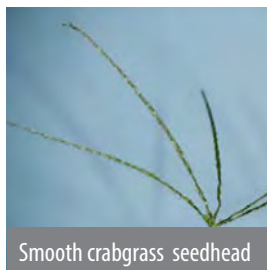
### GRASS FAMILY

#### Smooth crabgrass (22)\*

*Digitaria ischaemum*

- Stem:** flattened in cross section, often branched at the base, mostly upright, few at base horizontal to the soil surface
- Leaf:** wide leaves with prominent mid-vein, (up to 4 inches in length), mostly hairless with few hairs at the base or on underside of leaf, leaves wider and shorter, less hairy than large crabgrass
- Flower:** branches of spikelike flowers at stem tip, often appearing in a whorl or two
- Fruit/Seed:** small, football-shaped spikelets

\* indicates the page in *Weeds of the North Central States* that describes the plant



Smooth crabgrass seedhead



Smooth crabgrass stem



Smooth crabgrass plant

### GRASS FAMILY

#### Large crabgrass (22)

*Digitaria sanguinalis*

- Stem:** several stems from base, often laying flat on ground
- Leaf:** wide, stiff hairs on the leaf blade and sheath
- Flower:** 3–10 branches resembling a hand at top of stem, each bearing rows of tiny, pointed, green grains; blooms mid-summer
- Fruit/Seed:** yellow to brown seeds dropping September–October



Large crabgrass seedhead



Large crabgrass seedhead



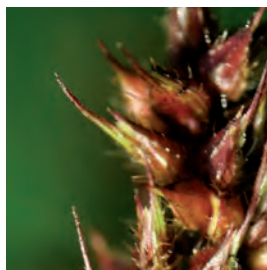
Large crabgrass plant

### GRASS FAMILY

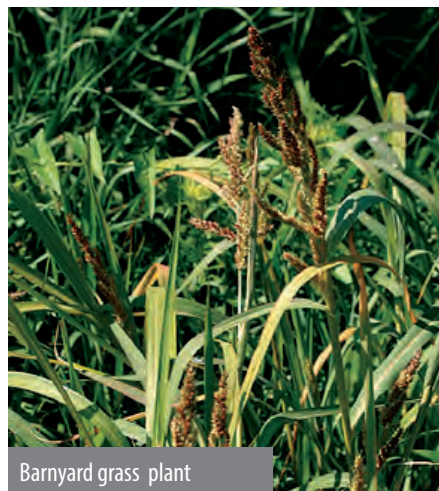
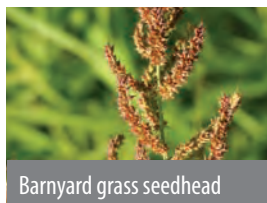
#### Barnyardgrass (23)

*Echinochloa crusgalli*

- Stem:** often several from one base
- Leaf:** up to 1/2 in. across
- Flower:** tightly clustered grains on short branches, resembling caterpillars, the grains are pointed, hairy, yellow to purple, with or without long awns at the tips; blooms July–September
- Fruit/Seed:** the grains fall individually when ripe



Barnyard grass seedhead



Barnyard grass plant

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## GRASS FAMILY

### Giant foxtail (35)

*Setaria faberi*

- Stem:** erect or drooping at tip, many stems from base
- Leaf:** large leaves often over 3/4 in. wide, hairy on upper surface, and along sheath margin
- Flower:** drooping foxtail-like inflorescence up to 8 in. long, with many long hairs
- Fruit/Seed:** seeds green to yellow, about 1/8 in. long, ripening and falling September–October



Giant foxtail seedheads



Giant foxtail plants

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## GRASS FAMILY

### Yellow foxtail (36)

*Setaria pumila*

- Stem:** erect, leafy, single or clumped
- Leaf:** slender, usually under 1/2 in. wide
- Flower:** spike-like inflorescence to 3 in. long, held erect, with many short, golden hairs; flowers July–September
- Fruit/Seed:** seeds green to yellow under 1/8 in. long



Yellow foxtail seedhead



Yellow foxtail plants

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## GRASS FAMILY

### Green foxtail (38)

*Setaria viridis*

- Stem:** erect, leafy, single or clumped
- Leaf:** large leaves often over 1/2 in. wide, blade without hairs
- Flower:** long, bushy fox-tail shaped inflorescence, to 6 in. long by 1/2 in. wide, and branched on robust plants; the foxtail is beset with long, dense, upward-pointing hairs, greenish to purplish, some tufts of hairs at the base of the fox-tail, often have no seeds among them; blooms June–October
- Fruit/Seed:** light yellow-green, about 1/16 in. long



Green foxtail seedhead



Green foxtail plants



# Annual Broadleaf Weeds

## BUCKWHEAT FAMILY

### Wild buckwheat (51)\*

*Polygonum convolvulus*

**Cotyledon:** oblong oval with granular waxy surface

**Ocrea:** at leaf axils; small

**Stems:** trailing vines

**Leaves:** heart-shaped with pointed tips

**Flowers:** greenish-white, small and inconspicuous

**Seeds:** 3-sided



Wild buckwheat seedling



Wild buckwheat ocrea



Wild buckwheat plant

## BUCKWHEAT FAMILY

### Pennsylvania smartweed (52)

*Polygonum pensylvanicum*

**Cotyledon:** lanceolate to oblong, rounded tips

**Ocrea:** at leaf axils; smooth top

**Stems:** reddish, branched swollen nodes

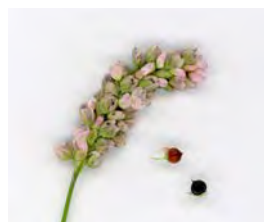
**Leaves:** rounded at base; pointed at tip

**Flowers:** pink, terminal flower clusters

**Other:** seed black, shiny, flattened, circular with pointed tip



Penn. smartweed ocrea



Penn. smartweed seeds



Pennsylvania smartweed flowering plants

## BUCKWHEAT FAMILY

### Ladysthumb smartweed (52)

*Polygonum persicaria*

**Cotyledon:** lanceolate to oblong, rounded tips

**Ocrea:** at leaf axils; hairy top

**Stem:** reddish with swollen nodes branched

**Leaves:** pointed at both ends, often have "thumb print"

**Flowers:** pink, terminal flower clusters

**Other:** seeds black, most triangular



Ladysthumb ocrea



Ladysthumb seeds



Ladysthumb smartweed plants

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## GOOSEFOOT FAMILY

### Common lambsquarters (57)

*Chenopodium album*

- Cotyledon:** linear, small
- Leaves:** often whitish, 'mealy'
- Covering:** shape is triangular or "goosefoot" shaped
- Stems:** have reddish streaks, branched
- Seed:** shiny, black, disk-shaped, 1/16 inch in diameter
- Other:** many biotypes, some resistant to herbicides



Lambsquarters seedling



Lambsquarters leaves



Lambsquarter flowers

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## PIGWEED FAMILY

### Redroot pigweed (65)

*Amaranthus retroflexus*

- Cotyledon:** linear, smooth
- Root:** often reddish-pink taproot
- Leaves (stems):** notch in tip of first leaves; finely pubescent; reddish-purple color on underside of leaves
- Seedhead:** somewhat spiny, small, black, shiny seeds
- Other:** also called rough pigweed



Redroot pigweed seedling



Redroot pigweed stem



Redroot pigweed seedhead

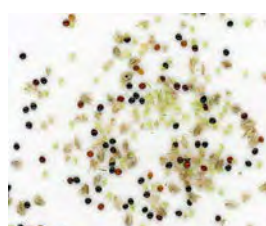
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## PIGWEED FAMILY

### Smooth pigweed (64)

*Amaranthus hybridus*

- Cotyledon:** linear, smooth
- Root:** often reddish-pink taproot
- Leaves (stems):** generally smooth
- Seedheads:** longer than redroot pigweed; rarely branched
- Other:** resistant biotypes



Smooth pigweed seeds



Smooth pigweed stem



Smooth pigweed seedhead



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## PIGWEEED FAMILY

### Common waterhemp (67)

*Amaranthus tuberculatus*

- Cotyledon:** linear; egg-shaped
- Leaves:** nick in tip of first leaves; long-petioled; 3 to 6 in. long; somewhat shiny
- Stems:** smooth, often with colored stripes
- Inflorescence:** small greenish flowers, male and female flowers on separate plants
- Other:** several species of waterhemp in the region; resistant biotypes



Waterhemp seedling



Waterhemp young plant



Waterhemp inflorescence

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## PURSLANE FAMILY

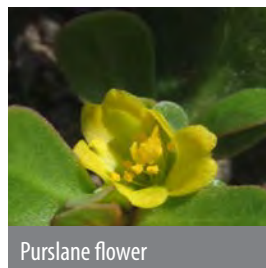
### Common purslane (71)

*Portulaca oleracea*

- Cotyledon:** linear or oblong, smooth
- Leaves:** fleshy, rounded, opposite
- Stems:** fleshy, prostrate, reddish, branched
- Flowers:** 5 yellow petals; small; numerous
- Seeds:** small, flattened, oval, glossy black
- Other:** plants can establish from stem pieces



Purslane seeds



Purslane flower



Purslane plant

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## PINK FAMILY

### Common chickweed (73)

*Stellaria media*

- Cotyledon:** small (1/8 to 3/8 inch long), smooth oblong cotyledons, often light green or yellow-green
- Leaves:** smooth leave opposite on stem, oval shaped with a rounded base and pointed tip.
- Stems:** weak with multiple branches, with a single line of white hairs alternating from one side of stem to the other
- Flowers:** small, white five-petaled flowers indented so deeply that there appear to be 10 petals. Flowers on long stalks originating in leaf axil.
- Seeds:** small (1/16 inch long) seeds that are dark brown or dark red
- Other:** rounder, smooth leaves and the single line of alternating stem hairs distinguish common chickweed from mouse-ear chickweed.



Common chickweed flower



Common chickweed plant



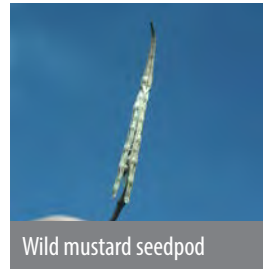
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## MUSTARD FAMILY

### Wild mustard (89)

*Brassica kaber*

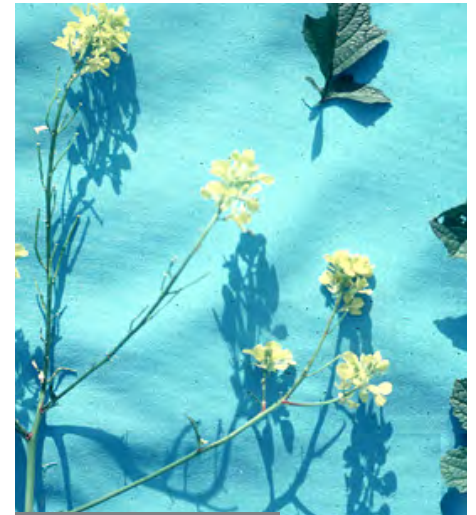
- Cotyledon:** heart or kidney-shaped; smooth
- Leaves (stems):** few bristly hairs
- Lower leaves:** large, triangular and lobed (not to midrib)
- Upper leaves:** reduced in size; no petioles
- Flowers:** 4 bright yellow petals
- Seed pods:** "beak" of seed capsule 1/3 length of whole capsule; open to release round seeds



Wild mustard seedpod



Wild mustard stem



Wild mustard flowers

---

## MUSTARD FAMILY

### Shepherd's purse (91)

*Capsella bursa-pastoris*

- Cotyledon:** ovate to rounded
- Rosette leaves:** starlike branched hairs on upper surface; leaf lobes point to leaf tip
- Stalk (stems):** elongated stalk; leaves clasp stem
- Flowers:** small with 4 white petals
- Seed pod:** small, triangular-shaped



Young plant



Seed pods



Shepherd's purse plant

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## MUSTARD FAMILY

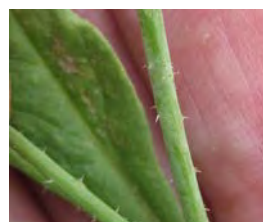
### Wild radish (100)

*Raphanus raphanistrum*

- Cotyledon:** heart or kidney-shaped, smooth
- Lower leaves:** rounded lobes often reach to midrib
- Leaves (stems):** stiff, scattered hairs
- Flowers:** 4 yellowish-white petals; sometimes with purplish veins
- Seed pods:** form constrictions and break into small segments with seed inside
- Other:** fruits contaminate oats and barley grain



Wild radish lower leaf



Wild radish stem



Wild radish flowers and seedpods

---

## MUSTARD FAMILY

### Field pennycress (104)

*Thlaspi arvense*

- Cotyledon:** round, bluish-green
- Leaves:** rosette and stem leaves; ear-like lobes that clasp stems on upper leaves
- Flowers:** flowers with 4 white petals; in clusters
- Seed pod:** notch in top of pod and flat wing around edge
- Other:** garlic-like odor in crushed leaves and stems



Young plant



Seed pods



Field pennycress flowers

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## MALLOW FAMILY

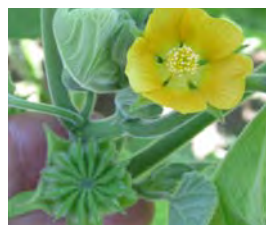
### Velvetleaf (122)

*Abutilon theophrasti*

- Cotyledon:** round or heart-shaped
- Leaves:** very large, heart-shaped, softly hairy
- Stem:** pubescent
- Flowers:** yellow with 5 petals
- Seed capsules:** 13-15 segments; resembles "butterprint"



Velvetleaf seedling



Flower and seed capsule



Velvetleaf leaf and flower

---

## NIGHTSHADE FAMILY

### Jimsonweed (157)

*Datura stramonium*

- Cotyledon:** lanceolate, smooth
- Leaves:** ovate (egg-shaped) with pointed tip lobes; wavy margins
- Stems:** hollow, purplish, and smooth
- Flower:** white tubular flowers
- Seed capsules:** spiny, golf ball sized with many seeds
- Other:** strong, foul odor in leaves and stems; poisonous



Jimson weed flower



Seed capsule



Jimson weed plant



## NIGHTSHADE FAMILY

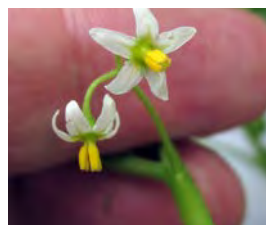
### Eastern black nightshade (162)

*Solanum ptycanthum*

- Cotyledon:** ovate, smooth, small
- Leaves:** purplish color on underside; often with “shot holes”
- Stems:** erect or spreading; widely branched
- Flowers:** 5 white reflexed petals
- Fruits:** green, turning black at maturity; contaminate harvested products



Seedling



Black nightshade flower



Black nightshade fruit

## NIGHTSHADE FAMILY

### Hairy nightshade

*Solanum sarrachoides*

- Cotyledon:** ovate, hairy
- Leaves:** ovate to nearly triangular; finely hairy, especially veins & margins
- Stems:** finely hairy
- Flowers:** 3-9 flowers on short stalk; 5-petaled; white or tinged with purple
- Fruit:** turns yellowish brown when ripe



Hairy nightshade flowers



Hairy nightshade stem



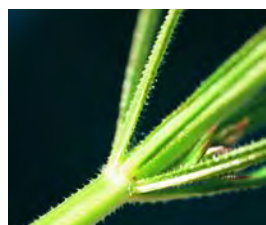
Hairy nightshade fruit

## MADDER FAMILY

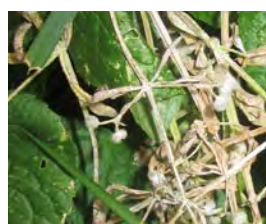
### Catchweed bedstraw (174)

*Galium aparine*

- Cotyledons:** smooth, egg-shaped with slightly indented leaf tips, leaf length ½ to 1 inch
- Leaves:** 6 to 8 leaves in a whorl around the stem, distinctive curved hair-like bristles on leaves result in a “sticky” touch that aids in plant dispersal
- Stems:** square, tangled stems
- Flowers:** very small, four-petaled white flowers in leaf axils
- Seedpod:** two-parted white to tan seedpod covered with dense, stiff hairs



Bedstraw whorl



Bedstraw seeds



Bedstraw stem

---

## GOURD FAMILY

### Bur Cucumber (178)

*Sicyos angulatus*

- Cotyledon:** large; spoon-shaped, thick with dense short hairs
- Stems:** long, ridged vines; sticky-hairy; branched tendrils allow plants to climb over crops
- Leaves:** 3 to 5 shallow lobes (pentagon-shaped), alternate, petioled
- Flowers:** male and female flowers arise at separate axils; 5 greenish-white fused sepals and petals
- Fruits:** in clusters of 3 to 20 egg-shaped, barbed, prickly pods; each pod with one seed



Bur cucumber seedling



Bur cucumber flowers



Bur cucumber plant

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## COMPOSITE FAMILY

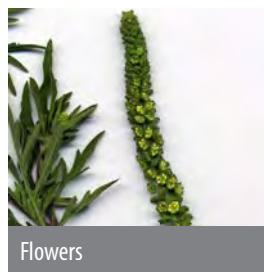
### Common ragweed (181)

*Ambrosia artemisiifolia*

- Cotyledon:** oval to spatulate, thick
- Leaves:** lacy, finely divided, opposite initially, then alternate; first leaves with 5 lobes
- Stems:** rough, hairy and branched
- Flowers:** male flowers in terminal clusters; female flowers in leaf axils



Seedling



Flowers



Common ragweed plant

---

## COMPOSITE FAMILY

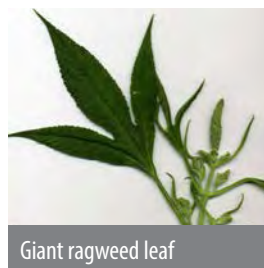
### Giant ragweed (183)

*Ambrosia trifida*

- Cotyledon:** oval to spatulate
- Leaves:** opposite, large and 3-5 lobed; upper leaves often simple; roughly hairy
- Stems:** woody and 1-2 inches thick; tough, hairy; 6-14 feet tall
- Flowers:** male flowers in terminal clusters; female flowers in leaf axils



Giant ragweed seedling



Giant ragweed leaf



Giant ragweed flowers



---

## COMPOSITE FAMILY

### Horseweed (204)

*Conyza canadensis*

- Cotyledon:** round to ovate
- Leaves:** many leaves, no petioles; hairy; entire or toothed
- Stems:** covered with bristly hairs; branched at top
- Flowers:** many small flowers on axillary branches
- Other:** also called mare's tail; common in no-till sites



Horseweed leaves



Horseweed flowers



Young horseweed plant

---

## COMPOSITE FAMILY

### Smallflower galinsoga (210)

*Galinsoga parviflora*

- Cotyledon:** oval to squarish, hairy; abruptly tapered at base
- Leaves:** opposite, toothed
- Stems:** branched, hairy
- Flowers:** 4-5 white ray flowers surrounding yellow disk flowers



Galinsoga flowers



Young galinsoga plant



Galinsoga plants

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## COMPOSITE FAMILY

### Prickly Lettuce (224)

*Lactuca serriola*

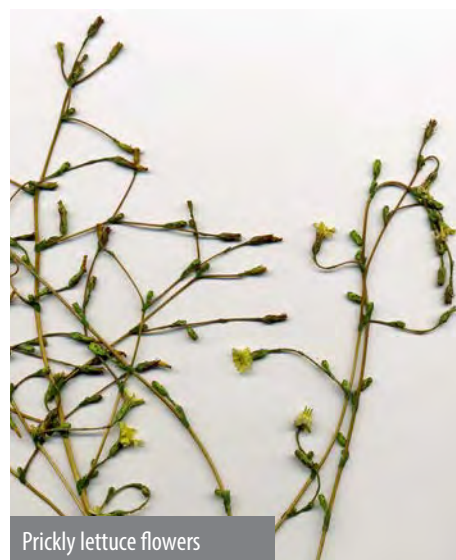
- Cotyledon:** ovate to spoon-shaped
- First leaves:** rosette of pale green leaves; no spines
- Later leaves:** lobed with spiny edges and spines on midrib of underside of leaves; leaf bases clasp the stem
- Stems:** hollow; top very branched when mature
- Flowers:** pale yellow flower heads that release seeds attached to a pappus
- Other:** leaves and stems with milky sap



Prickly lettuce stem



Prickly lettuce leaf



Prickly lettuce flowers



---

## COMPOSITE FAMILY

### Cocklebur (240)

*Xanthium strumarium*

- Cotyledon:** lanceolate, thick
- Leaves:** large, triangular and lobed; 3 prominent veins
- Stems:** rough texture, dark purple spots
- Leaves (stems):** sandpaper-like textured surface
- Flowers:** small, male and female separate but borne together in clusters in axils of upper leaves; two female flowers are enclosed in each oval bur



Cocklebur seedling



Oval bur



Cocklebur leaves

---

## COMPOSITE FAMILY

### Common groundsel

*Senecio vulgaris*

- Leaves:** smooth or slightly hairy leaves, lower, younger leaves are wavy, upper leaves with deep, irregular lobes
- Stems:** multiple branches on upright, smooth stem
- Flowers:** several yellow cone-shaped flowers clustered at end of stems
- Seedpod:** seed enclosed in a fruit with a long white hair, appears similar to a small dandelion flower head



Common groundsel seedling



Common groundsel seed head

## Biennial Broadleaves

---

## COMPOSITE FAMILY

### Common burdock (187)

*Arctium minus*

- Taproot:** large, thick, and fleshy
- Rosette leaves:** huge with heart-shaped base; white-woolly below
- Leaves:** alternate, prominent veins
- Stems:** tough; much branched
- Flowers:** red-violet color; 3/4 - 1 inch across
- Fruit:** a bur with hooked spines



Burdock flowerbuds



Burdock burs



Burdock young plant

---

## COMPOSITE FAMILY

### Musk thistle (199)

*Carduus nutans*

- Leaves:** smooth, waxy; grey-green margin with a white, hairless midrib; spiny edges that extend down stem
- Stems:** spiny from leaf bases except right below flower head
- Flowers:** 1-1/2 to 2 inches in diameter; rich pink color; head often tips downward



Musk thistle flowerbud



Musk thistle leaf



Musk thistle flower

---

## COMPOSITE FAMILY

### Plumeless thistle (198)

*Carduus acanthoides*

- Leaves:** leaves deeply divided; hairy esp. lower surface midrib; decurrent
- Stems:** spiny from base to flower head due to decurrent leaves
- Flowers:** ¾ to 1 ½ inches in diameter; pinkish



Plumeless thistle rosette



Plumeless thistle flowerbuds



Plumeless thistle flower

---

## COMPOSITE FAMILY

### Bull thistle (202)

*Cirsium vulgare*

- Leaves:** deeply cut, spiny margins with a wrinkled surface; hairy
- Spines:** prominent; needle-like
- Stems:** spiny with decurrent leaves (extend down the stem)
- Flowers:** 1-2 inches in diameter; are flask-shaped; pink to pink-lavender



Flower & stalk



Bull thistle stem



Bull thistle flower



# Perennial Weeds

## HORSETAIL FAMILY

### Horsetail (11)

*Equisetum arvense*

- Spreads:** by spores and rhizomes
- Fertile stems:** stems hollow, not branched; easily separated joints
- Vegetative stems:** "leaves" in whorls at joints; looks like small pine trees
- Other:** most common in wet areas



Horsetail roots



Horsetail seedheads



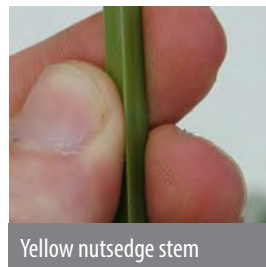
Horsetail plants

## SEDGE FAMILY

### Yellow nutsedge

*Cyperus esculentus*

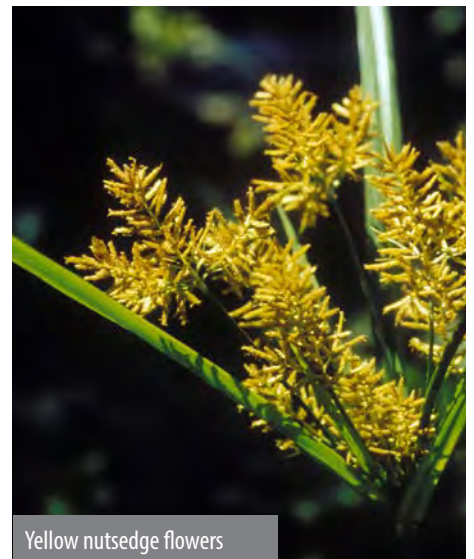
- Stems:** triangular in cross section, erect and rigid
- Leaf:** yellow-green, waxy on top side, dull below, with blade bent along prominent midvein
- Flower:** flat-topped yellow flower cluster originates at upright end of stem
- Other:** expansive root system with underground tubers that form new plants



Yellow nutsedge stem



Yellow nutsedge plants



Yellow nutsedge flowers

## BUCKWHEAT FAMILY

### Curly dock (55)

*Rumex crispus*

- Taproot:** fleshy, branched, and yellow
- Ocrea:** long; prominent
- Basal leaves:** 6-12 inches with wavy edges
- Stems:** smooth, erect, reddish
- Flowers:** small greenish becoming reddish brown at maturity, found in dense clusters on branches at tip of stem



Curly dock leaf



Curly dock seed pods



Mature curly dock flowers

---

## PINK FAMILY

### Mouse-ear chickweed (73)

*Cerastium vulgatum*

- Leaves:** opposite, 3/4 in. long, very hairy, pointed, untoothed, with a single impressed vein
- Stems:** sprawling to erect, hairy, single or several from base
- Flowers:** five white petals, each cleft down the middle, a single or few flowers clustered at top of stem; blooms May–October
- Fruit:** small pod, holding many tiny seeds



Mouse-ear chickweed flower



Mouse-ear chickweed plant

---

## PINK FAMILY

### White cockle (74)

*Lychnis alba*

- Leaves:** hairy and opposite, with no petiole; softly hairy
- Stems:** softly hairy
- Flowers:** white; male & female parts on separate plants (dioecious)
- Fruit:** seed pods with 10 short teeth



White cockle stem



White cockle flower



White cockle seed pod

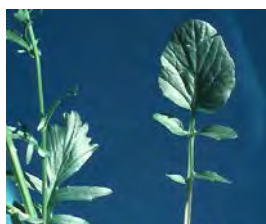
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## MUSTARD FAMILY

### Yellow rocket (86)

*Barbarea vulgaris*

- Rosette leaves:** pinnate with large terminal lobe
- Stem leaves:** smooth with waxy surface
- Upper leaves:** clasp stem
- Flowers:** 4 yellow petals, similar to wild mustard but smaller



Yellow rocket leaves



Yellow rocket seed pods



Yellow rocket flowers



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## MUSTARD FAMILY

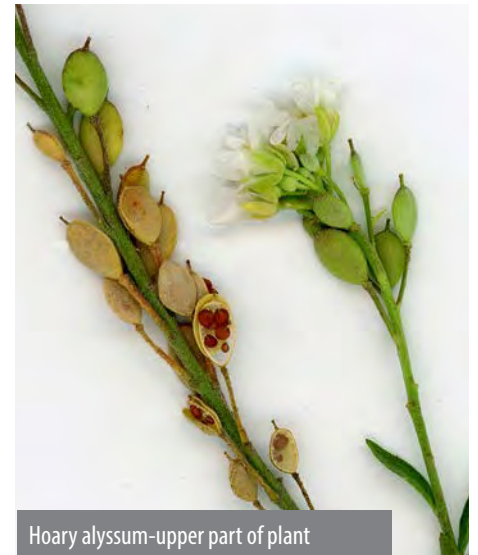
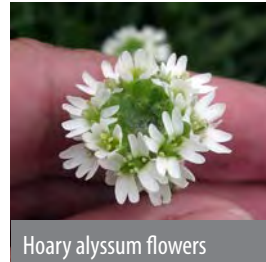
### Hoary alyssum (87)

*Berteroa incana*

**Leaves (stems):** grey-green in color; rough hairs on whole plant

**Flowers:** white with 4 deeply-divided petals

**Fruit:** seed pods small with short "beak"



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## SPURGE FAMILY

### Leafy spurge (118)

*Euphorbia esula*

**Roots:** deep and spreading

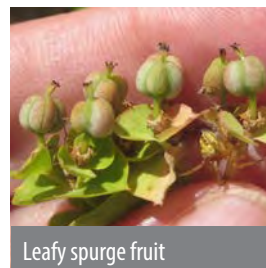
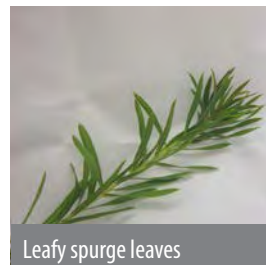
**Stems:** smooth

**Leaves:** alternate, strap-shaped, ¼ inch wide, usually drooping

**Flowers:** small and borne above greenish-yellow bracts

**Fruit:** explode when ripe, shooting 3 seeds, from parent plant

**Other:** all plant parts have milky sap



---

## DOGBANE FAMILY

### Hemp dogbane (134)

*Apocynum cannabinum*

**Roots:** deep and branched

**Leaves:** opposite, narrow and pointed tips

**Stems:** smooth, reddish

**Flowers:** 5 greenish white petals that are slightly longer than green sepals

**Fruits:** long, slender pods; occur in pairs

**Other:** all plant parts have milky sap



## MILKWEED FAMILY

### Common Milkweed (137)

*Asclepias syriaca*

- Roots:** deep and branched
- Leaves:** opposite, thick, oblong, rounded tips, prominent veins
- Flowers:** pink to white in large many-flowered ball-like clusters at tip of stem and in axils of upper stems
- Other:** all plant parts have milky sap



Milkweed seed pods



Milkweed flowers



Milkweed plant

## MORNINGGLORY FAMILY

### Field bindweed (139)

*Convolvulus arvensis*

- Roots:** deep and spreading
- Stems:** trailing or climbing
- Leaves:** "arrowhead"-shaped leaves with 3 "points"
- Flowers:** white or pink, funnel-shaped, 1 inch or less in diameter, found in axils of leaves
- Other:** flower stalks have 2 stipules below flowers



Field bindweed flowers



Field bindweed leaves

## MORNINGGLORY FAMILY

### Hedge bindweed (140)

*Convolvulus sepium*

- Roots:** deep and spreading
- Stems:** trailing or climbing (similar to field bindweed)
- Leaves:** "arrowhead"-shaped leaves with 5 "points"
- Flower stalks:** no stipules below flowers
- Flowers:** large, 1 1/2 to 2 inches, white or pinkish



Hedge bindweed bud



Hedge bindweed flower



Hedge bindweed plants



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## PLANTAIN FAMILY

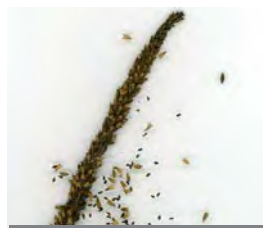
### Blackseed plantain (171)

*Plantago rugelii*

- Roots:** fibrous, tough
- Leaves:** in rosette, broad, ovate with 3 to 5 prominent veins; smooth; petioles purplish; egg-shaped, wavy margins
- Flowering stems:** leafless with many small inconspicuous flowers
- Other:** broadleaf plantain similar but lacks purple petioles and has smaller leaves



Young plantain plant



Blackseed plantain seeds



Blackseed plantain plant

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## NIGHTSHADE FAMILY

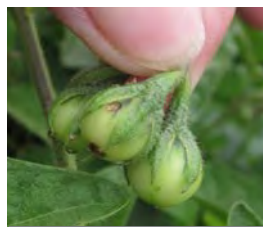
### Horsenettle (160)

*Solanum carolinense*

- Root:** spreading, deep with adventitious buds
- Leaves:** with yellow prickles on the petioles, veins and midribs; hairy; oblong with wavy edges (like oak leaf)
- Stems:** with sharp, stout spines; simple or branched
- Flowers:** potato-like with 5 fused white to purple petals; prominent anthers
- Fruits:** smooth green berries to 0.5" diameter, becoming yellow; become wrinkled and hang on plants most of winter
- Other:** plants poisonous



Horsenettle flower



Horsenettle fruit



Horsenettle stem

---

## COMPOSITE FAMILY

### Canada thistle (200)

*Cirsium arvense*

- Roots:** deep and branched
- Stems:** smooth
- Leaves:** crinkled edges and spiny margins; smooth
- Flowers:** pink to purple, flash-shaped rarely white, ¾ inches wide; male and female flowers on separate plants



Canada thistle stem



Canada thistle leaf



Canada thistle flowers

---

## COMPOSITE FAMILY

### Perennial sow thistle (234)

*Sonchus arvensis*

- Roots:** spreading; shoots arise from buds
- Leaves:** prickly toothed, lobed; milky sap
- Stems:** milky juice; hollow; branch near top
- Flower heads:** branched with yellow ray flowers
- Seeds:** ribbed; with feathery pappus



Perennial sow thistle leaf



Perennial sow thistle stem



Perennial sow thistle flowers

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## COMPOSITE FAMILY

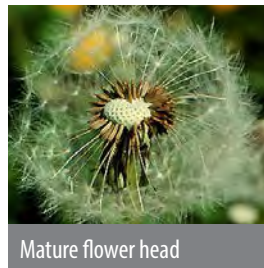
### Common dandelion (237)

*Taraxacum officinale*

- Roots:** deep taproot with many buds
- Leaves:** lobes point to base of plant; watery, milky juice
- Flowers:** bright yellow with many seeds
- Seeds:** ribbed with barbs to aid in soil penetration; pappus aids in seed spread



Dandelion young plant



Mature flower head



Dandelion flowers



# Resistance Management

## In-Season



Resistance of insects, weeds, and pathogens to specific pesticides is an increasing problem in agriculture. Once resistance has developed to a particular material, it no longer works as a control method. Prevent resistance by minimizing pesticide use and avoiding consecutive use of products with a similar mode of action against the same target pest.



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

- ☐ **A.** Pesticide resistance concerns are considered when choosing a pesticide.
- ☐ **B.** Pesticides with different modes of action are used within a growing season and during rotation years.
- ☐ **C.** Strategies to minimize pesticide use are used to slow the development of resistance.
- ☐ **D.** Disease, insect, and weed populations are monitored for resistance.

## A. How resistance develops

Pesticide resistance is the inherited ability of a weed, pathogen, or insect to survive and reproduce after exposure to a dose of pesticide that would normally be lethal. In general, resistance develops through the natural selection of insects, weeds or pathogens exposed to a particular family of pesticides over a period of years. The resistant organism then has the genetic potential to pass along the resistant traits to future generations.

Each pesticide has a specific way in which they affect a pest. This is known as the pesticide's mode of action. When resistance develops, it is to the particular mode of action of that pesticide. The genetic alterations that create resistant populations occur most rapidly when pesticides with similar modes of action are applied in consecutive sprays, in a single season, or over several seasons. Therefore, it is essential not to spray the same product or similar products against the same target pest in consecutive applications.

Complete reliance on pesticides for insect, weed, or disease control can greatly increase the likelihood of developing pesticide-resistant biotypes.

## B. Pesticide mode of action

The Environmental Protection Agency (EPA) and the Fungicide, Insecticide, and Herbicide Resistance Action Committees (FRAC, IRAC, HRAC, respectively) have developed a voluntary pesticide labeling system that groups pesticides with similar modes of action and designates them with a code. This is to help growers rotate pesticides by choosing different modes of action within a season and from year-to-year. In addition to minimizing pesticide use, this is the best way to reduce the likelihood that resistance to a particular active ingredient will develop. You will find the EPA resistance group code listed on the label of each pesticide product.

## C. Strategies to minimize pesticide use and risk of resistance

The best way to minimize pesticide use is to prevent the introduction and spread of insects, pathogens and weeds into your field. Many of the pest management strategies outlined in this workbook are prevention-based and aimed at keeping pest populations low.

When pesticides are needed, there are strategies you can do to prevent resistance from developing in your fields over time. The main strategy is to alternate chemical classes (mode of action) so that insects, weeds, and pathogens are not exposed to the same chemistries in consecutive applications, whether the exposure takes place within a season or over several years.



*Giant ragweed has developed resistance to certain herbicides*

**SPARTAN**

**4F Herbicide**

**For Use Only by Individuals/Firms Certified And/or Licensed as Pesticide Applicators**

EPA Reg. No. 279-3220

Active Ingredient: (1.0)

Sulfentrazone

Inert Ingredients

EPA Est. 279-IL-1

By Wt.

39.6%

60.4%

100.0%

Contains 4 pounds of active ingredient per gallon.

GROUP 14 HERBICIDE

FROM **FMC**

**ATTENTION**

Although this label may appear similar to the label on a product you may have used, there may be important label differences. Users must read, understand and strictly follow all label directions, precautions and restrictions.

It is the user's responsibility to be sure the product is approved for sale or use on the intended crop and for use in the specific geographic area.

It is the user's responsibility to be aware of and to follow all State or local precautions or restrictions not appearing on this product label.

Prior to purchase or use of this product, read the Terms of Sale or Use and Limitation of Warranty and Liability on page 2 of this label.

If the terms and conditions are unacceptable, return the product immediately in the original and unopened container.

**KEEP OUT OF REACH OF CHILDREN**

**CAUTION**

## D. Monitoring for pesticide resistance

Early detection is important if resistance is developing in a population of insects, pathogens or weeds. When you scout your fields, be on the lookout for patterns that would indicate resistance. For weeds, look for patches in fields, escapes scattered in no particular pattern throughout the field, or patches of dense populations of weeds with some radiating out from the central patch. Whole fields infested with weeds or strips of weeds do not typically indicate resistance.

If you are concerned that a particular insect, weed or pathogen is becoming resistant, you can have it tested. University laboratories and private companies have procedures to test for resistant populations. Check with your county Extension agent for further information about specific labs and how to take a sample.

### Notes:

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

## Strategies to prevent resistance

## WEEDS

- ▶ Rotate crops
- ▶ Mow or cultivate weedy escapes before they set seed
- ▶ Practice good sanitation to prevent the spread of weeds
- ▶ Integrate cultural, mechanical, and chemical weed control methods
- ▶ Rotate herbicide families and use herbicides with different modes of action
- ▶ Use herbicide combinations with different modes of action

## FUNGICIDES

- ▶ Rotate crops
- ▶ Use good sanitation methods to prevent pathogens from entering and spreading in the field
- ▶ Plant disease-resistant varieties
- ▶ Use fungicides only when necessary
- ▶ Use fungicides with different modes of action

## INSECTICIDES

- ▶ Rotate crops
- ▶ Use sanitation methods and other cultural controls to avoid introduction of pests into the field and keep established populations low
- ▶ Treat only at economic thresholds
- ▶ Time application to target the most vulnerable life stage of the pest and for least disruption of natural enemies
- ▶ Obtain good spray coverage
- ▶ Spot treat when feasible
- ▶ Use insecticides with different modes of action



# Irrigation

## In-Season



Irrigation management strategies, which provide adequate but not excessive water, should be used to ensure proper growth and development of the strawberry crop.



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

- ☐ **A.** Irrigation is applied to ensure optimum water for the crop.
- ☐ **B.** Irrigation scheduling tools are used to determine irrigation timing and amounts.
- ☐ **C.** Irrigation sources are clean and free from contaminants or other food safety concerns.
- ☐ **D.** Water is applied efficiently throughout the crop cycle using multiple techniques to reduce physiological stress and adverse environmental effects.

## A. Irrigation

Irrigation is a requirement in strawberry production for frost protection and to maintain adequate soil moisture to support productive growth. Supplemental watering is needed when precipitation is less than the combination of what is transpired by the plants and what is evaporated from the soil surface (known as evapotranspiration, or ET). ET's can vary depending on variety and weather conditions, but in general, the strawberry crop could need from an inch or more of water per week. This water can be from either precipitation or supplemented with irrigation.

Some smaller-scale, fresh market growers use drip irrigation systems. Drip irrigation puts the water exactly where it is needed – around the base of the strawberry plants, where weeds aren't watered and evaporation during irrigation is minimized. However, drip irrigation can't be used for frost protection, so overhead irrigation will still be needed. Drip irrigation adds upfront expense in equipment and labor, but reduces water use significantly, and thus may be appropriate in situations where water availability is limited.

### Goals for Strawberry Irrigation Management

- ▶ Maintain at least 50% soil moisture in the root zone throughout the growing season. Watering to runoff wastes resources and can cause damage to surrounding environments, such as with nutrient loss.
- ▶ Continue to manage soil moisture after renovation. This is a very important time of year as strawberry plant vigor after renovation directly affects runner production and flower bud set for the following harvest.
- ▶ Ensure that the water source is safe and free from contaminants that could cause food safety concerns.
- ▶ Check the uniformity of the irrigation system regularly to ensure efficient water use, avoid plant stress and reduce pumping costs. Uniform sprinkler irrigation is particularly important when it comes time to frost protect strawberries.

## B. Irrigation Scheduling Tools

Whatever the type of irrigation system, use irrigation scheduling to balance crop use with irrigation and rainfall. The simplest tool to use is a 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.



A general rule of thumb for strawberries is to maintain 50% of available water within the root zone of the plant. The amount of available soil water can be derived from computer irrigation scheduling tools, which are based on the Wisconsin Irrigation Scheduling Program (WISP) <http://wisp.cals.wisc.edu/>. 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.

### ★ Quick note:

Ensure that your irrigation equipment is providing uniform amounts of water by periodically calibrating your systems!

## C. Clean Water Sources

Irrigation water needs to come from a clean source, free from contaminants that could be a human health hazard. This is especially important with regard to food safety concerns.

**★ Quick note:**

Keep in mind that strawberry plants have a shallow root system and exhibit signs of water stress soon after drying that may reduce crop yield and long-term vigor. Water loss through ET and subsequent plant stress are greatest when temperatures are high, humidity is low and in windy conditions.

**Notes:**

## D. Efficient Water Use

Using available water resources wisely and efficiently ensures crop productivity without overuse. Using simple efficacy techniques, like those outlined here, helps determine water needs of the crop.

### Available Soil Water

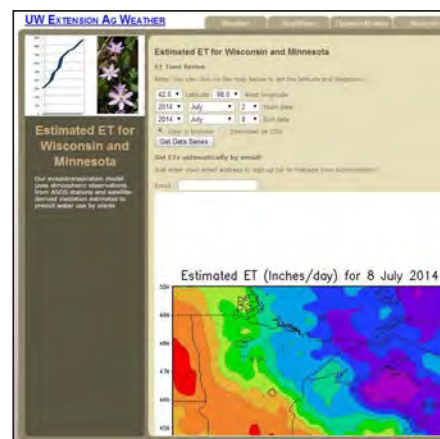
The available soil water is the difference between a soil's field capacity (total amount of water that can be held by a soil) and the permanent wilting point (point at which plants wilt and die). As strawberries show stress and loss of yield and quality before the permanent wilting point is reached,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

## Evapotranspiration (ET)

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

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

Various methods have been developed for estimating daily ET. ET numbers for production areas in Wisconsin and Minnesota can be viewed by accessing the WI-MN cooperative extension agricultural weather page at [http://agwx.soils.wisc.edu/uwex\\_agwx/weather/hyd](http://agwx.soils.wisc.edu/uwex_agwx/weather/hyd)



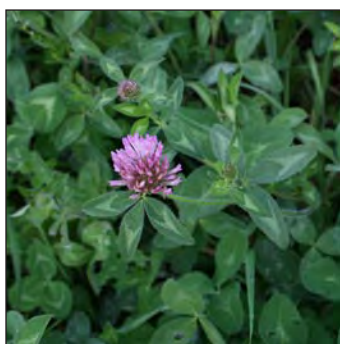


# Soil Fertility and Plant Nutrition

## In-Season



A good fertilizer program is crucial for vigorous growth during the season. Good plant nutrition improves plant resistance to pests and diseases, and increases the crop's competitiveness with weeds.



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

- ☐ **A.** Fertilizer for establishment is applied based on soil test results.
- ☐ **B.** The fertilizer source is considered when calculating fertilizer rates.
- ☐ **C.** Tissue testing is used to determine supplemental fertilizer needs.
- ☐ **D.** Organic amendments and cover crops are used to supply some crop nutrient needs and fertilizer rates are adjusted accordingly.

# A. Plant nutrition & fertilization

A good fertility program is an important part of IPM and is important for overall crop health and production. Good plant nutrition improves plant resistance to pests and diseases, and increases the crop's competitiveness with weeds. Good nitrogen nutrition is especially critical for overall growth and best yields of strawberries.

Applying fertilizers without regard to the soil conditions, cropping history, or current growing conditions will probably lead to excessive application. Applying too much fertilizer is not economical and can become a serious environmental contaminant if it moves into ground or surface water. Too much fertilizer can harm crops; for example, excessive nitrogen can make strawberries prone to disease infections.

Have the soil tested before planting. Use the results from your soil test together with the recommendations from from a Wisconsin Department of Agriculture, Trade, and Consumer Protection certified soil testing lab. The information in your soil test report will help you plan how much fertilizer and lime to apply for good crop productivity.

# B. Calculating fertilizer rates

In planning your fertilizer application, first look at your soil test results and check the test levels of phosphorus (P) and potassium (K). The University of Wisconsin soil testing lab will group them into one of the following categories: very low (VL), low (L), optimum (O), high(H), very high (VH) and excessively high (EH). These categories are based on the probability that adding P or K to the specific soil will benefit plant growth. Fertilizer should be broadcast and incorporated into the soil before planting.

Nitrogen does not accumulate in the soil so it needs to be applied only when the crop can utilize it. Be sure to take nutrient credits for applications of manure, legumes and green manures. If this information is provided on the soil submission form, then the lab will automatically adjust the recommendation based on the credits.

## Interpreting Soil Test Results

After submitting your soil sample, the soil testing lab will send you a soil test report for each of the samples you submit. Most of these reports will include three sections: the soil analysis, the test interpretation and the nutrient recommendations.

Interpretation of soil test P and K values includes placing each test result into a soil test category based on the crop demand level and the soil type in which it will be grown. Soil test categories include: very low, low, optimum, high, very high (soil test K only), and excessively high. The P and K fertilizer recommendations associated with each soil test interpretation category are based on optimal production levels. For a detailed description of soil test levels see **Nutrient application guidelines for field, vegetable, and fruit crops in Wisconsin** (UW-Extension A2809) and **Optimum Soil Test Levels for Wisconsin** (UW-Extension A3030). Soil test categories have also been developed for calcium, magnesium, manganese , zinc and boron. The sulfur requirement is determined based on soil type, manure history, and crop grown.

UW nutrient application guidelines are based on an approach that builds soil test levels to an optimal point and then maintains that level. Fertilizer recommendations are only provided for the establishment of strawberry when the soil test is in the low or very low category.

## Notes:





# Crop and Fruit Maintenance

## Harvest



Proper harvest and storage of the fruit is needed to ensure quality and limit perishability. After harvest, proper late summer to fall maintenance is essential to keep the crop viable for long-term growth and development.



<http://www.ppd.purdue.edu/PPDL/images/strawberryrep2.jpg>

*Mow strawberries just above the plant crown*

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

- ☐ **A.** Strawberries are harvested promptly and stored properly to ensure freshness.
- ☐ **B.** Post-harvest renovation is performed properly.
- ☐ **C.** Late season soil and plant fertility is monitored and managed.
- ☐ **D.** Crop is enhanced and maintained in late fall to ensure long-term health and productivity.

## A. Fruit harvest & storage

Strawberries mature quickly during the harvest season and are very perishable. They should be harvested at maturity and not left on the plant when over-mature, as over-mature berries attract insects and harbor plant diseases.

Fruit that will be stored or transported should be cooled immediately to 32 to 35 degrees F and kept at high humidity (90 to 95%). Increasing carbon dioxide in cold storage, such as with a simple block of dry ice, can also improve storability. Do not stack fruit more than 3 inches deep in harvest or storage containers. Even in the best storage conditions and with optimal fruit, storability is often only 3 to 5 days at best.

## B. Post harvest strawberry renovations

Immediately after harvest, matted row June-bearing strawberries should be renovated to stimulate new runner and daughter plant growth and to interrupt the life cycle of several pests. The recipe for renovation includes:

- ▶ **Pre-mowing weed control.** Existing weeds can often be controlled at this time with post-emergent herbicides labeled for use at renovation (please see Midwest Small Fruit and Grape Spray Guide and the herbicide labels for more details).
- ▶ **Mowing.** About 5 days after the last herbicide application, mow the strawberry plants to a height just above the plant crown.
- ▶ **Post-mowing weed control.** Pre-emergent residual herbicides labeled for such use in strawberry should be applied after mowing and before new weeds emerge. These herbicides are critical in minimizing competition between emerging weeds and new runners that form next year's crop.
- ▶ **Narrow the strawberry row to 12 to 18 inches wide.** The majority of the crop is produced along the edge of the row, thus wider rows produce less overall fruit. Narrower rows also support air movement and runner establishment. Rototill or cultivate the rows to a reasonable width, eliminating any existing weeds between the row and incorporating the leftover winter mulch.

## C. Late season fertility program

Maintain soil and plant fertility to assist in the establishment of next year's crop. A split application of nitrogen (one at renovation and one a month later) will support new crop growth. For the second application, enough new leaves should be present to conduct a leaf tissue analysis that will allow the amount of fertilizer to be custom-tailored to the need, thus supporting good crop growth while minimizing risk of off-site movement and unnecessary cost. See **Soil Fertility and Plant Nutrition** section for specific details.

## D. Late summer & fall maintenance

While it can be easy to forget about the strawberry planting at this time of year, continued attention and maintenance is necessary to promote next years crop. Between renovation and late fall mulching, be sure to:

- ▶ **Irrigate if necessary** as strawberry plants require sufficient water to establish runners, develop flower buds for the next year and maintain crop vigor. Attention to irrigation after harvest is often overlooked but plays a significant role in the next season's harvest.
- ▶ **Shallowly cultivate** the inter-row areas to maintain weed control and train runners within the desired row width.
- ▶ **Maintain adequate soil fertility** to support strawberry bud development.
- ▶ **Apply late-fall herbicides** labeled for use on dormant strawberries just prior to mulching. A well-timed herbicide that controls the known spectrum of weeds should control most weeds until the next harvest.

### Sanitation

Harvest is a time to make sure you are using proper sanitation practices to ensure safe and quality food. During harvest, make sure all containers, harvest equipment, and storage areas are kept clean and sanitize them often. Follow good agricultural practices to ensure clean and safe harvest and storage conditions. Simple tactics, like making sure you have adequate hand wash stations nearby, can make a big difference for safe strawberries.

# Overwintering Mulches and Frost Protection

Post-harvest



Strawberry plantings require nearly year-round attention. Winter mulches and frost protection enhance the health and future of the strawberry crop.

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

- ☐ **A.** Winter mulches are used and applied at proper timing.
- ☐ **B.** Growers accurately monitor for frost concerns.
- ☐ **C.** Proper frost protection is implemented.
- ☐ **D.** Mulches are removed properly in the spring.



## A. Winter mulches

Strawberry plants are not hardy enough to survive most Upper Midwest winters and therefore need to be covered with mulch to protect the plants. Most strawberry varieties succumb to the cold below 18° F. With that in mind, strawberries should be mulched after active growth has ceased, just as the ground begins to freeze, but air temperatures haven't dipped below 20° F, usually around mid- to late- November in most of Wisconsin.

The choice of mulch material is important. Most growers use wheat or rye straw as it is hardy enough to last through winter on the strawberry plants and then through harvest between the plant rows. Make sure that the straw is free of weed seed and perennial weed tissue (such as Canada thistle or nutsedge roots) that are difficult to control in strawberries. The mulch should be layered so that it settles to a depth of 3 or 4 inches.

### ★ **Quick note:**

Make sure that the straw is free of weed seed and perennial weed tissue – they should not contain Canada thistle or nutsedges since these are hard to control in strawberries.

## B. Growers accurately monitor for frost concerns

Strawberry plants become susceptible to frost after the winter mulch has been removed and active spring growth has resumed, but particularly as flower blossoms develop. Some varieties are more tolerant of cold spring temperatures than others —check with your nursery supplier when purchasing plants.

Flowering strawberry plants cannot tolerate temperatures at 28° F or below, and therefore irrigation should be used in these conditions for frost protection. Place a thermometer in the lowest part of the field to monitor air temperature. Automated temperature monitoring systems are available that can alert growers to dangerous temperatures via cell phone service and are commonly used today.

## C. Proper frost management practices are utilized

Don't wait until the temperature is 28° F to turn on the water – keep in mind that the temperature often varies across the field and may be lower within the strawberry canopy where flowers are located. Once the water is turned on, don't turn it off until the ice begins to melt and fall off the plants the following morning. The transition of water to ice releases heat, so as long as you are applying liquid water to icy plants, the ice will remain at 32°F. In general, between 0.1 and 0.15 inches of water per hour is adequate to protect plants. Be sure that you have adequate water stored in spring to be able to accommodate multiple or consecutive frost nights.

### Low Temperatures

Flowering strawberry plants cannot tolerate temperatures at 28°F or below, and therefore irrigation should be used in these conditions for frost protection. Place a thermometer in the lowest part of the field to monitor air temperature.

## D. Mulching removal and spring/summer mulch management

In spring, the mulch should be pulled off the plants when the temperature is above 20° F and left between the plant rows, where it decreases soil splash-back onto developing berries that is not only aesthetically unpleasant but also spreads some soil-borne plant diseases. Additionally, mulch between the rows conserves soil moisture and suppresses weeds.



*Make sure mulch is free of weed seed and perennial weed tissue*

# References and Resources

## **Pest management:**

*Midwest Small Fruit and Grape Spray Guide* (<http://learningstore.uwex.edu/>)

## **Plant nutrition:**

Nutrient Application Guidelines for Field, Vegetable and Fruit Crops in Wisconsin (<http://learningstore.uwex.edu/Nutrient-Application-Guidelines-for-Field-Vegetable-and-Fruit-Crops-in-Wisconsin.pdf>).

## **Strawberry production online resources:**

Cornell University Fruit: <http://www.fruit.cornell.edu/berry/production/strawberryproduction.htm>

Michigan State University Strawberry Resources: <http://libguides.lib.msu.edu/content.php?pid=315373&sid=2580621>

**Notes:**



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